SOME WAYS TO IMPROVE PRODUCTS RELIABILITY

Titu-Marius I. Băjenescu, prof.
Company for Consulting, C. F. C., La Conversion, Switzerland

1. INTRODUCTION

Modern engineering products, from individual components to large systems[1], must be designed and manufactured to be reliable in use. If the market for the product is competitive, improved quality and reliability can generate very strong competitive advantages. W. E. Deming[2] (1900-1993) taught the fundamental connections between quality, productivity, and competitiveness, but unfortunately, the development of quality and reliability engineering has been afflicted with more nonsense than any other branch of engineering. This has been the result of the development of methods and systems for analysis and control that contravene the deductive logic that quality and reliability are achieved by knowledge, attention to detail, and continuous improvement on the part of the people involved. Therefore it can be difficult for students, teachers, engineers, and managers to discriminate effectively, and many have been led down wrong paths.

Paradoxically, failure[3] at the detailed, individual level is absolutely necessary for the health and vitally of the system as a whole. We need change and evolution to make progress. But evolution implies extinction, the discarding of ways of working that have outlived their usefulness.

Product failure is deceptively difficult to understand. It depends not just on how customers use a product but on the intrinsic properties of each part - what it’s made of and how those materials respond to wildly varying conditions. Estimating a product’s lifespan is an art that even the most sophisticated manufacturers still struggle with. And it’s getting harder. In our Moore’s law-driven age, we expect devices to continuously be getting smaller, lighter, more powerful, and more efficient. This thinking has seeped into our expectations about lots of product categories: Cars must get better gas mileage. Bicycles must get lighter. Washing machines need to get clothes cleaner with less water. Almost every industry is expected to make major advances every year. To do this they are constantly reaching for new materials and design techniques. All this is great for innovation, but it’s terrible for reliability.

Change is difficult, change is disturbing, and change brings uncertainty. Change creates failures, but it also creates success [1]. Understanding when and why things fail is critical to our economic and societal well-being.

Often when materials fail unexpectedly it is not because the external circumstances were particularly severe, but because the materials microstructure is sub-optimal, there are defects present or develop in service, or because there are stresses locked into the material that we didn’t know about.

Materials are stored to failure. One of the biggest challenges in predicting when a product will fail, is understanding the material it’s made from. Every material, from metals to composites to ceramics, will have microscopic variations from unit to unit that affect a product’s lifespan. The company Vextec hopes to solve this problem, by creating statistically accurate computer 3D-models, down to the grains, voids, and crystals that make up a material’s microstructure (Figure 1).

What causes these failures? They can be due to inadequate design, improper use, poor manufacturing, improper storage, inadequate protection during shipping, insufficient test coverage and poor maintenance, to name just a few. A product can be designed to fail, although unintentionally. To achieve product reliability, we

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[1] “A system is a network of interdependent components that work together to try to accomplish the aim of the system. A system must have an aim. Without an aim, there is no system. The aim of the system must be clear to everyone in the system. The aim must include plans for the future. The aim is a value judgment. (We are of course talking here about a man-made system.)" [Deming].

[2] In the 1970s, Deming's philosophy was summarized by some of his Japanese proponents with the following '*a*'-versus-'*b*' comparison:
(a) When people and organizations focus primarily on quality, defined by the following ratio:

$$\text{Quality} = \frac{\text{Results of work efforts}}{\text{Total costs}}$$

Quality tends to increase and costs fall over time.
(b) However, when people and organizations focus primarily on *costs*, costs tend to rise and quality declines over time.

[3] A failure is anytime the product does not function to specification when the product or service is needed. The degree of failure can be varied, but the negative effect on your business is the same. A dissatisfied consumer results in the loss of repeat business.

a b. c,

Figure 1. Failure under the microscope. ***a***) Photo of a metal's microstructure. ***b***) Vextec's simulation – complete with voids, grains, and impurities. ***c***) The 3D version will show how and when cracks form [2].

must ask the question ''what will wearout before the end of the customer expected product life and why?'' By identifying the things that will fail in the field, design changes can be made to improve product performance or a maintenance program can be established. Through design changes, the poorly chosen fastener that slowly leads to an eventual failure can be removed from the possibility of causing a failure.

2. DEFECT, ERROR, FAULT

The following three terms are crucial and related to system failure and thus need to be clearly defined, which are named *defect*, *error*, and *fault*.

A defect in an electronic system is the unintended difference between the implemented hardware and its intended design. Some typical defects of VLSI chips include:

• Process defects, taking the form of missing contact windows, parasitic transistors, oxide breakdown, etc.;

• Material defects, due to bulk defects (cracks, crystal imperfections), surface impurities, etc.; and

• Age defects, taking the form of dielectric breakdown, electromigration, etc.

Defects can be also classified by the statistical effect they produce:

- Systematic, defects that have the same impact across large dimensions, such as die or wafer, and that can be modelled in a systematic way. These defects are usually the result of process–design interaction.
- Random (stochastic), all types of defects that cannot be controlled or modelled in a predictable and systematic way. They include random particles in the resist or in the materials, inserted or removed, or defects in the crystal structure itself that alter the intended behaviour of the material and results in excessive leakage or in a shift in the device threshold (V_{th}), eventually causing the failure of the device.

The failure modes resulting from these defects are: *(i)* Opens; *(ii)* Shorts; *(iii)* Leakage; *(iv)* V_{th} shift; *(v)* Variability in mobility (μ)

Random defects do not necessarily result in a complete failure of the device, but in a significant deterioration of its performance.

A wrong output signal produced by a defective system is called an *error*. An error is an effect whose cause is some defect.

A *fault* is a representation of a defect at the abstracted functional level. A fault is present in the system when physical difference is observed between the "good" or "correct" system and the actual system.

If error detection and recovery do not take place in a timely manner, a *failure* can occur that is manifested by the inability of the system to provide a specified service. *Fault tolerance* is the capability of a system to recover from a fault or error without exhibiting failure. A fault in a system does not necessarily result in an error; a fault may be latent in that it exists but does not result in an error; the fault must be sensitized by a particular system state and input conditions to produce an error. Error sources can be classified according to the phenomenon causing the error. Such origins are for instance related to the manufacturing process, physical changes during operation, internal noise caused by other parts of the circuit, and external noise originating from the chip environment. [3].

3. RELATIONSHIP BETWEEN FAULTS, ERRORS AND FAILURES

The creation and manifestation mechanisms of faults, errors, and failures are illustrated by Figure 3, and summarized as follows:

fault —*activation*→ error —*propagation*→ failure —*causation*→ fault

Figure 2. The fundamental chain of dependability threats (after [4]).

The arrows in Figure 2 express a causality relationship between faults, errors and failures. They should be interpreted generically: by propagation, several errors can be generated before a failure occurs. Faults can be categorized according to their activation reproducibility: faults whose activation is reproducible are called *hard*, faults, whereas faults whose activation is not systematically reproducible are *soft* faults. The similarity of the manifestation of elusive design faults and of transient physical faults leads to both classes being grouped together as *intermittent faults*. Errors produced by intermittent faults are usually termed *soft errors* [5].

4. FIRST IN, FIRST OUT (FIFO); LAMBDA; FAILURE IN TIME (FIT)

The grocery store places their products on shelves. When a new shipment arrives, the old product is rotated to the front of the shelf and the new product is placed at the rear. This is commonly known as rotating or facing the shelves. This ensures that some items do not rest on the shelf too long to spoil. This is done on dairy products everyday. The term used in industry is *FIFO, First In First Out*.

Many electronics components actually start to wear out right after they are produced. How soon after they arrive at the manufacturing location they are installed in the product and shipped to the customer can be important. These parts also have to be used on a FIFO basis to ensure that the decaying process does not accumulate to lower the part's life expectancy. For example, adhesives have short shelf lives. If not used for several months, many adhesives are susceptible to early failure. Sticky-backed labels are often purchased in large quantities to get good pricing. Often these labels are in storage for several years before the last ones are applied to the product. In the field, these old labels will usually fall off in a few months and as such their value is lost.

When a product has failed, the failure mechanism must be learned to determine the root cause of the failure. The design of the product or the process must be updated to remove the failure possibility from happening.

Since 1980s, the reliability of electronic components (in general) has improved two to four orders of magnitude. Parts were often specified in failures per million hours of operation [the term used is λ (lambda)]. Today, parts are specified in failures per billion hours of operation, which are referred to as *FITs* (Failures in Time). If parts were the main contributor to failures, then, with the vastly improved complexity of new devices, they would be failing constantly. We can all attest that they are not. Televisions, radios, and automobiles all have more parts and last longer. This is due to the inherent design and the manufacturing processes, not the parts count. What is needed to improve the reliability of a manufactured assembly is to improve the design and the manufacturing process. Much work has been done over the past few decades to improve the quality and reliability of components. This effort has, for the most part, been very successful. In fact, the measurement used to describe the quality of components has been changed three orders of magnitude as well (from λ to FIT).

5. RELIABILITY

The world is changing. Companies have to change to stay in business. Today's managers have to adapt their companies to these new paradigms[4]. Change the rule and you change the outcome. What we see in the marketplace is that the same old rules don't work any more. The paradigm has changed. Rules change on a continuous basis. Today, they change even faster.

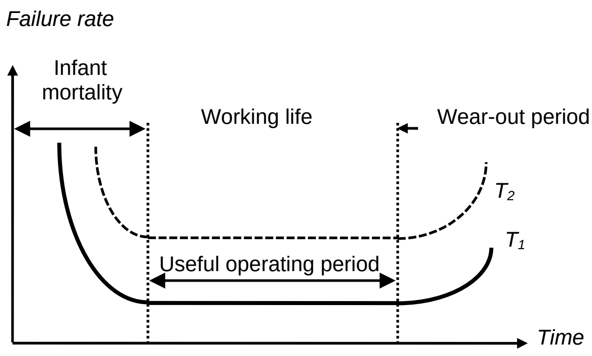

Figure 3. The "bathtub" failure curve of a large population of statistically identical items (electronic components), for two ambient temperatures $T_2 > T_1$ (After [6]). The time axis is not to scale.

Another new paradigm is reliability. When your designs are mature and your processes are in control, the reliability of your product will be high. The return is in dollars/euros not lost to warranty claims and upset customers. You, as a manager, have to make the changes that ensure quality and reliability. Otherwise the market will look to those who have learned these new rules earlier.

The process yield of a manufacturing process is defined as the fraction, or percentage, of acceptable parts among all parts that are fabricated. A system failure occurs or is present when the *service*

[4] Paradigms don't change rapidly. Rules do; one at a time. Paradigms are what we believe to be true, not necessarily what really is true. Paradigms are made up of an assortment of rules. With more rules, the paradigm is more entrenched. With more established rules, our belief in the paradigm is stronger. When many rules support the old paradigm, more obstacles have to be overcome to move into the new paradigm [3].

provided by the system differs from the specified service or the service that should have been offered. In other words, the system *fails* to perform what it is expected to. The so-called bathtub curve which is shown in Figure 3 is widely accepted to represent a realistic model of the failure rate of electronic equipment and systems over time. The bathtub curve consists of three characteristic zones. Failure rates follow a decreasing pattern during the early times of operation, where infant mortality deteriorates the system, typically due to oxide defects, particulate masking defects, or contamination-related defects. Failure rate remains constant over the major part of the system operation life. Failures are random, mostly manifesting themselves as soft errors. Wearout occurs in the final stage of the system lifetime, where failure rate increases, typically due to electromigration-related defects, oxide wearout, or hot carrier injection.

There are many possible classifications of the failures that could appear in the functioning of technical systems (including electronic systems and electronic components).

From the reliability viewpoint, the most known classification depends on the moment when the failure appears, and is synthesized in Table 1. Other types of classifications are mentioned in Table 2. One must be note that an investigator of product reliability must go beyond these classifications of failures and find out the failure mechanism in each case. This is the only way to facilitate both the selection of best components and their correct use, helping to the reliability growth, in general.

At the beginning, reliability engineering efforts were carried out as a part of semiconductor device development so that maximum inherent reliability can be designed into the device. These efforts encompass physics of failure, failure analysis, reliability testing, and reliability sciences.

6. CAN THE BATCH RELIABILITY BE INCREASED?

The reliability of a batch of components can be increased in three different ways, which may be used separately or combined.

Firstly, it is the so-called *pre-aging,* which can be applied to all components before the input control. The pre-aging eliminates a part of the early failures and awards to the surviving components a stable behaviour during the operation time. This type of pre-aging has nothing to do with the pre-aging performed – for example – by the manufacturer of the components, as part of the fabrication process, for stabilizing the normal operating properties. To increase the reliability by pre-aging it is necessary

Table 1. Classifications of Failures Depending on the Moment of Appearance (after [7])

Types of failures	***Comments***
Early (infant mortality) failures that appear during the early period of product life.	Can be explained by a faulty manufacture and an insufficient quality control. Could be eliminated by a systematic screening test.
Accidental failures that appear during the useful life of the product.	Cannot be eliminated neither by a screening test, nor by an optimal use politics (maintenance). Could be provoked by sudden voltage increases that can strongly influence the component quality and reliability. These failures appear erratically, accidentally, and unforeseeably.
Wear out failures that appear in the final period of product life.	Are indicators of the product aging.

Table 2. Various Classifications of the Failures (after [7])

Classification parameter	***Types of failures***
Failure cause	Failure due to an incorrect assembling Failure due to an inherent weakness
Speed of the phenomenon	Sudden failure Progressive failure
Technical complexity	Total failure Partial failure Intermittent failure
Emergence manner	Catastrophic failure Degradation failure

to know the conditions of the input control in order to design the stress conditions during pre-aging. In general, the pre-aging is realized by an inferior component loading (in comparison with the ulterior operating conditions). If a rapid pre-aging is needed, a load greater than the nominal operational load value could be selected. However, the loading must not be too high, because otherwise the component can reach the failure limit, will be damaged and will not have at the input control the desired behaviour.

The second way is the operational derating or the devaluation that contributes to a substantial increase of reliability.

The third method is linked to the tolerance limits, which can also influence the system reliability. By using this method, one may pay attention to the outrunning, since an optimal efficiency can be obtained only as parts are inside the established limits. Exceeding these limits can operate inversely, reducing the reliability. With the aim to not allow to these variations to perturb the system function, the circuit designer must establish tolerance limits that are harmonized with the parameter variations. To define these tolerance limits, the density function and the long-term behaviour of the given parameters must be known. By modifying the distribution function for the lifetime, those parameters that exceed the prescribed limits can be identified. The knowledge of this behaviour of the parameters allows either to select the parameters that are inside the prescribed limits, or to establish the limits that must not to be exceeded during the operation.

7. DERATING TECHNIQUES

One of the most used methods to improve the reliability of the equipped printed circuits boards (PCBs) is the *derating technique:* the mounted component is functioning at values of voltages, currents, tests and/or temperatures that are well below the manufacturer's rating for the part (nominal operating values). In this way an increase of the lifetime duration for the respective component is obtained. We encourage users to implement derating as appropriate for their application in all instances. The under loading values can be found by the manufacturer or in failure rates handbooks such as GPRD-97, RDF 2000 [8-10], PRISM [11], FIDES [12]. This data – in which the values corresponding to the prescriptions are taken as parameter – can provide specific failure rates for each one of the operating conditions. You must begin with the study of the operating conditions of the system, by evaluating–in percentage of the nominal values–the voltage, the load and the temperature, for each component. With the aid of the given tables the value for the specific operating conditions can be determined and the sum of the failure rates with a tolerance of approximately 10% can be found, allowing to take into account the solder joints, the connections, and so forth.

On demand, special selection tests (thermal cycles, high temperatures, thermal shocks, vibrations) could be designed. By using a minimum number of components operating well below the nominal values, the circuit designer himself may settle the circuit reliability.

If the reliability problem is correctly treated, any apparatus, device or equipment can be decomposed in modules, subsystems, units, ensuring for each element the best reliability level, so that the desired reliability of the ensemble can be obtained.

8. METHODS FOR INCREASING THE RELIABILITY OF ELECTRONICS

The technical direction of CALCE EPRC has concentrated on evaluating widely accepted reliability methods, including allocation, parts selection, reliability prediction, derating, environmental control, screening, and qualification. It became apparent that many manufacturers of electronic hardware had come to rely on the security of government-approved reliability documents such as *MIL-STD-785* (*Reliability Program for Systems and Equipment*) and *MIL-HDBK-217* (*Reliability Prediction of Electronic Equipment*), even though following them often led to poor part selection, improper derating, high-cost cooling solutions, and long development times. Using these documents, any solution to a reliability question was deceptively simple: select specific devices, derate them, run them cool, and introduce redundancies. Auditing quality was accomplished similarly, with government mandated tests such as *MIL-STD-883* (*Test Methods and Procedures for Microelectronics*), perpetuating the myth that reliability and quality could be tested into a product. The costs for following the mandated guidelines were passed on to the customer, resulting in more expensive products without a commensurate increase in performance or reliability.

The CALCE EPRC is now implementing a fundamentally new approach to addressing reliability. Based on research into the mechanics of failure processes, knowledge of how failures occur is being gathered in order to gain control over failure mechanisms and manufacturing flaws. Coupling this data with novel simulation techniques, the CALCE EPRC is enabling design for reliability, reliability assessment, and virtual qualification (or qualification by design) of new electronic products [13].

9. ACCELERATED AGING METHODS FOR EQUIPPED BOARDS

Another recommended method for increasing the reliability of the system, which is complementary to the screening performed at component level, is the accelerated aging of printed circuits boards (PCBs).

An example of such proceedings is given below:

- Visual control; rough electrical testing;
- 10 temperature cycling (-40°C / +70°C), with a speed of 4°C/minute and a break of maximum 10 minutes. During cooling, the bias will be disconnected;
- 24 hours burn-in at ambient temperature or, even better, at +40°C ("debugging"), with periodic "on" and "off";
- Final electrical testing.

This method is complementary with the screening performed at component level.

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DEPENDENCIES OF SPICE LEVEL3 PARAMETERS ON IRRADIATION

V. Rusanovschi, dr. hab.[1], M. Rusanovschi, dr.[2], P. Stoicev, dr. hab. [2]
State Agency on Intellectual Property of Republic of Moldova[1]
Technical University of Moldova[2]

INTRODUCTION

The action of radiation on Integrated Circuits (IC) leads to a significant change of electrophysical characteristics of active bipolar and MOS elements, caused by the formation of load capture and storage centers in dielectric, increase of concentration of the surface states (SS) at the Si–SiO_2 interface and decrease of load mobility in the immediate region of the semiconductor surface [1-3].

Experimental investigations [4-6] have shown that in the process of irradiation the degradation of IC elements characteristics is mainly due to the formation of oxide and SS defects.

One of the methods of forecasting the functioning of the active elements upon irradiation may be reduced to determining the load value in oxide and on SS. The methods of forecasting the functioning developed so far can be divided into several groups which include methods that rely on determining the initial parameters of the structures and their correlation with the values of parameters under the action of IR, testing methods upon irradiation with sources of isotopes Co^{60}, Cz^{137} and Sr_{γ}^{90}–γ^{90} and research methods upon X-ray irradiation.

In the given work are presented the dependencies of bipolar and MOS element parameters on irradiation. On the basis of results obtained, using the schematic simulation program SPICE LEVEL3, were simulated the characteristics of bipolar and MOS elements before and after irradiation.

1. DEPENDENCIES OF BIPOLAR STRUCTURE PARAMETERS ON IRRADIATION

Using the program developed for extraction of parameters the parameter values of bipolar transistors were obtained: *IS* – saturation current; *NF* – direct emission coefficient; *IKF* –threshold current for the high injection level in the literal sense; *IRB* – the current to which the base resistance is halved compared to the maximum value; *RB* – maximum ohmic resistance of base; *NE* – nonideality coefficient; *ISE* –saturation current of BE junction; *BF* – direct transfer factor.

Bipolar structure parameters variation is determined by the structural defects occurring after IR [7]. Parameters extracted from the experimental characteristics obtained before and after the irradiation, for different sources of irradiation, are shown in tab. 1.

Therefore, upon neutron irradiation the saturation current *IS* has a slowly decreasing tendency, due to the fact that at low doses of irradiation the concentration of point defects occurring in the structure is low. When increasing the irradiation dose the *IS* decreases due to the defect concentration increase in the structure which determines the formation of whole regions of defects of “clusters” type. Upon γ quanta irradiation the *IS* decreases due to the dependence of directly proportional relationship between the irradiation flux and the number of electron-hole pairs. Increase of flux intensity causes the increase in the number of electron-hole pairs. The same effect is also observed for X-ray irradiation. Increase in the intensity of the irradiation flux leads to an increase in the number of electron-hole pairs which recombine in the base, an increase in the base current and, therefore, a decrease in the saturation current.

Neutron irradiation causes a decrease in the *IRB* current which has a pronounced downward trend, base resistance still having high values. At high doses of irradiation can be observed that the decreasing trend of the *IRB* current is slower due to the fact that at these doses the value of the base resistance is much smaller, and therefore the decrease of the *IRB* current is also much slower. The same effect is also observed for the γ quanta and X-ray irradiation due to the fact that the increase in the number of electron-hole pairs which recombine in the base tends to saturation, as a result, the saturation of I_B base current occurs.

Neutron irradiation determines the decrease of *RB* base resistance due to point defects occurring in the structure upon irradiation. These defects cause an increase in the number of electron-hole pairs

Table 1. Dependencies of Bipolar Transistor Parameters Depending on Dose.

Doza	Parameters							
	IS (A)	NF	IKF (A)	IRB (A)	RB (Ohm)	NE	ISE (A)	BF
0	7,95E-18	1,02	1,07	1,88E-3	1,00E+2	1,72	6,00E-14	8,5E+1
Neutrons (n/cm^2)								
2,4E+12	5,72E-18	1,02	9,98E-1	9,11E-4	1,60E+1	1,45	1,52E-14	6,9E+1
2,4E+13	5,49E-18	1,03	9,98E-1	5,17E-4	1,70E+1	1,58	2,64E-13	6,0E+2
2,4E+14	1,99E-19	1,02	9,92E-1	1,88E-4	2,00E+1	1,70	3,53E-11	4,3E+1
γ quanta (Gr(SiO_2))								
1,2E+3	1,49E-17	1,02	1,04E+0	6,64E-4	1,00E+1	1,45	7,08E-16	7,6E+1
1,2E+4	9,79E-18	1,03	9,12E-1	5,74E-4	1,20E+1	1,42	2,95E-15	7,0E+1
1,2E+5	1,25E-18	1,02	1,86E-1	1,96E-4	1,40E+1	1,36	1,04E-13	4,2E+1
X-rays (Gr(SiO_2))								
0,6E+4	4,90E-18	1,02	1,04E+0	2,59E-2	3,26E+2	1,57	2,80E-14	7,0E+1
1,2E+4	1,31E-18	1,02	1,02E+0	2,46E-2	3,36E+2	1,56	2,69E-14	5,9E+1
1,8E+4	7,71E-19	1,00	9,98E-1	2,11E-2	3,24E+2	1,40	4,12E-14	5,5E+1
2,4E+4	5,09E-19	1,03	9,87E-1	1,75E-2	3,18E+2	1,65	5,66E-14	5,0E+1
3,0E+4	2,43E-19	1,03	6,53E-2	1,68E-2	2,63E+2	1,91	2,48E-13	4,2E+1
3,6E+4	9,49E-20	1,02	1,38E-2	1,66E-2	2,17E+2	1,68	3,91E-13	3,9E+1
4,2E+4	7,73E-20	1,02	1,21E-2	1,48E-2	2,06E+2	1,82	2,11E-12	3,0E+1

which recombine in the base. As a result, the increase of base current and decrease of *RB* base resistance takes place. The same trend is also observed upon γ quanta or X-ray irradiation, mentioning that in these cases an increase in the number of electron-hole pairs which recombine in the base region takes place.

Neutron irradiation also determines the increase of BE junction saturation current. It is observed that the *ISE* current has a relatively constant trend, since the irradiation induced defects are point defects and the number of electron-hole pairs which recombine in the base is relatively small. Increase of irradiation dose determines the agglomeration of point defects in the form of clusters and the significant increase in the number of electron-hole pairs. As a result, the increase of the I_B base current, I_E emitter current and *ISE* saturation current of the BE junction takes place. The same trend is also observed in the case of γ quanta or X-ray irradiation.

The amplification coefficient *BF* is decreased for all types of irradiation due to the increase of I_B base current. Increase of irradiation dose leads to a significant increase in the number of electron-hole pairs, which recombine in the base region, influenced by the agglomeration of occurring defects. This leads to the increase of I_B base current and decrease of the *BF* amplification coefficient.

On the basis of these dependences, the comparative analysis of parameters for various types of irradiation was carried out. It was determined that the *IS* parameter value is essentially reduced in the case of neutron and X-ray irradiation. The same is also observed in the case of *ISE* parameter. *BF* parameter indicating the direct current gain decreases essentially in the case of X-ray irradiation for the whole dose range.

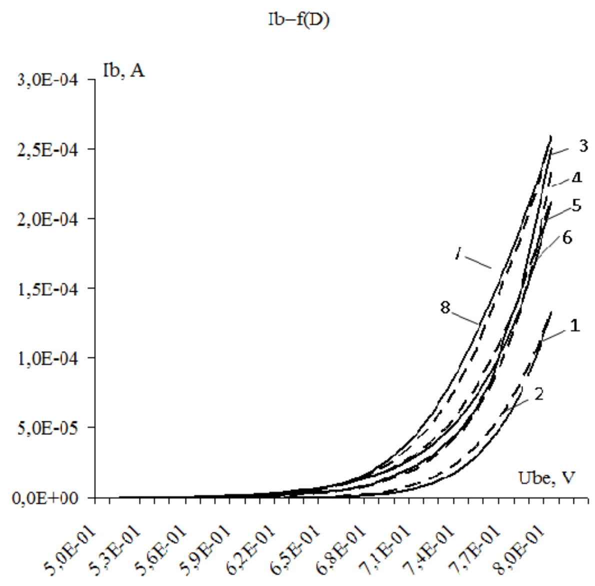

Figure 1. Dependence Ib=f(Ube) (___experimental, --- simulated) for bipolar transistor: *1,2 - before irradiation; 3,4 - irradiated with neutrons, D=2.4E+12 ncm^{-2}; 5,6 - irradiated with γ quanta, D=1.2E+5 Gr(SiO_2); 7,8 – irradiated with X-rays, D=4.2E+4 Gr(SiO_2).*

The degradation of *BF* parameter also determines the decrease of the *IKF* parameter value because it represents the current from which *BF* starts to decrease. For the *IKF* current which is determined by the occurrence of defects in the structure and their agglomeration in the form of clusters, the decreasing trend is higher in the case of X-ray irradiation. It was observed that the decrease of *RB* base resistance is lower in the case of γ quanta irradiation and more pronounced in the case of neutron and X-ray irradiation.By means of a bipolar transistor parameter extraction program, from the experimental dependencies obtained before and after irradiation, the values of these parameters were determined.

Their use in the SPICE LEVEL3
LEVEL3 program allowed the CVA simulation for the investigated structures. The results presented in fig. 1 demonstrate the correlation between the data obtained experimentally and those obtained by simulation at different irradiation doses.

2. DEPENDENCIES OF MOS STRUCTURE PARAMETERS ON IRRADIATION

Using the program developed for extraction of parameters necessary to simulate the characteristics of TMOS [8, 9], the values of the following parameters were obtained: *VTO* – threshold voltage at null polarization, *NSUB* – substrate doping concentration, *KP* – transconductance coefficient, *ETA* – parameter of short channel effect, *THETA* – parameter of mobility modulation by the electric field in the channel, and their dependencies depending on irradiation doses. The obtained results [10] are shown in tab. 2.

Table 2. Dependence of TMOS Parameters on the Accumulated Dose upon X-ray Irradiation.

Doza $Gr(SiO_2)$	**Parametrs**				
	VTO (V)	**NSUB (m^{-3})**	**KP (A/V^2)**	**ETA**	**THETA (1/V)**
0	1,94	4,10E+22	1,73E+5	0,83	1,27E-1
0,6E+4	1,39	5,09E+22	1,41E+5	1,51	5,26E-2
1,2E+4	0,99	6,72E+22	1,18E+5	2,28	0
1,8E+4	0,70	6,67E+22	1,16E+5	3,24	2,08E-2
2,4E+4	0,64	6,60E+22	1,11E+5	4,66	2,29E-2
3,0E+4	0,48	6,80E+22	1,11E+5	6,14	4,03E-2

Variation of MOS structure parameters as a result of IR is determined by the effects occurring in the dielectric and at the $Si–SiO_2$ interface. When increasing the irradiation dose, the threshold voltage at the null polarization of *VTO* substrate is reduced due to the decrease of parameter value related to the *GAMMA* substrate action and the decrease of *PHI* surface potential. The diminution of carriers' mobility in the channel is due to the appearance of donor and acceptor centers at the formation of electron-hole pairs upon irradiation.

The *NSUB* substrate doping concentration remains practically constant upon irradiation (within the limits of experimental data error) and is not dependent on the dose of irradiation.

On irradiation, the *KP* transconductance coefficient remains practically constant due to the saturation effect at high doses of irradiation. At high doses of irradiation MOS structures enter into the saturation more quickly than at doses of low irradiation intensities and the carriers' mobility no longer acts on the *KP* transconductance coefficient.

When increasing the irradiation dose the parameter *of ET*A short channel also increases. For high irradiation doses of the order $10^4 Gr(SiO_2)$ the faster entry into saturation of the structures takes place and the length of the channel diminishes with the increase of irradiation dose.

THETA parameter decreases with the increase of irradiation dose and increases at the load annealing on the oxide traps after irradiation, which enables its correlation with the SS formation process. The decrease of *THETA* parameter under the action of IR is caused by the reduction of the degree of dependence mobility in the TMOS channel and the action of transverse electric field. Variation of mobility parameter is determined by the following equation:

$$\theta = \frac{\mu_o - \mu}{\mu(V_{GS} - VTH)}, \quad (1)$$

wherein: μ_o – initial mobility; μ – effective mobility; V_{GS} –grid-source junction voltage; *VTH* – threshold voltage.

From this relation is observed that the determinant parameter for small doses of irradiation is the mobility μ, which with the increase of the irradiation dose is reduced. *THETA* parameter at doses of small irradiation intensities has a decreasing trend because the channel diminution process occurs more slowly and the mobility does not act on the mobility parameter. The decreasing trend is due to the reduction of the *VTH* threshold voltage. At higher irradiation doses the channel diminution and saturation process is more pronounced and the mobility acts substantially on the *THETA* parameter. The *VTH* threshold voltage, tending to zero, leads to an increase in the *THETA* coefficient.

The mathematical model and the extracted parameters enable the CVA simulation for the investigated structures, using the SPICE program. Dependencies $I_d = f(U_{ds})$ are shown in fig. 2, 3.

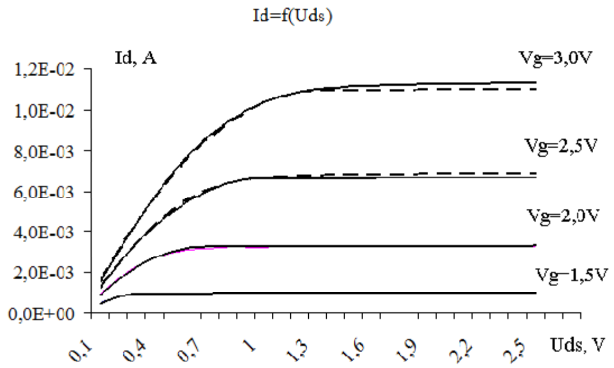

Figure 2. Dependence Id=f(D) (___experimen-tal, --- simulated) for nonirradiated TMOS.

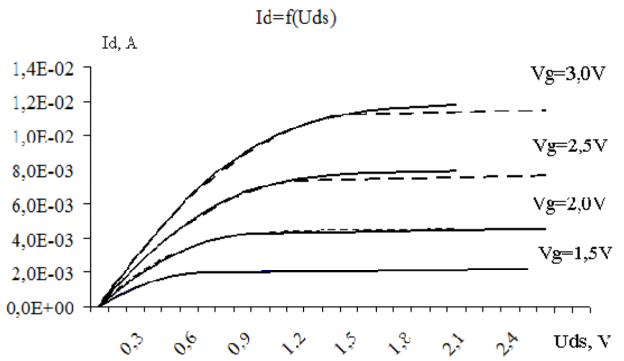

Figure 3. Dependence Id=f(Uds) (___experi-mental, --- simulated) for TMOS, D=3E+4 Gr(SiO_2).

CONCLUSIONS

1. Using the program developed for extraction of parameters, the bipolar transistor and MOS parameter variations before and after irradiation were obtained.

2. Bipolar structure parameters variation is determined by the considerable increase in the concentration of defects in the structure which determines the formation of a whole region of defects of clusters type (neutron irradiation) and the increase in the number of electron-hole pairs (γ quanta and X-ray irradiation).

3. MOS structure parameters variation is determined by the diminution of carriers' mobility in the channel which is caused by the appearance of donor and acceptor centers at the formation of electron-hole pairs upon irradiation. When increasing the irradiation dose the diminution of mobility contributes to the variation of channel length.

4. On the basis of parameter values obtained before and after irradiation, the CVA simulations of bipolar and MOS structures of different topological dimensions were carried out. The discrepancy between the experimental curves and those obtained by simulation differ by about 3%, which confirms that the mathematical parameter extraction model is adequate to the studied processes.

5. On the basis of irradiation research and CVA simulation results, the irradiation stability of active bipolar and MOS elements was determined.

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PERFORMANCE MODELING OF COMPUTING PROCESSES USING RECONFIGURABLE DIFFERENTIAL STOCHASTIC PETRI NETS

E. Guțuleac, dr. hab, prof. univ., Iu. Țurcanu, drd., D. Palii, drd.
Technical University of Moldova

INTRODUCTION

A natural modeling framework for many complex systems, such as communication or computer systems and networks, is provided through discrete event systems and, in particular, generalized stochastic Petri nets (*GSPN*) models [3]. However, factors such as huge traffic volumes, increasingly complex operating rules, and performance requirements make such models highly impractical. From an analytical standpoint, traditional models from classical queuing theory fail to capture new features such as complicated traffic source behavior or blocking phenomena. An alternative modeling paradigm for the purpose of analysis and simulation is based on Stochastic Fluid Models (*SFM*). The SFM paradigm allows the aggregation of multiple events into a single event associated with a "significant change" in the system dynamics.

Among the formalisms of *SFM* that are used, the fluid stochastic Petri nets (*FSPN*) [9] and hybrid stochastic Petri nets (*HSPN*) [1, 8] are popular. To make design issues and analysis procedures more transparent with negative-continuous values, we tried to deviate as little as possible from the concepts and the nets of *FSPN* and *HSPN*. Thus, we propose our extension of differential Petri nets (*GDPN*) [5], which we call Generalized Differential Stochastic Petri Net (*GDSPN*), and that is able to represent the behavior of computing processes in a common model. The features of *GDSPN* accept the *negative-continuous place capacity, negative real values for continuous place marking and token-dependent arc cardinalities* that permit to generalize the concept of *GDPN*, *FSPN* and *HSPN*.

1. GENERALIZED DIFFERENTIAL STOCHASTIC PETRI NETS

The problem of state space explosion has challenged numerical solution of Markovian models for a generation. In this paper we propose a means of avoiding this problem for large scale models of repeated components, represented in GSPN. By adopting a continuous approximation of the model behavior we are able to analyze systems of arbitrarily large scale. However, work is progressing on relaxing these assumptions.

Let IN_+ and IR be the sets of discrete natural and real numbers, respectively.

Definition 1. A Generalized differential Petri net (*GDPN*) is a 10-tuple $H\Gamma = <P, T, Pre, Post, Test, Inh, K_p, K_b, G, Pri>$, where:

- P is the finite set of places partitioned into a set of discrete places $P_d = \{p_1, \cdots, p_{n_d}\}$, $n_d = |P_d|$, and a set of continuous places $P_c = \{b_1, \cdots, b_{n_c}\}$, $n_c = |P_c|$, $P = P_d \cup P_c$, $P_d \cap P_c = \varnothing$. The discrete places may contain a natural number of tokens, while the marking of a continuous place is a real number (fluid level). In the graphical representation, a discrete place is drawn as a single circle while a continuous place is drawn with two concentric circles;
- T is a finite set of transitions, that can be partitioned into a set $T_d = \{t_1, \cdots, t_{k_d}\}$, $k_d = |T_d|$ of discrete transitions and a set $T_c = \{u_1, \cdots, u_{k_c}\}$, $k_c = |T_c|$ of continuous transitions, $T = T_d \cup T_c$, $T_d \cap T_c = \varnothing$. A transition $t_j \in T_d$ is drawn as a black bar; a continuous transition $u_l \in T_d$ is drawn as an empty rectangle.
- *Pre*, *Test* and $Inh: P \times T \to Bag(P)$ respectively, are forward flow, test and inhibition functions. $Bag(P)$ are discrete or real-valued multisets functions over *P*. The backward flow function in the multisets of *P* is $Post: T \times P \to Bag(P)$. These functions define the set of arcs $\mathcal{A}$ and describe the marking-dependent cardinality of arcs connecting transitions with places and vice-versa. Also, the $\mathcal{A}$ set is partitioned into subsets:

$$\mathcal{A} = \mathcal{A}_d \cup \mathcal{A}_c \cup \mathcal{A}_h \cup \mathcal{A}_t \cup \mathcal{A}_s,$$
$$\mathcal{A}_d \cap \mathcal{A}_c \cap \mathcal{A}_h \cap \mathcal{A}_t \cap \mathcal{A}_s = \varnothing.$$

The subset $\mathcal{A}_d$ and $\mathcal{A}_s$ contains respectively the *discrete normal* and *continuous normal* set arcs which can be seen as a function:

$\mathcal{A}_d$: $((P_d \times T_d) \cup (T_d \times P_d)) \times Bag(P) \to IN_+$, and $\mathcal{A}_s$: $((P_c \times T_d) \cup (T_d \times P_c)) \times Bag(P) \to IR$.

The arcs of $\mathcal{A}_d$ and $\mathcal{A}_s$, are drawn as single arrows. The subset of *inhibitory* and *test* arcs is $\mathcal{A}_h$, $\mathcal{A}_t$: $(P \times T) \times Bag(P) \to IN_+$ or that of *continuous inhibitory* and *test* arcs is $\mathcal{A}_h$, $\mathcal{A}_t$: $(P_c \times T) \times Bag(P) \to IR$. These arcs are directed from a place to any kind to a transition of any kind. The *inhibitory* arcs are drawn with a small circle at the end and *test* arcs are drawn as dotted single arrows. It does not consume the content of the source place. The subset $\mathcal{A}_c$ defines the *continuous flow* arcs $\mathcal{A}_c$: $((P_c \times T_c) \cup (T_c \times P_c)) \times Bag(P) \to IR$, and these arcs are drawn as double arrows to suggest a pipe. The arc of a net is drawn if the cardinality is not zero and it is labeled to the arc with a default value being 1;

- $K_p : P_d \to IN_+ \cup \{\infty\}$ is the capacity-function of discrete places and for each $p_i \in P_d$ this is represented by the maximum capacity $K_{p_i}^{\max}$, $0 < K_{p_i}^{\max} < +\infty$, which can contain an natural number of *tokens*. By default, the $K_{p_i}^{\max} \to +\infty$, and it has no blocking effect;
- $K_b : P_C \to IR \cup \{\infty\}$ is the capacity-function of continuous places and for each $b_i \in P_c$ it describes the fluid lower bounds $x_i^{\min}$ and upper bounds $x_i^{\max}$ of the fluid, so that $-\infty < x_i^{\min} < x_i^{\max} < +\infty$. By default, $x_i^{\min} = 0$ and $x_i^{\max} \to +\infty$, and it has no blocking effect;
- $G : T \times Bag(P) \to \{true, false\}$ is the *guard function* defined for each transition. For $t \in T$ a guard function $g(t,\mathcal{M})$ will be evaluated in each marking $\mathcal{M}$, and if it evaluates to *true*, the transition may be enabled, otherwise t is disabled (by default it is *true*);
- $Pri: T \times Bag(P) \to IN_+$ defines the priority functions for the firing of each transition. By default it is 0. The enabling of a transition with higher priority disables all the lower priority transitions. ■

The structure of a *GDPN* is static. The dynamics of a net structure is specified by defining its initial marking and its marking evolution rule.

Definition 2. A system stochastic timed marked *GDPN* net (*GDSPN*) is a pair $\mathcal{NH} = <\mathcal{N}, \mathcal{M}_0>$, where $\mathcal{N} = <H\Gamma, \Lambda, W, V>$ is a system timed stochastic timed *GDPN* structure (see Definition 1) with the respective attributes of timed transitions and $\mathcal{M}_0$ is the initial marking of the net so that:

- The set of discrete transitions T_d also is partitioned into two subsets $T_d = T_0 \cup T_\tau$, $T_0 \cap T_\tau = \varnothing$ so that: T_0 is a set of *immediate* discrete transitions and T_τ is a set of *timed* discrete transitions, so that, $\forall t_j \in T_0$ and $\forall t_k \in T_\tau$, $Pri(t_j) > Pri(t_k)$. The immediate transitions are drawn as a black thin bar and timed transitions are drawn as a black rectangle;
- The current marking (state) value of a net depends on the kind of place, and it is described by a pair of vector-columns $\mathcal{M}$=($\boldsymbol{m}$, $\boldsymbol{x}$), where $\boldsymbol{m}$: $P_d \to IN_+$ and $\boldsymbol{x}$: $P_c \to IR$ are the marking functions of respective type of places. The discrete marking $\boldsymbol{m} = (m_i p_i, m_i \geq 0, \forall p_i \in P_d)$ with $m_i p_i$ describe the number $m_i = \boldsymbol{m}(p_i)$ of tokens in discrete place p_i, and it is represented by black dots. The continuous marking $\boldsymbol{x} = (x_k b_k, x_k^{\min} \leq x_k \leq x_k^{\max}, \forall b_k \in P_c)$ with $x_k b_k$ describe the fluid level $x_k = \boldsymbol{x}(b_k)$ in continuous place b_k and it is a real number, also allowed to take *negative* real value. The initial marking of net is $\mathcal{M}_0 = (\boldsymbol{m}_0, \boldsymbol{x}_0)$. Vectors $\boldsymbol{m}_0$ and $\boldsymbol{x}_0$ give the initial marking of discrete places and of continuous places, respectively;
- $\Lambda : T_\tau \times Bag(P) \to IR_+$ is the rate function that maps timed discrete transition onto real nonnegative numbers IR_+. It can be marking dependent. The firing rate $\lambda_j(\mathcal{M})$ define the parameter of negative exponential distribution governing it firing duration for each timed discrete transition of $t_j \in T_\tau$.
- $W : T_0 \times Bag(P) \to IR_+$ is the weight function of immediate discrete transitions $t_k \in T_0$, and this type of transitions is drawn with a black thin bar and has a zero constant firing time.
- $V : T_c \times Bag(P) \to IR$ is the marking dependent fluid rate function of timed continuous transitions $u_j \in T_c$. If u_j is enabled in *tangible* marking $\mathcal{M}$ it fires with rate $V_j(\mathcal{M})$, so that it continuously changes the fluid level of continuous place $b_k \in P_c$. ■

The role of the previous set of arcs and functions will be clarified by providing the enabling and firing rules. Let us denote by m_i the i-th component of the vector $\boldsymbol{m}$, i.e., the number of tokens in discrete place p_i when the marking is $\boldsymbol{m}$, (and x_k denote the k-th component of the vector $\boldsymbol{x}$, i.e. the fluid level in continuous place p_k).

Figure 1 summarizes the graphical representation of all the $\mathcal{NH}$ primitives.

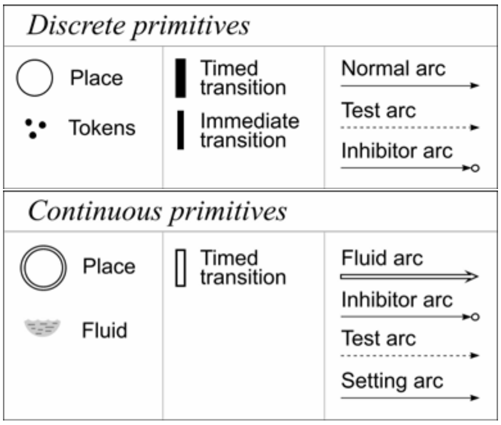

Figure 1. Graphical representation of all the $\mathcal{NH}$ primitives.

Let $T(\mathcal{M})$ be the set of enabled transitions in current marking $\mathcal{M}$. We say that a discrete transition $t_j \in T_d(\mathcal{M})$ is enabled in current marking $\mathcal{M}$ if the following logic expression (enabling condition $ec_d(t_j)$) is verified:

$$ec_d(t_j) = (\bigwedge_{\forall p_i \in {}^\bullet t_j} (m_i \geq Pre(p_i, t_j)) \,\&$$
$$(\bigwedge_{\forall p_k \in {}^\circ t_j} (m_k < Inh(p_k, t_j)) \,\&$$
$$(\bigwedge_{\forall p_l \in {}^* t_j} (m_l \geq Test(p_l, t_j)) \,\&$$
$$(\bigwedge_{\forall p_n \in t_j^\bullet} ((K_p - m_n) \geq Post(p_n, t_j)) \,\& \,(\bigwedge_{\forall b_i \in {}^\bullet t_j} (x_i \geq Pre$$
$$(b_i, t_j)) \,\& \,(\bigwedge_{\forall b_k \in {}^\circ t_j} (x_k < Inh(b_k, t_j)) \,\&$$
$$(\bigwedge_{\forall b_l \in {}^* t_j} (x_l \geq Test(b_l, t_j)) \,\&$$
$$(\bigwedge_{\forall b_n \in t_j^\bullet} ((K_b - x_n) \geq Post(x_n, t_j)) \,\& \,g(t_j, \mathcal{M}).$$

The transition $t_j \in T_d(\mathcal{M})$ fires if no other transition $t_k \in T_d(\mathcal{M})$ with higher priority is enabled. If an immediate discrete transition is enabled in current marking $\mathcal{M}$ = ($\boldsymbol{m}$, $\boldsymbol{x}$), it is *vanishing*. Otherwise, the marking is *tangible* and any timed discrete transition is enabled in it [3, 5]. If several enabled immediate discrete transition $t_j \in T_0(\mathcal{M})$ for $t_j \in {}^\bullet p_i$ are scheduled to fires at the same time in *vanishing* marking $\mathcal{M}$, with the respective weight speeds, $w_j(\mathcal{M})$, the $q_j(\mathcal{M}) = w_j(\mathcal{M}) / \sum_{t_l \in (T_0(M) \& {}^\bullet p_i)} w(t_l, \mathcal{M})$ is the probability that enabled immediate transition $t_j \in T_0$ can *fires*.

Also, we say that a continuous transition $u_j \in T_c(\mathcal{M})$ is enabled and continuously fires in current marking $\mathcal{M}$ if the following logic expression (the enabling condition $ec_c(u_j)$) is verified:

$$ec_c(u_j) = (\bigwedge_{\forall b_i \in {}^\bullet u_j} (x_i > 0) \,\& \,(\bigwedge_{\forall p_k \in {}^\circ u_j} (m_k <$$
$$Inh(p_k, u_j)) \,\& \,(\bigwedge_{\forall p_l \in {}^* u_j} (m_l \geq Test(p_l, u_j)) \,\&$$
$$(\bigwedge_{\forall b_k \in {}^\circ u_j} (x_k < Inh(b_k, u_j)) \,\& \,g(t_j, M) \,\&$$
$$(\bigwedge_{\forall b_l \in {}^* u_j} (x_l \geq Test(b_l, u_j)) \,\&$$
$$(\bigwedge_{\forall b_n \in u_j^\bullet} ((K_{b_n} - x_n) \geq V_j \cdot Post(x_n, u_j)),$$

and no transition with higher priority is enabled.

An immediate discrete transition t_j enabled in marking $\mathcal{M}$ = ($\boldsymbol{m}$, $\boldsymbol{x}$) yields a new vanishing marking $\mathcal{M}$'= ($\boldsymbol{m}$', $\boldsymbol{x}$). We can write ($\boldsymbol{m}$, $\boldsymbol{x}$) [t_j>($\boldsymbol{m}$', $\boldsymbol{x}$). If the marking M = ($\boldsymbol{m}$, $\boldsymbol{x}$) is tangible, fluid could continuously flow through the flow arcs $\mathcal{A}_c$ of enabled continuous transitions into or out of fluid places. As a consequence, a transition t_c is *enabled* at $\mathcal{M}$ if for every $b \in {}^\bullet u$, $\boldsymbol{x}(b)>0$, and its *enabling degree* is: *enab*(u, $\mathcal{M}$)= $\min_{b \in {}^\bullet u} \{\boldsymbol{x}(b)/Pre(u, b)\}$.

Upon firing, the discrete (continuous) transition removes a specified number (quantity) of tokens (fluid) for each discrete (fluid) input place, and deposits a specified number (quantity) of tokens (fluid) for each discrete (fluid) output place. The levels of fluid places can change the enabling/disabling of transitions.

We allow the firing rates and the enabling functions of the timed discrete transitions, the firing speeds and enabling functions of the timed continuous transitions, and arc cardinalities to be dependent on the current state of the $\mathcal{NH}$, as defined by the current marking $\mathcal{M}$.

4. DYNAMIC REWRITING GDSPN

In this section we introduce the model of *descriptive dynamic net rewriting systems.*

Let $X \rho Y$ be a binary relation. The *domain* of ρ is the *Dom*(ρ) = ρY and the *codomain* of ρ is the *Cod*(ρ) = $X\rho$. Also, let A= < *Pre*, *Post*, *Test*, *Inh* > be a set of arcs belonging to net $\mathcal{NH}$ $\mathcal{N}$= < $H\Gamma$,

Λ, W, V >, $H\Gamma$ = < P, T, Pre, $Post$, $Test$, Inh, K_p, K_b, G, Pri > (see *Definition* 2).

Definition 3**:** A *dynamic rewriting GDPN* is a system RH =< $\mathcal{N}$, R, ϕ, G_r, M >, where:

- $\mathcal{N}$= < $H\Gamma$, Λ, W, V > and $R=\{r_1,...,r_k\}$ is a finite set of discrete rewriting rules (*DR*) about the run-time structural modification of a net, so that $P \cap T \cap R = \varnothing$. In the graphical representation, the *DR* rule is drawn as two embedded empty rectangles;
- $\phi: E \rightarrow \{T_D, R\}$ is a function which indicates for every rewriting rule the type of event that can occur and $E = T_D \cup R$ denote the set of *events* of the net;
- $G: E \times Bag(P) \rightarrow \{true, false\}$ is the *event rule guard function* associated with $e \in E$, and $G_r: R \times Bag(P) \rightarrow \{true, false\}$ is the *rewriting rule guard function* defined for each rule of $r \in R$, respectively. For $\forall e \in E$, the function $g_e(M) \in G$ and $g_r(M) \in G_r$ will be evaluated in each marking and if they are evaluated to *true*, the event *e* may be *enabled*, otherwise it is *disabled*. The default value of $g_e(M) \in G$ and $g_r(M) \in G_r$ is *true* in current marking M.

Let RN=<RH, M> be represented by the descriptive expression $DE_{R\Gamma}$ and DE_{RN}, respectively [8]. A dynamic rewriting structure modifying rule $r \in R$ of *RN* is a map $r: DE_L \rhd DE_W$, where the *codomain* of the $\rhd$ *rewriting operator* is a fixed descriptive expression DE_L of a subnet RN_L of current net *RN*, where $RN_L \subseteq RN$ with $P_L \subseteq P$, $E_L \subseteq E$ and the set of arcs $A_L \subseteq A$, and the *domain* of the $\rhd$ is a descriptive expression DE_W of a new RN_W subnet with $P_W \subseteq P$, $E_W \subseteq E$ and set of arcs A_W. The rewriting operator $\rhd$ represents the binary operation which produces a *structure change* in the DE_{RN} and the net *RN* by replacing (rewriting) the fixed current DE_L of the subnet RN_L (DE_L and RN_L are dissolved) with the new DE_W of the subnet RN_W, now belonging to the new modified resulting $DE_{RN'}$ of the net $RN' = (RN \setminus RN_L) \cup RN_W$ with $P' = (P \setminus P_L) \cup P_W$, $E' = (E \setminus E_L) \cup E_W$, and the set of $A' = (A \setminus A_L) \cup A_W$, where the meaning of \ (and $\cup$) is operation of removing (adding) RN_L from (RN_W to) the net *RN*. In this new net RN', obtained by execution (firing) of enabled rewriting rule $r \in R$, the places and events with the same attributes which belong to RN' are fused. By default, the rewriting rules $r: DE_L \rhd \varnothing$ or $r: \varnothing \rhd DE_W$ describe the rewriting rule holding the $RN' = (RN \setminus RN_L)$ or $RN' = (RN \cup RN_W)$.

A state configuration of a net *RN* is a pair ($R\Gamma, s$), where $R\Gamma$ is the current structure of net RH together with a current state $s = (M, \beta(M))$. The ($R\Gamma_0, s_0$) with $P_0 \subseteq P, E_0 \subseteq E$ and state s_0 is called the initial state configuration of a net *RN*. ■

Figure 2 summarizes the graphical representation of *RH* discrete rewriting primitives.

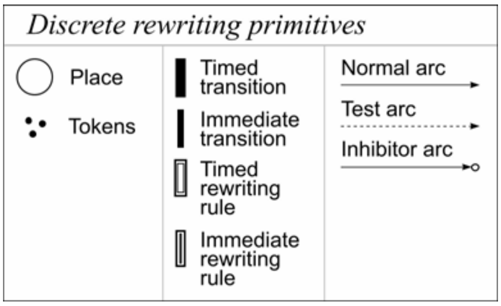

Figure 2. Discrete rewriting primitives of RH.

Enabling and Firing of Events. The enabling of events depends on the of the event e_j is enabled in current marking *M* if marking of all places. We say that a transition $t_j \in T_D$ the enabling condition $ec_d(t_j, M)$ is described in [7] and is verified.

The discrete rewriting rule $r_j \in R$, that changes the structure of *RN*, is enabled in current marking *M* if the $ec_d(e_j)$ and the $g_e(r_j, M))$ are verified.

Let $T_D(M)$ and $R(M)$, $T_D(M) \cap R(M) = \varnothing$, be the sets of enabled discrete transitions and enabled rewriting rule in current marking *M*, respectively. We denote the set of enabled events in a current marking M by $E(M) = T_D(M) \cup R(M)$.

The event $e_j \in E(M)$ fires if no other event $e_k \in E(M)$ with higher priority is enabled. Hence, for each e_j *if* $((\phi_j = t_j) \vee (\phi_j = r_j) \wedge (g_e(e_j, M) = False))$ *then* the firing of transition $t_j \in T_D(M)$ or rewriting rule $r_j \in R(M)$ changes only the current marking: $(R\Gamma, s) \xrightarrow{e_j} (R\Gamma, s') \Leftrightarrow (R\Gamma = R\Gamma$ and in $R\Gamma$ the $M[e_j > M']$). Also, for e_j event ***if*** $((\phi_j = r_j) \wedge (g_r(r_j, M) = True))$ ***then*** the event e_j occurs to firing of rewriting rule r_j and it changes the configuration and marking of the current net in the following way:

$(R\Gamma, s) \xrightarrow{r_j} (R\Gamma', s')$, $M[r_j > M'$.

The accessible state graph of a $RN = < R\Gamma, M >$ net is the labeled directed graph whose nodes are the states and whose arcs which are labeled with events or rewriting rules of *RN* are of two kinds:

a) *firing* of an enabled $e_j \in E(M)$ event determines an arc from the state $(R\Gamma, s)$ to the state $(R\Gamma, s')$ which is labeled with event e_j when this event can fire in the net configuration $R\Gamma$ at marking *M* and leads to a new state:

$$s' : (R\Gamma, s) \xrightarrow{e_j} (R\Gamma', s') \Leftrightarrow$$

$$(R\Gamma = R\Gamma' \text{ and } M[e_j > M' \text{ in } R\Gamma);$$

b) *change configuration*: arcs from state $(R\Gamma, s)$ to state $(R\Gamma', s')$ labelled with the rewriting rule $r_j \in R$, so that $r_j : (R\Gamma_L, M_L) \triangleright (R\Gamma_W, M_W)$ which represent the change configuration of current *RN* net: $(R\Gamma, s) \xrightarrow{r_j} (R\Gamma', s')$ with $M[r_j > M'$.

3. ANALYTICAL DESCRIPTION OF SGDPN MODELS

For the analysis of an *SGDPN* the underlying stochastic process must be defined. The node of the discrete part reachability graph consists of all discrete markings supplemented by vector of random variable for the fluid levels. It gives rise to a stochastic process, which is a Markov process in continuous time with mixed state space [4, 6]. The bounded, live and reversible *GSDPN* are isomorphic to continuous-time hybrid Markov chains (*CHMC*) due to the memory less property of exponential distribution.

We denote the set of all *markings* (or the partially discrete and partially continuous state space) of the net by $S = IN_+^{|P_d|} \times IR^{|P_c|}$. In the following we denote by S_d and S_c the discrete and the continuous component of the state space, respectively, so that $S = S_d \cup S_c$, $S_d \cap S_c = \varnothing$.

The current marking $\mathcal{M} = (\boldsymbol{m}, \boldsymbol{x})$ of $\mathcal{NH}$ evolves in time. We denote the time by τ, and $\mathcal{M}(\tau)$ the current marking at time τ of the marking process $S(\tau) = \{ \boldsymbol{m}(\tau), \boldsymbol{x}(\tau), \tau > 0 \}$ of $\mathcal{NH}$ net.

In the $\mathcal{NH}$, the instantaneous fluid speed (*dynamic balance*) $\upsilon_{i,k}(\mathcal{M})$ that change of fluid level in continuous place $b_i \in P_c$ in current marking $\mathcal{M} = (\boldsymbol{m}_k, \boldsymbol{x})$, $\boldsymbol{m}_k \in S_d$, $\boldsymbol{x} \in S_c$ is given by: $\upsilon_{i,k}(\mathcal{M}) = \upsilon_{i,k}^{+}(\mathcal{M}) - \upsilon_{i,k}^{-}(\mathcal{M})$, $i = \overline{1, n_c}$, $n_c = |P_c|$, where for any given $u_k, u_n \in T_c(\mathcal{M})$, the $\upsilon_i^{+}(\mathcal{M})$ is an input instantaneous fluid speed of continuous place $b_i \in P_c$ and $\upsilon_i^{-}(\mathcal{M})$ is an output instantaneous fluid speed of this place:

$$\upsilon_{i,k}^{+}(\mathcal{M}) = \sum\nolimits_{u_k \in {}^\bullet b_i} [\, V_k(\mathcal{M}) \cdot Pre(u_k, b_i) \,],$$

$$\upsilon_{i,k}^{-}(\mathcal{M}) = \sum\nolimits_{u_n \in b_i^\bullet} [\, V_n(\mathcal{M}) \cdot Post(u_n, b_i) \,].$$

Live and bounded *HSPN* are isomorphic to continuous-time hybrid Markov chain (*CHMC*) due to the memory less properly of exponential distribution [3].

Let S_d be the discrete set of state space of *CHMC* and let $\boldsymbol{D}(x) = [d_{l,j}(x)]$, $i, j = 0, \ldots, |S_d|$ be the *dynamic matrix* of transition rates derived from the rate function of discrete transitions of discrete part *GDSPN* [1, 8].

The dynamic balances $\upsilon_i(\mathcal{M})$ that changes levels for each continuous place b_i in discrete marking $\boldsymbol{m}_k \in S_d$ are collected in the diagonal matrice:

$$\upsilon_k(\boldsymbol{x}) = diag(\upsilon_{i,0}(\boldsymbol{x}), \ldots, \upsilon_{i,k}(\boldsymbol{x})),$$

$$i = 1, \ldots, n_c = |P_c|.$$

The 3-tuple $(\boldsymbol{m}(\tau), \boldsymbol{x}(\tau); \upsilon_k(\boldsymbol{x}))$ describes the state of *CHMC* chain. The transient probability of being in discrete state $\boldsymbol{m}_k$ with fluid levels in an infinitesimal environment around x_i, for all continuous places $b_i \in P_c$ are called the fluid density probability and are denoted by $f_k(\boldsymbol{x}, \tau)$. Let $x_i^{\min} = {}^{-}h_i$ and $x_i^{\max} = {}^{+}h_i$. Let also $\rho_k^{-}(\boldsymbol{x}, \tau)$ or $\rho_k^{+}(\boldsymbol{x}, \tau)$ be a probability mass if $\boldsymbol{x}(\tau)$ has at least one component equal to $x_i = {}^{-}h_i$ or $x_i = {}^{+}h_i$, respectively.

Using the approach described in [8, 9] we have derived the Chapman-Kolmogorov forward equations that are in the following:

- for internal fluid levels values $\forall\ {}^{-}h_i < x_i < {}^{+}h$ of $b_i \in P_c$:

$$\frac{\partial}{\partial \tau} f_k(\boldsymbol{x}, \tau) + \sum_{i=1}^{n_c} \frac{\partial}{\partial x_i} (f_k(\boldsymbol{x}, \tau) \cdot \upsilon_{i,k}(\boldsymbol{x})) = \sum_{l=0}^{|S_d|} (d_{l,k}(\boldsymbol{x}, \tau) \cdot f_l(\boldsymbol{x}, \tau)), \qquad (1)$$

$$k = 0, \ldots, N_d, \ N_d = |S_d|.$$

For the boundary conditions two different cases arise, depending on the direction of the fluid flow:

- for the lower boundary fluid levels values $x_i = {}^-h_i$ of $b_i \in P_c$:

$\rho_k^-(\boldsymbol{x},\tau)=0$ if $(x_i = {}^-h_i) \wedge (\cdot\upsilon_{i,k}(\boldsymbol{x})>0)$, and

$$\frac{\partial}{\partial\tau}\rho_k^-(\boldsymbol{x},\tau)+\sum_{\forall i: x_i={}^-h_i}(f_k(\boldsymbol{x},\tau)\cdot|\upsilon_{i,k}(\boldsymbol{x})|) + \sum_{\forall i: x_i>{}^-h_i}(\frac{\partial}{\partial x_i}f_k(\boldsymbol{x},\tau)\cdot\upsilon_{i,k}(\boldsymbol{x})) = \sum_{l=0}^{|S_d|}(d_{l,k}(\boldsymbol{x},\tau)\cdot\rho_l^-(\boldsymbol{x},\tau)),$$

if $(x_i = {}^-h_i) \wedge (\upsilon_{i,k}(\boldsymbol{x})<0)$, $\forall b_i \in P_c$, $\forall\ m_k \in S_d$; (2)

- for the upper boundary fluid levels values $x_i = {}^+h_i$ of $b_i \in P_c$: $\rho_k^+(\boldsymbol{x},\tau)=0$ if $(x_i = {}^+h_i) \wedge (\cdot\upsilon_{i,k}(\boldsymbol{x})<0)$, and (3)

$$\frac{\partial}{\partial\tau}\rho_k^-(\boldsymbol{x},\tau)+\sum_{\forall i: x_i={}^+h_i}(f_k(\boldsymbol{x},\tau)\cdot\upsilon_{i,k}(\boldsymbol{x})) + \sum_{\forall k:\ {}^-h_i<x_i<{}^+h_i}\frac{\partial}{\partial x_i}(f_k(\boldsymbol{x},\tau)\cdot\upsilon_{i,k}(\boldsymbol{x},\tau)) = \sum_{l=0}^{|S_d|}(d_{l,k}(\boldsymbol{x},\tau)\cdot\rho_l^+(\boldsymbol{x},\tau)),$$

if $(x_i = {}^+h_i) \wedge (\cdot\upsilon_{i,k}(\boldsymbol{x})>0)$, $\forall b_i \in P_c$, $\forall\ m_k \in S_d$

Assuming the system converges to a stationary solution of equations (1), (2) and (3), the stationary fluid density function and fluid mass function exists $f_k(\boldsymbol{x})=\lim_{\tau\to\infty} f_k(\boldsymbol{x},\tau)$, $\rho_k^-(\boldsymbol{x})=\lim_{\tau\to\infty}\rho_k^-(\boldsymbol{x},\tau)$ and $\rho_k^+(\boldsymbol{x})=\lim_{\tau\to\infty}\rho_k^+(\boldsymbol{x},\tau)$ only if the system is stable. Stability conditions of *GDSPN* are still a research topic.

For these equation systems the steady-state distribution exists when the underlying of *GDSPN* discrete part is bounded, life, reinitialized and the following relations are verified:

$$\lim_{\forall h_i^+\to\infty}\sum_{\forall \boldsymbol{m}_k\in S_d}(\pi_k(\boldsymbol{x})\cdot\upsilon_{i,k}(\boldsymbol{x}))<0,\ \forall b_i \in P_c, \quad (4)$$

where $\pi_k(\boldsymbol{x})$ is the stationary probability of discrete marking $m_k \in S_d$ determined by the underlying continuous-time Markov chain (*CTMC*) of *GDSPN* discrete part [4, 10]. These relations are obtained by solving the following linear system equations that describe the behavior of *CTMC*:

$$\vec{\pi}(\boldsymbol{x})\cdot\boldsymbol{D}(\boldsymbol{x})=\boldsymbol{0},\quad \sum_{\forall \boldsymbol{m}_k\in S_d}\pi_k(\boldsymbol{x})=1. \quad (5)$$

Over the ${}^-h_i < x_i < {}^+h$ internal fluid levels value intervals the stationary distribution of $f_k(\boldsymbol{x})$, $k = 0,\ldots,N_d$, $N_d = |S_d|$, satisfies:

$$\sum_{i=1}^{n_c}\frac{\partial}{\partial x_i}(f_k(\boldsymbol{x})\cdot\upsilon_{i,k}(\boldsymbol{x}))=\sum_{l=0}^{|S_d|}(d_{l,k}(\boldsymbol{x})\cdot f_l(\boldsymbol{x})),\quad \forall\ {}^-h_i < x_i < {}^+h. \quad (6)$$

For the boundary conditions, depending on the direction of the fluid flow [3, 6]:

- for the lower boundary fluid levels values $x_i = {}^-h_i$ of $b_i \in P_c$:

$\rho_k^-(\boldsymbol{x})=0$ if $(x_i = {}^-h_i) \wedge (\cdot\upsilon_{i,k}(\boldsymbol{x})>0)$, and

$$\sum_{\forall i: x_i={}^-h_i}(f_k(\boldsymbol{x},\tau)\cdot|\upsilon_{i,k}(\boldsymbol{x})|) + \sum_{\forall k: x_i>{}^-h_i}(\frac{\partial}{\partial x_i}f_k(\boldsymbol{x})\cdot\upsilon_{i,k}(\boldsymbol{x}|) = \sum_{l=0}^{|S_d|}(d_{l,k}(\boldsymbol{x})\cdot\rho_l^-(\boldsymbol{x})), \quad (7)$$

if $(x_i = {}^-h_i) \wedge (\upsilon_k(\boldsymbol{x})<0)$, $\forall b_i \in P_c$, $\forall\ m_k \in S_d$;

- for the upper boundary fluid levels values $x_i = {}^+h_i$ of $b_i \in P_c$:

$\rho_k^+(\boldsymbol{x})=0$ if $(x_i = {}^+h_i) \wedge (\upsilon_{i,k}(\boldsymbol{x})<0)$, and

$$\sum_{\forall i: x_i={}^+h_i}(f_k(\boldsymbol{x},\tau)\cdot\upsilon_{i,k}(\boldsymbol{x})) + \sum_{\forall i: x_i>{}^+h_i}(\frac{\partial}{\partial x_i}f_k(\boldsymbol{x})\cdot\upsilon_{i,k}(\boldsymbol{x}))+\sum_{i:\ {}^-h_i<x_i<{}^+h_i}\frac{\partial}{\partial x_i}(f_k(\boldsymbol{x})\cdot\upsilon_{i,k}(\boldsymbol{x}))= \sum_{l=0}^{|S_d|}(d_{l,k}(\boldsymbol{x})\cdot\rho_l^+(\boldsymbol{x})), \quad (8)$$

if $(x_i = {}^+h_i) \wedge (\cdot\upsilon_{i,k}(\boldsymbol{x})>0)$, $\forall b_i \in P_c$, $\forall\ m_k \in S_d$

The *GDSPN* model solution problem is in general not analytically tractable. The numerical solution algorithms proposed in [2, 6, 9] are applicable only when the interactions between the discrete and continuous portions of the net satisfy fairly strong assumptions.

To obtain the steady-state solution of the dynamics for the stationary fluid mass probability:

$$\rho_k(\boldsymbol{x}) = (\rho_k^-(\boldsymbol{x}) + \rho_k^+(\boldsymbol{x}) + \int_{{}^-\vec{h}}^{\vec{x}} f_k(\boldsymbol{x})\boldsymbol{dx},\quad \forall m_k \in S_d$$

with $\int_{{}^-\vec{h}}^{\vec{x}}\boldsymbol{dx} = \int_{{}^-h_{n_c}}^{x_{n_c}}\ldots\int_{{}^-h_1}^{x_1}dx_1\ldots dx_{n_c}$

of the *GDSPN* model has been computed by using an extension of the finite difference solution technique proposed in [6, 9], which confirms to the boundary conditions and satisfies the normalization condition at the same time. These are quite complex and hard to solve.

Hence, discrete-event simulation becomes an important alternative avenue to study the behavior and the solution of *GDSPNs* models under some restrictions. However, due to the mixed nature of the state space, with discrete and continuous components and arbitrary interactions between them, simulation also poses several challenges that we address. In [3] are characterized the types of these interactions as belonging to one of the several restricted classes of models and are proposed a better suited, and faster, simulation algorithms can be employed for the solution and to predict the behavior.

Thus, for visual simulation and analysis of *GDSPNs* we have elaborated the VHPNtool [7].

Continuous performance measures can be classified as *fluid state measures* and *flow measures*. Fluid state measures give the probability of a condition connected to the fluid levels in the net, while flow measures can be considered as the continuous counterpart of discrete throughput measures.

In order to show the applicability of *GDSPNs* we consider a pipe-line hybrid computing system consisting of three processing elements PE_j, j=1,2,3 (see figure 3). Each element PE_j can be in two local states $\alpha_j \in \{0, 1\}$. In the active state $\alpha_j = 1$, the element PE_j with speed V_j will, in continuous mode, decrease the level x_k of buffer b_k , k = 4-j and in the same time it will in continuous mode increase the level x_j of buffer b_j, j=1, 2, 3. In the passive state $\alpha_j = 0$ it will not change them anymore. The time sojourn of each element PE_j in the states $\alpha_j = 1$ or $\alpha_j = 0$ are negative exponentially distributed random variables with rates λ_j or μ_j.

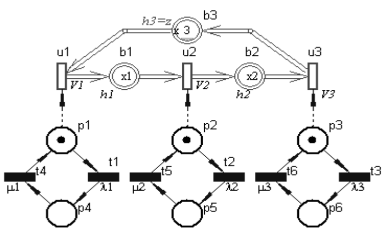

Figure 3. Translation of DE_{sys} in NH_{sys}.

The blocking effect of PE_j in $\alpha_j = 1$ is represented by capacity $K_{b_j} = h_j$ of buffer b_j if this is full. Further, we will note x_1=x, x_2=y and x_3=z. The net NH_{sys} has four P-invariants that cover all places: $m(p_j) + m(p_{j+3})$=1, j=1,2,3 for discrete places and $x + y + z = h$ for continuous places. For the initial marking $m(p_j)$=1, x_0=y_0=0, z_0= h_3=h_1+h_2, and the current state of $NH1$ can be described by 7-tuple $(\alpha_1\alpha_2\alpha_3, xy; \beta_x, \beta_y)$, where β_x and β_y are respectively dynamic balances of buffers b_1 and b_2.

The analytical analysis of underlying hybrid continuous time Markov Chain *HMC* of this NH_{sys} model in general case is very difficult. For this analysis is necessary to use the special tool.

Here we give a simplified case for $\lambda_2 = \lambda_3 = 0$, where the elements PE_2 and PE_3 always will be in active state $\alpha_2 = \alpha_3 = 1$ and in this way, the element PE_2 (respective PE_3) with the speed V_2 (respective V_3), will transfer the content of buffer b_1 (respective b_2) in buffer b_2 (respective b_3).

The behavior of NH_{sys} depends on the ratio between speeds V_j. For $V_1 > V_2 > V_3$ the chain *HMC1*, with the respective internal and boundary states, in considerate case, is represented in figure 5, where the discrete marking is $m_i \in \{0, 1\}$ because the element PE_i can be or in passive or in active state.

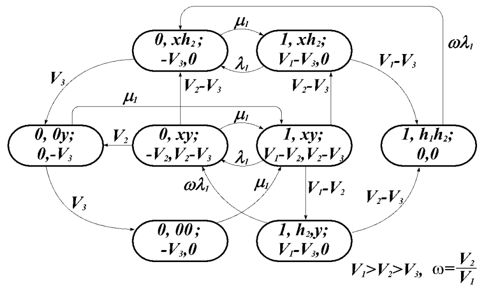

Figure 5. *HMC1* of NH_{sys}.

Let $f_i(x, y)$ denote the steady-state fluid density of *CHMC1* in current marking (m_i, xy), i=0,1. For each internal state (m_i, xy; v_x, v_y), 0<x<h_1 and 0<y<h_2 of the chain *CHMC1* the $f_i(x, y)$ obeys the following system of partial differential equations (*PDE*):

$$-V_2 \cdot \frac{\partial f_0(x,y)}{\partial x} + (V_2 - V_3) \cdot \frac{\partial f_0(x,y)}{\partial y} + \mu_1 f_0(x,y) = \lambda_1 f_0(x,y);$$

$$(V_1 - V_2) \cdot \frac{\partial f_1(x,y)}{\partial x} + (V_2 - V_3) \cdot \frac{\partial f_1(x,y)}{\partial y} + \lambda_1 f_1(x,y) = \mu_1 f_0(x,y) \cdot \tag{9}$$

To write the boundary equation directly from graph of chain *HMC1* we introduce the notation: $\pi_i(0)$ or $\pi_i(h_1)$, which are the probabilities of boundary states of buffer b_1 for x=0 or x=h_1, but Q(0) or $Q(h_2)$ of buffer b_2 for y=0 or y=h_2, respectively.

For each state with $\omega = V_2/V_1$ we can write the steady-state probabilities from the boundary equations: $\omega\lambda_1 \cdot \pi_1(h_1) = V_3 \cdot \varphi_0(h_1)$;

$$\omega\lambda_1 \cdot \pi_1(h_1) = (V_2 - V_3) \cdot \varphi_1(h_1);$$

$$\omega\lambda_1 \cdot Q_1(h_2) = (V_2 - V_3) \cdot \varphi_1(h_2);$$
$$\mu_1 \cdot \pi_0(0) = (V_1 - V_2) \cdot \varphi_1(0);$$
$$\mu_1 \cdot Q_0(0) = V_3 \cdot \psi_1(0);$$
$$\mu_1 \cdot Q_0(0) \cdot \psi_0(h_2) = V_3 \cdot \varphi_0(0) Q_0(h_2).$$

Solutions of these equation systems permit us to determine the distribution of steady-state probability and the performance indicators of system, i.e. the average levels $\hat{x}$ and $\hat{y}$ in buffers b_1 and b_2 are:

$$\hat{x} = C \cdot [(V_3 h_1/\mu_1\lambda_1 + (1+a_1)(\gamma_1 h_1 - 1)/b_1 + $$
$$+ (1+a_1)/\gamma_1^2,\ b_1 = \gamma_1^2 e^{\gamma_1 h_1}$$
$$\hat{y} = C \cdot \left[(h_2((V_1 - V_2)/(V_2 - V_3) + (V_2 - V_3)a_2/\mu\lambda_1) + D\right],$$

where: $D = (1+a_2)(\gamma_2 h_2 - 1)/\gamma_2^2)e^{\gamma_2 h_2} + (1+a_2)/\gamma_2^2$,

$$a_2 = A/a_1,\ \gamma_1 = \delta_1 \mu_1/V_2 - \lambda_1/(V_1 - V_2),$$
$$\delta_1 = \mu_1/V_3 - \lambda_1/(V_1 - V_3),\ a_1 = V_3/(V_2 - V_3),$$
$$\gamma_2 = (A\mu_1 + \gamma_1 V_2 - \lambda_1)/(V_2 - V_3).$$

The value of C is a constant obtained from the normalization condition, but γ_2 and A are obtained like solution of following character-ristic equation of system *PDE* :

$A^2 + b \cdot A - \rho = 0$, where $\rho = \lambda_1/\mu_1$, and

$b = 1 + V_1/V_2 - (\rho(2V_1 - V_2)/(V_1 - V_2))$.

From this characteristic equation and from the normalization condition, that density probability always is a positive value, we obtain the solution, $A>0$.

The time redundancy is: $\hat{\tau}_x = \hat{x}/V_2$ and $\hat{\tau}_y = \hat{y}/V_3$. The same considerations hold for system throughput.

4. CONCLUSIONS

In this paper we propose the generalized differential stochastic Petri nets (GDSPN) for performance modeling of discrete-continuous computing processes. The features of GDSPN accept the negative-continuous place capacity, negative real values for continuous place marking and marked-dependent arc cardinalities. With our approach, the modeling power of fluid models is extended to include the case with fluid-dependent rates. Also, we provide the set of partial differential equations and boundary conditions that determines the stationary behavior and we discuss potential numerical methods that evaluate the stationary distribution based on this description.

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TRAFFIC ACCIDENTS WITH INVOLVEMENT OF PEDESTRIANS. CASE STUDIES

I. Manoli, dr.assoc.prof., A. Malanciuc, drd.
Technical University of Moldova

INTRODUCTION

Methods for the speed determination of the pedestrian, as well as of the vehicle at the moment of impact with the victim have obtained a fairly large spread for the situations when on the spot inspections do not record the presence of the braking traces and of the categories of signs which generally allow a direct establishment of the victim position in the moment of its hitting by the front part of the vehicle. Other types of traces (pieces of damaged machinery parts, biological traces, signs of the contact created upon the impact) are also analyzed, allowing the quantification of the collision magnitude. On the other hand, their relative arrangement on the under question road segment, together with the stop position of the vehicle after the collision, may provide in some cases the required elements for the establishment of the kinematical parameters mentioned above (the speed on the impact and the projection distance), through the use of empirical relationships together with those of Newtonian mechanics.

1. DETERMINATION OF THE PROBABLE VEHICLE SPEED AND OF THE PLACE OF IMPACT

There aren't particular problems in a situation when on the spot were found traces printed by the tires of the vehicle during the braking process and the place of impact is indicated either by the presence of the certain traces coming from the projection of the fixed objects by a reduced contact with the victim's body (hat, keys, etc.), either by the presence of biological traces (frequently dynamic traces of blood − drops), either by the rubbing traces printed on the carriageable by the footwear soles objects. It is considered an issue approach that is typical for the situations when such signs are missing.

1.1. Basic objectives

The two objectives that are in question (the establishment of the moving speed of the vehicle and the place of impact), frequently required in the framework of the traffic accident criminal expertise, can be treated in many cases at the same time, starting from the fact that the distance of the victim projection is dependent mainly on the speed of the vehicle at the moment of impact. Production method of a road traffic event with involvement of pedestrian is subsequently materialized through the existence of some material evidences. In what follows will be taken into consideration four categories of traces, namely:

− biological traces that materialize the rest position of the victim;

− traces derived from the projection of the glass shards that belong to damaged assemblies (windshield /headlights);

− signs of contact created on the vehicle body upon the impact;

− the stop position of the vehicle after the braking process.

1.2. Concepts applied to the methodology

Approached methodology is based on the use, according to the available data provided by the on the spot research, of the only two of the sample material evidences referred to above. It is clear that in case you have three or even all four listed items, the reached degree of certainty is higher. Their creation and arrangement at the accident site will take place via dynamic action, common element being the speed of the vehicle at the moment of impact. Possible situations will be illustrated through practical cases, chosen according to the types of signs that were found on the spot. Road events where the rest relative position of the vehicle and of the pedestrian are known.

An event with pedestrian involvement can be divided into three phases: phase of switch, flight phase and the phase of tumbling and slipping of the victim on the surface on which it is projected. Upon the collision, the pedestrian acquires the speed of the vehicle, describing in the flight phase a parabolic trajectory which differ depending on the position of the point of impact in relation with the pedestrian center of mass. Relative position of these two points determines or not the existence of the rotation component around the center of mass.

Following the impact, the pedestrian may remain in the rest position on the surface of falling behind or in front of the vehicle frontal plane in its stop position (at the limit − in the frontal plane of the vehicle).

First case is characteristic for the situations when the impact speed is very high. The impact velocity is higher than 55-60 km/h and the vehicle is not decelerated or is braked with less intensity, in cases of collision with the extreme parts of the frontal plane of the vehicle body. In the latest case (impact with slipping), the design distances are much reduced in relation with the situation of the impact with the middle part of the vehicle body (total impact), being ascertained a reduction by up to 45% of the projected distance. On the other hand, the amplitude of the side projection will increase.

The second case is specific for the impacts at speeds up to 50 km/h, either the car is braked vigorously at the moment of impact, whether it is braked vigorously immediately after the impact and the victim is taken on the hood, case when there may be significant distances between the car frontal plane and the position of rest of the victim in front of it.

Studies conducted both in real cases and as a result of the mannequins usage that reproduce the size and consistency of the human body, resulted in the establishment of several empirical formulas that show the relationship between the speed at the moment of impact and the projection distance of the victim for situations in which pedestrian is hit by the front plane of the car in the middle part of it (Stcherbatcheff, Searle, Kühnel, Barzeley, Appel, etc.). Some of these relations reveal for certain arrangements of deceleration a less projection distance of the pedestrian than it is required to stop the vehicle from the speed of impact. In these cases it is possible to establish simultaneously the projection distance of the victim, and therefore, by default, the place of impact, and the speed at the moment of impact on the basis of a system of equations.

Road events when are known relative arrangements of the first fragments that belong to the smashed windshield or headlights and of the pedestrian after the projection.

In practice are frequently encountered situations when the stopping position of the vehicle is not known because the driver changed it from various reasons (transportation of victims, not to stop the traffic, etc), or this position does not exist, as long as the driver did not stop at the site of the accident.

Road events when are known relative arrangements of the first fragments that belong to the smashed windshield or headlights and of the vehicle after stopping.

The characteristic of this situation is the lack of biological traces (static traces of blood) which mark the last position of the victim, subsequently transported to hospital. The case will be illustrated by a situation from the expertise practice that have other elements also, but which, in this case, will be used only as a check for the proposed methodology.

Road events which require to estimate the impact speed based on car deformations.

An important category of evidences that fit the estimation of the velocity on impact are the traces of crash contact. The estimation of the impact velocity can be achieved through a comparative analysis, having access to a database which includes damaged vehicles for which are known the impact speed based on the measures made using others types of tracks (breaking traces, projection distances, etc.). This analysis is based also on the other cues offered by the practice in this area. Thus, we refer to the certain stages between which can be made first estimations.

For lower speeds, up to 15 km/h, in most cases there is no plastic deformation of the car to be found, the most common signs in these cases being traces of dust delamination or, optionally, a lamp breakage.

For a speed of about 20-35 km/h, deformations are with reduced amplitude and are located generally on certain singular body parts (bumper or engine hood in the frontal part). Characteristic for these remaining deformations is their location on the frontal side which mark an impact which not involves, in many cases, taking of the victim by the engine hood, the pedestrian being projected forward. For impact speeds of around 35-45 km/h, the adult pedestrian generally doesn't have contact with the car windshield or its breakage not occurs (Figure 1).

Figure 1. Impact at speed of around 20-35 km/h.

At the speeds above 40 km/h, the victim is taken on the engine hood. Windshield breakage, in its lower section, takes place for the speeds of 45-60 km/h (Figure 2).

Figure 2. Impact at speeds of approx. 45-60 km/h.

At the speeds of about 60-70 km/h, windshield breakage takes place at a higher rate. At higher speeds, crashes touch also vehicle pillars in their upper side, or the car flag. At the speeds above 75 km/h, the vehicle may pass under the strongly accelerated pedestrian. He may fall behind the vehicle on the carriageable or, in many cases, remain in contact with the body of the vehicle, entered partially in the passenger compartment.

This category of signs is in the most majority of the cases at the disposal of the expert through the judicial photos, in such a way that the determinations of the previous sections should be in conjunction with the deformation analysis. But there are situations where the estimation of the moving velocity of the vehicle on the basis of the damages amplitude may constitute the point of departure in subsequent determinations. The methodology is characteristic for the situations when it isn't known the stop position of the vehicle or the regime of deceleration until stopping and either the position in which were found the fragments derived from the smashed windshield or headlights.

2. DETERMINATION OF THE PEDESTRIAN POSITION AND SPEED AT THE MOMENT OF IMPACT

In case of traffic accidents with pedestrian involvement, the method for the determination of the speed and movement direction of the pedestrian is based on the testimonial evidence, by the choice of speed values from the specialized literature on the basis of the age and sex of the involved pedestrian. This was proved to be a good method under conditions when most of the testimonies match each other, but there are many situations where statements are contradictory or there are no witnesses or survivors. In this circumstance, it is absolutely necessary to consider the speed and trajectory of the pedestrian based on the traces remained after the impact and on the injuries suffered by him.

There are plenty of variables that affect the event of a collision between a motor vehicle and a pedestrian, making it a very complex equation. Further reference is made for a part of the aspects that occur in the accidents with pedestrian involvement, being confined only on those that have a direct connection to the proposed calculation method.

2.1. Calculation parameters

In a collision with a pedestrian, for the same value of the collision speed (40 km/h), it can be proved that the way it takes the pedestrian and the places of impact with his different parts of the body differ from one vehicle type to another, depending on its frontal shape and the relative position of the pedestrian towards the longitudinal axis of the vehicle.

Besides the frontal shape of the vehicle, the pedestrian height has a particular importance in the analysis of the traces left on the windshield after the collision (Figure 3). The damages suffered by the vehicle overlapped with the height of the pedestrian may provide clues for an approximate evaluation of the speed of impact, the pedestrian's direction, his speed and post-crushing trajectory.

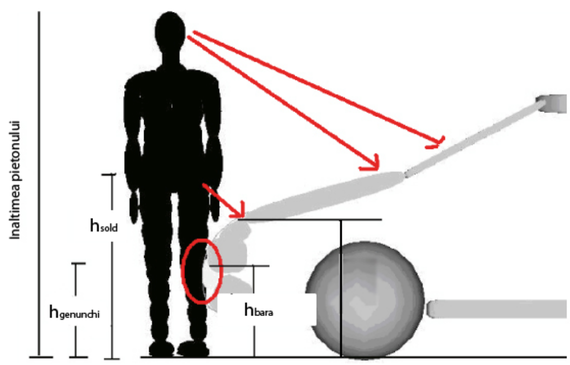

Figure 3. Typical places of contact between pedestrian and motor vehicle.

The time passed between the impact between different parts of the pedestrian body and the vehicle body, represents an important element by which can be done the determination of the pedestrian's relative speed towards the vehicle one.

Some specific studies over the kinematic impact between the pedestrian and vehicle shows that for the same impact velocity the type of the car and its frontal shape influence significantly the pedestrian movement and the time on which his hip, shoulder and head hit the front part of the vehicle.

2.2. Methodology application

According to the received data, person B. M. was moving on a street towards the town center driving a car brand Subaru Justy.

Around ---- o'clock, according to his own words, he observed belatedly a pedestrian engaged in crossing the street from the left to right behind some other cars moving in the opposite direction. The pedestrian, ignoring the red light of the semaphore, began to cross the street on the crosswalk among the vehicles that were circulating in the direction of Central Square and entered on the other direction of movement. At that moment he was hit by the front-right side of the Subaru vehicle. Proceeded to the analysis of the possibilities to avoid the accident, analytically was determined the speed of the pedestrian compared to the vehicle one. The distance between the place of impact of the hip and head was measured according to the images made on the spot by police, resulting a value of approx. 30 cm (Figure 4).

Figure 4. Distance between pedestrian hip and head places of impact.

Also, taking into account the lower class of the car and considering that the impact speed was around 40 km/h, was deduced the time between the hip impact and the head impact with the car, being of approx. 100 ms.

Substituting the data in the formula, we get:

$$\boldsymbol{V_p = 3,6 \cdot \frac{d_{S-C}}{T_{S-C}} = 3,6 \cdot \frac{0,3}{0,1} = 10,8 \approx \approx 11\ [km/h]} \quad (1)$$

where:

$d_{S-C} = 0{,}3\ m$ represent the distance between the place of impact of the hip and the place of impact of the head with the car;

$T_{S-C} = 0{,}1\ s$ is the time passed between the hip impact and the head impact with the car.

The travel speed of the pedestrian thus calculated shall be in accordance with the testimonial evidence properly administered and are within the limits given by the literature.

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IDENTIFICATION OF THE MICRO-HETEROGENEOUS MEDIUM MODEL PARAMETERS AND FUNCTIONS

N. Sveatenco, dr.fiz.mat.
Universitatea Tehnică a Moldovei

INTRODUCTION

This study focuses on the problem of the representation of a real material in the structural model of micro-heterogeneous medium. External conditions are considered when an element of body is deformed along a rectilinear trajectory with the constant state parameters. The internal constants, reflecting simultaneously the heterogeneities of the stress and strain tensors fields at the microscopic scale are determined on basic of the thermodynamic principles and of hypothesis that from all possible schemes of kinematic interaction between sub-elements the scheme with extreme discrepancy of macroscopic and microscopic measures corresponds to real interaction. The thermorheological features of the subelements are determined by proportional and isothermal tests of the thin-walled tubes strained by axial force and internal pressure.

1. LOCAL PHYSICAL EQUATIONS AND PRINCIPLES OF TRANSITION FROM MICROSTATE TO MACROSTATE

At the original time the studied macroscopic element is in a natural state then is subjected to mechanical and thermal action. It is assumed that during deformation the material behavior depends significantly on the velocity of loading and heating.

To describe the behavior of the micro-heterogeneous medium the macroscopically homogeneous volume element V_0 of the polycrystalline body bounded by the surface S_0 is considered to be composed of an infinite number of kinematically connected subelements with different thermorheological features. Subelement as the elementary structure identifies the set of all material particles in the interior domain V_0 that have the same irreversible strain tensors

$$\bar{p}_{ij} = \tilde{p}_{ij}, \qquad \bar{p}_{ij} = \left\langle \tilde{p}_{ij} \right\rangle_{\bar{V}}, \tag{1}$$

where $\bar{p}_{ij}$ implies average irreversible strain of the subelement with the volume $\bar{V}$.

The composition of material particles in the subelement remains invariable in all processes of the conglomerate strain. Particles of the same subelement may have different orientations and situations in the conglomerate space. Because the granules of the polycrystalline aggregate are nonuniformly deformed so that the mass and the volume of a single accepted subelement can be arbitrarily small. It is evident that proceeding from the selection of material particles in the accordance with the irreversible strain tensor other thermo-mechanical quantities change from a material particle to other one in the given subelement.

Despite the fact that subelements have only basic properties their set because of interactions between them possesses an extremely broad spectrum of features. Conglomerate characteristics are much more diverse than sum of the structural elements properties.

Within the limits of the examined model let us assume that all types of interactions between sub-elements in the conglomerate are formed only under the influence of average connections, i.e. material particles in the conglomerate do not deform independently, but only in a coordinated manner.

The phenomenon of the auto concordance of irreversible strain processes of subelements can be represented according to the concept of the average connections in the way of two equations [1, 4]:

– the yield condition for the subelement under the influence of structural modifications in conglomerate

$$\bar{e}_{ij} \frac{d\bar{p}_{ij}}{d\bar{\lambda}} = \tau(\psi, \gamma, \upsilon) + s + \bar{r}\cos\bar{\alpha}, \tag{2}$$

$$d\bar{\lambda} = \sqrt{d\bar{p}_{ij} d\bar{p}_{ij}}, \qquad \cos\bar{\alpha} = \frac{\bar{p}_{ij}}{\bar{p}} \frac{d\bar{p}_{ij}}{d\bar{\lambda}}; \tag{3}$$

– law about the overall orientation of irreversible yield processes for subelements

$$\frac{d\bar{p}_{ij}}{d\bar{p}} = \frac{dp_{ij}}{dp}, \tag{4}$$

$$d\bar{p} = d\sqrt{\bar{p}_{ij}\bar{p}_{ij}}, \qquad dp = d\sqrt{p_{ij}p_{ij}}, \tag{5}$$

where the functional τ represents scalar properties of subelements in the structurally stable state and can be identified with the initial yield point of subelement; $\overline{\alpha}$ is the angle between the tangent to the irreversible strain path and irreversible strain vector; and deviator of strain tensor is written as the sum of reversible $\overline{e}_{ij}$ and irreversible $\overline{p}_{ij}$ strains

$$\overline{\varepsilon}_{ij} = \overline{e}_{ij} + \overline{p}_{ij} ; \tag{6}$$

As the state parameter identifying quantities $\overline{\tau}$ and $\overline{r}$ with certain subelement is chosen weight of irreversibly deformed subelements $\psi\ (0 \le \psi \le 1)$ that reflects the sequence of subelements transition from reversible to irreversible state under initial loading.

The interaction between two subelements is realized by means of the interactions between material particles which are appertained to the different subelements. This fact is reflected by replacement of the local state parameters in physical equation for subelement on the average values of the whole set:

$$\gamma = \frac{1}{\psi_\lambda}\int_0^1 \dot{\overline{\lambda}}(\psi')d\psi', \qquad \upsilon = \frac{1}{\psi_\upsilon}\int_0^1 \overline{\upsilon}(\psi')d\psi', \tag{7}$$

$$\dot{s} = \frac{1}{\psi_s}\int_0^1 \dot{\overline{s}}(\psi')d\psi', \qquad 0 \le \psi_\lambda, \psi_\upsilon, \psi_s \le 1, \tag{8}$$

where γ is the average velocity of irreversible deformation in a subset of subelements being under the loading above the elastic limit; υ describes inelastic volume variation; ψ is the distinctive parameter of subelement which during the initial loading coincides with the weight of irreversibly deformed subelements when this subelement exceeded the elastic limit; ψ_λ, ψ_υ, ψ_s – summary weights of subelements for which the corresponding parameters $\dot{\overline{\lambda}}$, $\overline{\upsilon}$, $\dot{\overline{s}}$ are nonzero.

Evolutional equation of the state parameter $\overline{s}$ characterizing the isotropic hardening owing to the modification of structure in the irreversible processes, is accepted as

$$\dot{\overline{s}} = \begin{cases} a\sqrt{\dot{\overline{p}}_{ij}\dot{\overline{p}}_{ij}}, & \overline{s} < \overline{x}(\gamma,\upsilon), \\ \dot{\overline{x}}, & \overline{s} = \overline{x}(\gamma,\upsilon). \end{cases} \tag{9}$$

At the beginning of the irreversible deformation $\overline{s}\big|_{t=0} = s_0$, where s_0 depends on the type of the heat treating of the material. If at the start of the process of the irreversible deformation the material is in the structurally stable state, then $s_0 = 0$.

The relation between the kinematic hardening $\overline{r}$ and the state parameters is expressed as follows

$$\overline{r} = \begin{cases} a_0\overline{p}, & a_0\overline{p} < \overline{x}_0(\gamma,\upsilon), \\ \overline{x}_0(\gamma,\upsilon), & a_0\overline{p} = \overline{x}_0(\gamma,\upsilon), \end{cases} \tag{10}$$

$$\overline{r} = \sqrt{\overline{r}_{ij}\overline{r}_{ij}}, \qquad \overline{r}_{ij} = \overline{r}\,\frac{\overline{p}_{ij}}{\overline{p}}. \tag{11}$$

In monotonous processes throughout the subset of irreversibly deformed subelements an active process of loading occurs, that corresponds to the monotony of the evolution of weight of irreversibly deformed subelements in this process. This means that towards ψ only one separation boundary forms between reversibly $\psi' < \psi \le 1$ and irreversibly $0 \le \psi \le \psi'$ deformed subelements. Since the variations $d\overline{p}$ in all subelements have one and the same sign, the law of the admissible trajectories (4) can be written as

$$\frac{d\overline{p}}{d\overline{\lambda}} = \frac{dp}{d\lambda}, \qquad \frac{d\overline{p}_{ij}}{d\overline{\lambda}} = \frac{dp_{ij}}{d\lambda}, \tag{12}$$

from where

$$\cos\overline{\alpha} = \frac{\overline{p}_{ij}}{\overline{p}}\frac{d\overline{p}_{ij}}{d\overline{\lambda}} = \frac{d\overline{p}}{d\overline{\lambda}} = \frac{dp}{d\lambda} = \frac{p_{ij}}{p}\frac{dp_{ij}}{d\lambda} = \cos\alpha, \tag{13}$$

$$d\lambda = \int_0^{\psi'} d\overline{\lambda}d\psi, \qquad d\overline{p}\big|_{\psi>\psi'} = 0, \qquad \gamma = \frac{\dot{\lambda}}{\psi'}. \tag{14}$$

On the basis of the stresses and strains fluctuations principle, formulated by V.Marina [2], of the first law of thermodynamics and of the law of the elastic volume variation in [3-5] was obtained the general scheme of the kinematic interaction between subelements:

$$\Delta\overline{t}_{ij} = -B\Delta\overline{d}_{ij} + \alpha\sqrt{\frac{B(B+K)}{3}\Delta\overline{d}_{nm}\Delta\overline{d}_{nm}}\;\delta_{ij}, \tag{15}$$

$$\alpha = \begin{cases} 1, & dacă\ \ \overline{d}_{nm}\overline{d}_{nm} > d_{pq}d_{pq} \\ -1, & dacă\ \ \overline{d}_{nm}\overline{d}_{nm} \le d_{pq}d_{pq} \end{cases},$$

where K volume compressibility modulus; internal parameter B reflects the fact that the processes of loading and deformation of subelements in the conglomerate occur both heterogeneously.

In consequence of the decomposition of stresses and strains fluctuations into the deviators and the spherical tensors

$$\Delta\overline{t}_{ij} = \Delta\overline{\sigma}_{ij} + \Delta\overline{\sigma}_0\delta_{ij}, \qquad \Delta\overline{d}_{ij} = \Delta\overline{\varepsilon}_{ij} + \Delta\overline{\varepsilon}_0\delta_{ij}. \tag{16}$$

were obtained two groups of equations

$$\Delta\bar{\sigma}_{ij} = -B\Delta\bar{\varepsilon}_{ij}\,, \qquad (17)$$

$$\Delta\bar{\sigma}_0 = \alpha\sqrt{\frac{BK}{3}\Delta\bar{\varepsilon}_{nm}\Delta\bar{\varepsilon}_{nm}}\,, \qquad (18)$$

$$\alpha = \begin{cases} 1, & dacă \quad \bar{\varepsilon}_{nm}\bar{\varepsilon}_{nm} > \varepsilon_{pq}\varepsilon_{pq} \\ -1, & dacă \quad \bar{\varepsilon}_{nm}\bar{\varepsilon}_{nm} \le \varepsilon_{pq}\varepsilon_{pq} \end{cases}.$$

The elastic properties of subelementelor and of the body element are assumed identical

$$\bar{e}_{ij} = \frac{\bar{\sigma}_{ij}}{2G}\,, \qquad e_{ij} = \frac{\sigma_{ij}}{2G}\,. \qquad (19)$$

The equations of fluctuations of reversible and irreversible deformations are determined taken into consideration (6) and (19) in (17):

$$\bar{e}_{ij} - e_{ij} = m\left(p_{ij} - \bar{p}_{ij}\right), \quad m = \frac{B}{B+2G}\,. \qquad (20)$$

Unknown internal parameter m is determined on the basis of the principle of the measures discrepancy, formulated by V.Marina [2-3]: in all real interactions in conglomerate the discrepancy between the macroscopic measure and the suitable microscopic analogue reaches extreme values

$$\left\langle\bar{\sigma}_{ij}\bar{\varepsilon}_{ij}\right\rangle - \left\langle\bar{\sigma}_{ij}\right\rangle\left\langle\bar{\varepsilon}_{ij}\right\rangle = Extr\,. \qquad (21)$$

From extremum of the discrepancy Δ [4,6] we obtained that parameter of the kinematic scheme m depends on the linear hardening coefficient a_0:

$$m = -a_0 + \sqrt{a_0 + a_0{}^2}\,. \qquad (22)$$

Interdependence between the internal parameters B and m we find from the relation (20):

$$B = 2G\frac{m}{1-m}\,. \qquad (23)$$

2. IDENTIFICATION OF UNKNOWN PARAMETERS AND FUNCTIONS OF THE STRUCTURAL MODEL

The problem of the representation of a real material in the model will be solved if we will fix experiences from which rheological functions of subelements $\tau = \tau(\psi,\gamma,\upsilon)$ and unknown parameters a, a_0, m, B will be unequivocally identified.

To determine the functions $\tau = \tau(\psi,\gamma,\upsilon)$, reflecting thermoviscoplastic properties of the subelements, we will examine the deformation of the body element along a rectilinear trajectory.

Tensor properties of subelements in conglomerate under proportional loading are given, taking into account that the directris of the deviators reversible e_{ij}, $\bar{e}_{ij}$ and irreversible p_{ij}, $\bar{p}_{ij}$ strains coincide:

$$\frac{\bar{e}_{ij}}{\bar{e}} = \frac{e_{ij}}{e} = \frac{\bar{p}_{ij}}{\bar{p}} = \frac{p_{ij}}{p} = a_{ij}\,, \qquad (24)$$

$$\bar{e} = \sqrt{\bar{e}_{ij}\bar{e}_{ij}}\,, \qquad \bar{p} = \sqrt{\bar{p}_{ij}\bar{p}_{ij}}\,. \qquad (25)$$

Local relation between reversible and irreversible strains (20) is represented in the form:

$$\bar{e} - e = m\left(p - \bar{p}\right). \qquad (26)$$

In the monotonous process in the subelements set the two zones are formed with respect to ψ.

The irreversible deformation law in the first zone $(\psi \le \psi')$ according to (2) is written as:

$$\bar{e} = \sqrt{\bar{e}_{ij}\bar{e}_{ij}} = \tau(\psi,\gamma,\upsilon) + s + \bar{r}\,, \qquad (27)$$

where

$$\cos\alpha = \frac{p_{ij}}{p}\frac{dp_{ij}}{d\lambda} = 1\,, \qquad s = ap\,, \qquad \bar{r} = a_0\bar{p}\,. \qquad (28)$$

For the group of subelements, operating in the reversible domain ($\psi > \psi'$, $\bar{p} = 0$), and according to (26) elastic deformations of subelements are identical and coincide with the limit elastic strain in the boundary subelement $\psi = \psi'$:

$$\bar{e} = e + mp = \tau(\psi',\gamma,\upsilon) + s\,. \qquad (29)$$

The function $\tau(\psi',\gamma,\upsilon)$, reflecting thermo-viscoplastic properties of the subelements, can be expressed in terms of macroscopic quantities:

$$\tau(\psi',\gamma,\upsilon) = e + (m-a)p\,. \qquad (30)$$

Differentiating (26) and (27) at a constant values of the state parameters γ and υ we obtain that the velocity of irreversible deformation has the same value for the subset of all subelements $\psi \le \psi'$

$$\dot{\bar{p}} = \frac{\dot{e} + (m-a)\dot{p}}{a_0 + m}\,. \qquad (31)$$

According to the average connections concept

$$\dot{p} = \int_0^1 \dot{\bar{p}}\,d\psi = \int_0^{\psi'} \dot{\bar{p}}\,d\psi + \int_{\psi'}^1 \dot{\bar{p}}\,d\psi = \int_0^{\psi'} \dot{\bar{p}}\,d\psi\,. \qquad (32)$$

Thus the distinctive parameter of subelements ψ' can be represented by the following relation

$$\psi' = \frac{\dot{p}(a_0 + m)}{\dot{e} + (m-a)\dot{p}}\,. \qquad (33)$$

Based on (30) and (33) we can determine the thermoviscoplastic properties of subelements at the known state parameters γ and υ.

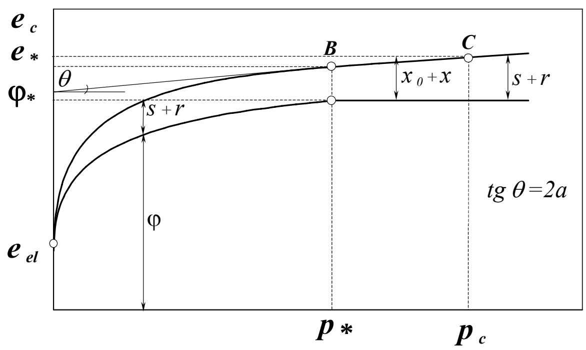

Figure 1. Diagram of the proportional loading of the thin-walled tubes by axial force and internal pressure at the constant temperature and the longitudinal strain velocity

The function $\tau(\psi',\gamma,\upsilon)$ can be determined at $\gamma = const$, $\upsilon = const$ by means of the diagram of the proportional loading, represented in the figure 1:

$$e = \varphi(p,\gamma,\upsilon) + s + r\,, \qquad (34)$$

During the scleronomous and isothermal loading we have $e,_p = \varphi,_p + a + a_0$, hence the relations (30) and (33) are obtained as follows

$$\tau(\psi',\gamma,\upsilon) = \varphi(p,\gamma,\upsilon) + (m + a_0)p\,, \qquad (35)$$

$$\psi' = \frac{a_0 + m}{\varphi,_p + m + a_0}\,. \qquad (36)$$

Thus, the thermoviscoplastic properties of subelements at the known values of the parameters a_0 and m may be determined, based on diagrams of the proportional loading $e = e(p,\gamma,\upsilon)$ at the various constant value of the state parameters γ and υ.

The rheological effects of subelement due to inelastic volume variation are characterized by the parameter υ, representing the identical for all subelements ratio of the volume variation and its possible limit

$$\upsilon = \frac{1}{\varepsilon_{0k}}\int_0^1 (\bar{\varepsilon}_0 - \beta\bar{e}_0)\,d\psi\,. \qquad (37)$$

or

$$\upsilon = \frac{\varepsilon_0 - \beta e_0}{\varepsilon_{0k}}\,, \quad \varepsilon_0 = \int_0^1 \bar{\varepsilon}_0\,d\psi\,, \quad e_0 = \int_0^1 \bar{e}_0\,d\psi\,. \qquad (38)$$

Differentiating (38) with respect to time we find the loading conditions at $\upsilon = const$:

$$\dot{\varepsilon}_0 = \beta\dot{e}_0 = \beta\frac{\dot{\sigma}_0}{K}\,. \qquad (39)$$

Taking into account

$$\dot{\varepsilon}_0 = \dot{e}_0 + \dot{p}_0 + \dot{\varepsilon}_T\,, \qquad \dot{\varepsilon}_T = \alpha_T\dot{T}\,, \qquad (40)$$

and assuming, that at the low level of irreversible deformations the elastic volume variation considerably exceeds the irreversible, we obtain that the velocity of temperature's change is proportional to the velocity of average stress's change

$$\dot{T} = -\frac{1-\beta}{\alpha_T K}\dot{\sigma}_0\,. \qquad (41)$$

The deformation at $\upsilon = const$ corresponds to isothermal loading, if $\beta = 1$.

Let us specify the conditions of the experiment at the constant parameter γ. In the monotonous process of deformation along a rectilinear trajectory

$$\dot{\bar{\lambda}} = \frac{d}{dt}\sqrt{\bar{p}_{ij}\bar{p}_{ij}} = \dot{\bar{p}}\,, \qquad (42)$$

$$\gamma = \frac{1}{\psi'}\int_0^{\psi'} \dot{\bar{p}}\,d\psi = \frac{\dot{p}}{\psi'}\,, \quad \dot{\bar{p}}\Big|_{\psi > \psi'} = 0\,. \qquad (43)$$

The state parameter γ can be expressed in terms of macroscopic quantities, taking into account the relation (33), obtained for the distinctive parameter of subelements ψ':

$$\gamma = \frac{\dot{e} + (m-a)\dot{p}}{a_0 + m}\,, \qquad (44)$$

Let's pass to the velocities of the modules of the stress and strains tensor deviators

$$\gamma = \frac{1-m+a}{a_0+m}\frac{\dot{\sigma}}{2G} + \frac{m-a}{a_0+m}\dot{\varepsilon}\,. \qquad (45)$$

where

$$\dot{\varepsilon} = \dot{e} + \dot{p}\,, \qquad \dot{e} = \frac{\dot{\sigma}}{2G}\,, \qquad (46)$$

$$\dot{\varepsilon} = \frac{d}{dt}\sqrt{\varepsilon_{ij}\varepsilon_{ij}}\,, \qquad \dot{\sigma} = \frac{d}{dt}\sqrt{\sigma_{ij}\sigma_{ij}}\,. \qquad (47)$$

The relation structure (45) follows that within the limits of the investigated model the continuity condition of the material transition from reversible to irreversible state is satisfied automatically.

During deformation along a rectilinear trajectory the directrixes of the stress and strain deviators velocities coincide:

$$\frac{\dot{\sigma}_{ij}}{\dot{\sigma}} = \frac{\dot{\varepsilon}_{ij}}{\dot{\varepsilon}} = a_{ij} \,. \tag{48}$$

Considering that $a_{ij} = const$ we obtain

$$\dot{\sigma} = \frac{\dot{t}_{ij} - \dot{\sigma}_0 \delta_{ij}}{a_{ij}}, \qquad \dot{\varepsilon} = \frac{\dot{d}_{ij} - \dot{\varepsilon}_0 \delta_{ij}}{a_{ij}}, \tag{49}$$

$$\langle i, j = 1,2,3 \rangle \,.$$

The indexes taken in the angle brackets talk about the fact that in the corresponding formulas the summation is not performed.

Substituting (49) and (39) into (45) we obtain the following expression for the state parameter γ

$$\gamma = \left[\frac{1-m+a}{a_0+m} \frac{\dot{t}_{ij} - \dot{\sigma}_0 \delta_{ij}}{2G} + \frac{m-a}{a_0+m} \left(\dot{d}_{ij} - \beta \frac{\dot{\sigma}_0}{K} \delta_{ij} \right) \right] \frac{1}{a_{ij}},$$

$$\langle i, j = 1,2,3 \rangle \,. \tag{50}$$

We will examine the loading of the thin-walled tubes with the tensile force F and the internal pressure P_i. The radial stress t_{rr}, being of the internal pressure order, can be neglected in comparison to the axial t_{zz} and circumferential $t_{\varphi\varphi}$ stress

$$t_{zz} = \frac{F}{2\pi R h} + \frac{P_i R}{2h}, \qquad t_{\varphi\varphi} = \frac{P_i R}{h} \,. \tag{51}$$

The orientation of the loading trajectory in the space of axial t_{zz} and circumferential $t_{\varphi\varphi}$ stresses we will define by the parameter

$$\zeta = \frac{t_{\varphi\varphi}}{t_{zz}}, \tag{52}$$

and will determine the ratio of tensile force and the internal pressure using parameter ζ

$$\frac{F}{P_i} = \frac{2-\zeta}{\zeta} \pi R^2 \,. \tag{53}$$

Let us transform equation (50) considering (52)

$$\gamma = \left[\frac{(1-m+a)(2-\zeta)}{6G(a_0+m)} - \frac{\beta(m-a)(1+\zeta)}{3K(a_0+m)} \right] \frac{\dot{t}_{zz}}{a_{zz}} + \frac{m-a}{a_0+m} \frac{\dot{d}_{zz}}{a_{zz}} \,. \tag{54}$$

In laboratory conditions, the simplest is experiment at a constant velocity of movement of the grip, in this case $\dot{d}_{zz} = const$. To achieve this condition we establish the rectilinear trajectory orientation of the loading in the stress space t_{zz} and $t_{\varphi\varphi}$, equaling to zero the expression in square brackets

$$\zeta = \frac{2-\eta}{1+\eta}, \qquad \eta = \beta \frac{2G}{K} \frac{m-a}{1-m+a} \,. \tag{55}$$

According to (48)

$$a_{zz} = \frac{\sigma_{zz}}{\sigma} = \frac{2-\zeta}{\sqrt{6\left(1-\zeta+\zeta^2\right)}}, \tag{56}$$

or if $\dot{d}_{zz} = const$

$$a_{zz} = \frac{\eta}{\sqrt{2\left(1-\eta+\eta^2\right)}} \,. \tag{57}$$

If the condition (55) is satisfied then deformation at a constant velocity $\dot{d}_{zz} = const$ is the outward sign of loading with the constant parameter γ, which is given by the expression

$$\gamma = \frac{m-a}{a_0+m} \frac{\sqrt{6\left(1-\zeta+\zeta^2\right)}}{2-\zeta} \dot{d}_{zz}, \tag{58}$$

or

$$\gamma = \frac{m-a}{a_0+m} \frac{\sqrt{2\left(1-\eta+\eta^2\right)}}{\eta} \dot{d}_{zz} \,. \tag{59}$$

Let us determine the ratio of the tensile force and the internal pressure, that must be observed during the experiment at the constant state parameter γ

$$\frac{F}{P_i} = \frac{3\eta}{2-\eta} \pi R^2 \,. \tag{60}$$

In the case of axial tension $\zeta = 0$ and, according to (55), to make the experiment at the constant state parameter γ we must satisfy the following condition

$$\frac{m-a}{1-m+a} = \frac{1}{\beta} \frac{2(1+\nu)}{1-2\nu} \,. \tag{61}$$

Taking into account the limits of variation of the parameters $0 \le a < \infty$ and $0 \le m \le 0{,}5$, the left side of the relationship ranges from -1 to 0. The right side relationship with regard to the possible theoretical limits of the Poisson's $0 \le \nu < 0{,}5$ ranges from 2 to ∞. Thus, in the case of the axial tension is impossible to carry out experiment at a constant state parameter γ. Therefore, the solution of the problem of the representation of the real material in the structural model on the basis of experiments conducted by stretching can be achieved only in an approximate way.

In order to execute the tensile tests at a constant velocity of movement of the gripping device $\dot{d}_{zz} = const$ we must know the rectilinear trajectory orientation ζ, expressed in the parameters of a and m, which are still unknown.

A number of authors [7] found that in the strain diagram $e \sim \varepsilon$ is observed a linear hardening sector, the slope of which does not depend on the temperature and rate of loading.

Within the linear hardening sector of the diagram $t_{zz} \sim d_{zz}$, according to (54), the axial tension at a constant velocity of the grip movement approaches the test at a constant parameter γ. Let us rebuild the diagram $t_{zz} \sim d_{zz}$ in the space of modules of strain deviators $e \sim \varepsilon$

$$\sigma = \sqrt{\frac{2}{3}} t_{zz}, \quad e = \sqrt{\frac{2}{3}} \frac{t_{zz}}{2G}, \quad \varepsilon = \sqrt{\frac{3}{2}} \left(d_{zz} - \varepsilon_0 \right). \quad (62)$$

Assuming that the volume varies elastically, we find

$$\varepsilon = \sqrt{\frac{3}{2}} \left(d_{zz} - \frac{t_{zz}}{3K} \right). \quad (63)$$

Linear hardening coefficient æ according to the diagram $e \sim \varepsilon$

$$æ = \frac{\Delta e}{\Delta \varepsilon} = \frac{\Delta \sigma}{2G \Delta \varepsilon}, \quad (64)$$

or taking into account the relations (62) and (63)

$$æ = \frac{2(1+\nu) æ_{zz}}{3 - (1 - 2\nu) æ_{zz}}, \quad æ_{zz} = \frac{\Delta t_{zz}}{E \Delta d_{zz}}. \quad (65)$$

Knowing the hardening coefficient æ on the diagram $e \sim \varepsilon$, we determine the hardening coefficient on the diagram $e \sim p$ in the figure 1 within sector $p_* \le p \le p_c$ (where p_* corresponds to the time when all the subelements exceeded the elastic limit $\psi' = 1$, p_c is a measure, starting from which the linear isotropic hardening is broken)

$$a + a_0 = \frac{\Delta e}{\Delta p} = \frac{\Delta e / \Delta \varepsilon}{1 - \Delta e / \Delta \varepsilon} = \frac{æ}{1 - æ}, \quad (66)$$

$$a = \frac{æ}{(1 - æ)(1 + \chi)}, \quad a_0 = \frac{\chi æ}{(1 - æ)(1 + \chi)}. \quad (67)$$

Next, using the formula (22), we define the parameter m, then on the basis of expression (55) find the orientation of the rectilinear trajectory of loading ζ.

To the obtained value of the ratio ζ are performed experiments under various constant velocity of movement of the gripping device and temperature levels.

CONCLUSIONS

It is considered solution of the problem of the representation of a real material in the structural model of micro-heterogeneous medium that satisfies the uniqueness condition.

Local yield laws simultaneously consider kinematic and isotropic hardening of subelements. Using the laws of thermodynamics, the phenomenon of the auto concordance of irreversible processes of local deformation and the hypothesis that from all possible schemes of kinematic interaction between subelements the scheme with extreme discrepancy of macroscopic and micro-scopic measures corresponds to real interaction, the parameters of the equation of the interconnection between subelements have been identified.

To determine the thermorheological properties of subelements have been studied the external conditions when an element of body is deformed along a rectilinear trajectory at the constant state parameters.

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STUDY OF PHYSICAL AND MECHANICAL PROPERTIES OF IRON-NICKEL COMPOSITE COATINGS MACRO INDENTATION

V. Javgureanu, PhD, professor, P. Gordelenco PhD, associate professor
Technical University of Moldova, Chisinau

1. INTRODUCTION

1.1. Research and testing of physical and mechanical properties of materials

The relevance of research and testing of physical and mechanical properties of materials at the surface and in the surface layers due to the fact that the contact interaction and contact deformation associated with nearly all modern methods of treatment, hardening and metal compounds, but also service properties of metals in terms of friction, fatigue, seizure and wear.

One of their methods of testing the surface properties of materials - test macrohardness.

1.2. The common information

In recent years developed methods and devices, allowing obtaining a wealth of information about the properties of materials at macro indentation. Material test method allows macro indentation measure several important parameters characterizing the physical and mechanical properties of composite plating, traditional and new, obtained only when these tests.

The method of investigation of physical and mechanical properties of the coating is based on recording the kinetic diagram of a spherical diamond indenter indentation.

As the spherical diamond indenter was used with artificial diamond sphere radius equal 1mm. Tests subjected composites, iron-nickel coating with a thickness of 0.5 mm, while the diameter of the sample was 30mm.

Test method for macrohardness allows testing of the wide application of materials with a thickness of 1 mm or more. Thus it is possible to determine not only the strength characteristics of the material but also its elastic-plastic properties.

Many researchers have studied the shape of the plastically deformable deformation zones, and in the nature of a screen where the fingerprint shown that the boundary area of plastically deformable nature of the deformation and the diameter d a fingerprint similar in shape to the part of a sphere for both metals and polymers.

We studied the deformation of deep and surface layers of materials under the indenter by applying a grid meridian section in the plane of the sample. We prove that the maximal deformation axis indentation depth of approximately half the radius of the print at the point of maximum shear stress. On the surface indentation deformation grow from the centre of the contour near the circuit decreases and beyond change direction. Inverting the direction of deformation occurs due to the fact that the printout at some distance underneath the material undergoes axial compression and broadening in the radial direction.

This paper presents the study of physical and mechanical properties of Fe-Ni composite coatings by indentation spherical diamond indenter.

Experimentally determined: elastic-plastic characteristics (he, hp, h); work spent on elastic (Ae), plastic (Ap), and the total deformation (A); not restored (Hh) and dynamic (Hd) hardness, indentation load on a spherical diamond indenter (P), the volume of elastic (Ve), a plastic (Vp) and the total (V) of a deformable composite material of iron-nickel coatings produced from the electrolyte 4 [2]. The above characteristics were determined at the facility for the study of the hardness of materials in macro volume equipped with an inductive sensor and a differential amplifier to record chart indentation spherical diamond indenter and indentation recovery after unloading.

The dynamic hardness (Hd) was determined as the ratio of the total of (A) consumed for the total deformation of the material (V) the volume of deformable material all studied Fe-Ni coating.

2. EXPERIMENTAL STUDIES.

Studies have shown that the investigated characteristics of composite iron-nickel coatings vary with the conditions of their receipt (D_K, T).

With increasing current density (CD) of from 5 to 80 ($\times 10^{-4}$ kA/m^2) at a constant temperature of electrolysis (40^{0}C), the elastic indentation depth (he) and the amount of elastic indentation of the coating

Table 1. Elastic properties of hardness and **Fe-Ni** composite coatings

Terms electrolyze		***Hh, H/mm²*** ***(h=2μm)***	***Hd, H/mm²***	***P, H***	***Elastic properties of the Fe-Ni coating***		
Dk, ×10⁻⁴ кA/m²	***T,⁰C***				***he, μm***	***Ae H×mm***	***Ve, ×10⁻⁷ mm³***
5	40	3630	2422	45,6	1,134	0,01723	40,34
10	40	3670	2449	46,1	1,150	0,01767	41,47
20	40	3800	2534	47,7	1,172	0,01863	43,11
30	40	3980	2656	50,0	1,210	0,02017	45,93
40	40	4120	2746	51,7	1,240	0,02137	48,23
50	40	4470	2980	56,1	1,26	0,02356	49,80
60	40	4020	2683	50,5	1,28	0,02020	51,40
80	40	3320	2215	41.7	1,35	0,01577	57,17

material (Ve) increases, respectively, from 1.134 to 1.35 (microns) and from 40.34 to 57.17×10^{-7} (mm^3) Table 1. Dependence is not restored by the hardness (Hh), a dynamic hardness (Hd) on the indenter load (P) and the work consumed by the elastic deformation of coatings (Ae) are extreme. With increasing current density from 5 to 50 ($\times 10^{-4}$ $_K A/m^2$), hardness (Hh) increased from 3630 to 4470 (N/mm^2), the dynamic hardness (Hd) increased from 2422 to 2890 (N/mm^2), load spherical diamond indenter increased from 45.6 to 56.1 (H), and the work spent on the elastic deformation Fe-Ni composite coatings (Au) increased from 17.23×10^{-3} to 23.56×10^{-3} (N.mm). With further increasing current density from

Table 2. Plastic properties and hardness **Fe-Ni** composite coatings.

Terms electrolyze		***Hh, H/mm²*** ***(h=2μm)***	***Hd, H/mm²***	***P, H***	***Plastic properties of the Fe-Ni coating***		
Dk, ×10⁻⁴ кA/m²	***T,⁰C***				***hp, μm***	***Ap H×mm***	***Vp, ×10⁻⁷ mm³***
5	40	3630	2422	45,6	0,8660	0,01316	23,57
10	40	3670	2449	46,1	0,8500	0,01351	22,67
20	40	3800	2534	47,7	0,8280	0,01357	21,50
30	40	3980	2656	50,0	0,7900	0,01361	19,56
40	40	4120	2746	51,7	0,7600	0,01369	18,11
50	40	4470	2980	56,1	0,7400	0,01384	17,17
60	40	4020	2683	50,5	0,7200	0,01212	16,26
80	40	3320	2215	41,7	0,6500	0,00904	13,25

50 to 80 ($\times 10^{-4}$ KA/m^2). Hardness (Hh) decreased from 4470 to 3320 (N/mm^2), the dynamic hardness (Hd) decreased from 2980 to 2215 (N/mm^2), the load on the diamond spherical indenter (P) decreased from 56.1 to 41.7 (H) and the work spent on the elastic deformation (Ae) Fe-Ni composite coatings decreased from 23.56×10^{-3} to 15.77×10^{-3} (N/mm).

Extreme hardness (Hh), a dynamic hardness (Hd), load on a spherical diamond indenter (P) and the work consumed by the elastic deformation of Fe-Ni composite coatings coincide with the existing guidelines for the choice of electrolysis conditions for optimum Fe-Ni coating from the standpoint their wear resistance. With increasing current density (D_K) Table 2, from 5 to 40 ($\times 10^4$ kA/m^2) electrolysis at constant temperature (40^0C) plastic indentation depth (hp) and the volume of plastic indentation test material (Vp), respectively, are reduced from 0.866 to 0.740 (microns) and from 23.57×10^{-7} do 17.17×10^{-7} (mm^3). density increases from 5 to 50 ($\times 10^{-4}$ kA/m^2) electrolysis at constant temperature (40^0C) hardness (Hh), a dynamic hardness (Hd), indentation load (P) increased as in the previous case (Table 1), and the work expended in plastic deformation (Ap) Fe-Ni composite coatings increased from 13.16 to 13.84×10^{-3}(H×mm, table 2).

With a further increase in current density (Dk) at a constant temperature of electrolysis (40^0C) of 50 to 80 ($\times 10^{-4}$kA/m2) hardness (Hh), a dynamic hardness (Hd), indentation load (P) is decreased as in the preceding case (table 1), and the work expended in plastic deformation of Fe-Ni composite coatings decreased from 13.84×10^{-3} to 9.04×10^3 (H×mm, table 2).

Table 3. Elastic-plastic properties and hardness of Fe-Ni composite coatings.

Terms electrolyze		***Hh, H/mm2 (h=2μm)***	***Hd, H/mm^2***	***P, H***	***Elastic-plastic properties***		
Dk, $\times 10^{-4}$ $\kappa A/m^2$	***$T,^0C$***				***he, μm***	***Ae, H×mm***	***Ve, $\times 10^{-7} mm^3$***
5	40	3630	2422	45,6	2,0	0,03040	125,51
10	40	3670	2449	46,1	2,0	0,03073	125,51
20	40	3800	2534	47,7	2,0	0,03180	125,51
30	40	3980	2656	50,0	2,0	0,0333	125,51
40	40	4120	2746	51,7	2,0	0,0347	125,51
50	40	4470	2980	56,1	2,0	0,03740	125,51
60	40	4020	2683	50,5	2,0	0,0337	125,51
80	40	3320	2215	41,7	2,0	0,02780	125,51

Table 4. Elastic properties of hardness and Fe-Ni coating.

Terms electrolyze		***Hh, H/mm2 (h=2μm)***	***Hd, H/mm^2***	***P, H***	***Elastic-plastic properties***		
Dk, $\times 10^{-4}$ $\kappa A/m^2$	***$T,^0C$***				***he, μm***	***Ae, H×mm***	***Ve, $\times 10^{-7} mm^3$***
50	20	3320	2215	41,7	1,52	0,02113	72,50
50	40	4470	2980	56,1	1,260	0,02356	49,80
50	60	3630	2422	45,6	1,028	0,01563	33,15

And in this case, the extreme hardness (Hh), dynamic hardness (Hd), indentation load (P) and the work expended in plastic deformation (Ap) Fe-Ni composite coatings coincide with existing recommendations for choosing electrolysis conditions to obtain optimal properties Fe-Ni coatings in terms of wear resistance [2].

With increasing current density (Dk) in Table 3, from 5 to 80 (10^{-4} kA/m^2) (at a constant temperature of electrolysis (40^{0}C) total indentation depth (h) and a common pressed into the coating material volume (V) are constant and equal to 2.0, respectively (m) and 125.51 x 10^{-7} (mm^3).

With increasing current density (Dk) from 5 to 50×10^{-4} kA/m^2 at a constant temperature of electrolysis (40^{0}C), hardness (Hh), a dynamic hardness (Hd) indentation load (P) increases in both the previous cases (Table 1 and 2), and the work expended on the deformation of Fe-Ni composite coatings (A) increased from 30.4×10^{-3} to 37.4×10^{-3} (H×mm, table 3).

With further increase of the current density (Dk), with electrolysis constant temperature (40^{0}C) of 50 to 80 (10^4 kA/m^2) Hardness (Hh), a dynamic hardness (Hd), pressing load by spherical diamond indenter (P) decreases as in the previous case (table 1 and 2) and total work expended on the deformation of Fe-Ni composite coatings decreased from 37.4 to 27.8×10^{-3} (H×mm, table 3).

In this case, the experimental values of hardness (Hh), a dynamic hardness (Hd), pressing load of the spherical diamond indenter (P) and work spent on the total deformation of Fe-Ni composite coatings (A) coincide with the existing recommendations on the choice of conditions electrolysis to obtain optimal properties of Fe-Ni composite coatings in terms of wear resistance.

With increasing temperature electrolysis (T) for obtaining Fe-Ni composite coatings (Table 4) of 20 to 60^{0}C (Dk=50x10^{-4} kA/m^2), the elastic component of the depth of the indentation (he) decreased from 1.52 to 1.028 micron, print volume (Ve) also decreased from 72.5×10^{-7} to 33.15×10^{-7} mm^3. With increasing temperature electrolysis from 20 to 40^{0}C, hardness (Hh) has increased from 3320 to 4470 (N/mm^2), dynamic hardness (Hd) increased from 2215 to 2980 N/mm^2, indentation load on the diamond spherical indenter (P) increased from 41,7 to 56.1 (H), the work spent on the elastic deformation of Fe-Ni composite coatings (Ae) increased from 21.13 x 10^{-3} to 23.56 x 10^{-3} (N.mm), and the volume of print on elastic deformation of coatings (Ve) decreased from 72.5 x 10^{-7} to 49.8 x 10^{-7} (mm^3, table 4).

Table 5. Plastic properties and hardness Fe-Ni composite coating.

Terms electrolyze		**Hh, H/mm² (h=2μm)**	**Hd, H/mm²**	**P, H**	***Elastic-plastic properties***		
Dk, ×10⁻⁴ кA/m²	***T,⁰C***				***hp, μm***	***Ap, H×mm***	***Vp, ×10⁻⁷mm³***
50	20	3320	2215	41,7	0,480	0,00667	7,22
50	40	4470	2980	56,1	0,740	0,01384	17,17
50	60	3630	2422	45,6	0,972	0,01877	29,64

Table 6. Elastic-plastic properties and hardness of the composite coatings Fe-Ni.

Terms electrolyze		**Hh, H/mm² (h=2μm)**	**Hd, H/mm²**	**P, H**	***Plastic properties***		
Dk, ×10⁻⁴ кA/m²	***T,⁰C***				***h, μm***	***A, H×mm***	***V, ×10⁻⁷mm³***
50	20	3320	2215	41,7	2,0	0,02780	125,51
50	40	4470	2980	56,1	2,0	0,03740	125,51
50	60	3630	2422	45,6	2,0	0,03040	125,51

With further increase of the electrolysis temperature (T) of 40^0C to 60^0C, a hardness (Hh) was reduced from 4470 to 3630 (N/mm^2) dynamic hardness (Hd) decreased from 2980 to 2422 (N/mm^2), the load on a spherical diamond indenter (P) decreased from 56.1 to 45.6 (H), and the work spent on the elastic deformation (Ae) Fe-Ni composite coatings decreased from 23.56×10^{-3} to 15.63×10^{-3} (H×mm, table 4).

In this case, the experimental values of hardness (Hh), a dynamic hardness (Hd), at indentation load spherical diamond indenter (P), the work expended in elastic deformation Fe-Ni composite coating (Ae), depending on the electrolysis temperature (T) at constant current density (Dk= 50 x 10^{-4} kA/m^2) coincide with current recommendations for choosing electrolysis conditions to obtain optimal properties of Fe-Ni composite coating with the point of view of their optimal durability [2].

With increasing temperature electrolysis (T), upon receipt of Fe-Ni composite coating (see Table 5) of 20^0C to 60^0C (with Dk=50×10^{-4} kA/m^2) plastic components extrusion depth (hn) increased from 0.48 to 0,972 (μm) and the volume of print for plastic indentation (Vp) increased from 7.22×10^{-3} to 29.64×10^{-3} (mm^3).

With increasing temperature electrolysis from 20^0C to 40^0C hardness (Hh), dynamic hardness (Hd), indentation load on diamond spherical indenter (P) increased in value as in the previous case (Table 4), and the work expended in plastic deformation (Ap is) composite coatings Fe-Ni increased from 6.67×10^{-3} to 13,84×10^{-3} (H×mm).

With further increase in temperature electrolysis (T) from 40^0C to 60^0C hardness (Hh) dynamic hardness (Hd), indentation load on the diamond spherical indenter (P) decreased in value as in the previous case (Table 4), and the work expended in plastic deformation Fe-Ni composite coatings (Ap) decreased from 13.84×10^{-3} to 18,77 ×10^{-3} (H×mm, table 5).

With increasing temperature electrolysis (T) of 20^0C to 60^0C, in preparing the Fe-Ni composite coating at a constant current density (Dk =50×10^{-4} kA/m^2), estimated penetration depth (h) of the diamond and the amount of spherical indenter indentation (V) under elastic-plastic indentations are constants and are respectively 2,0 (μm) and 125.51x10^{-7} (mm^3) table 6.

With increasing temperature electrolysis (T) 20^0C to 40^0C, at a constant current density (Dk = 50×10^{-4} kA/m^2) hardness (Hh), a dynamic hardness (Hd), at indentation load spherical diamond indenter (P), increasing in value as in the previous case (Table 4 and 5) and the work spent on elastic-plastic indentations Fe-Ni composite coatings with indentations increased from 27.8×10^{-3} to 37.4×10^{-3} (N×mm).

With further increase in temperature electrolysis (T) from 40^0C to 60^0C (at Dk = 50×10^{-4} kA/m^2), hardness (Hh), dynamic hardness (Hd), indentation load on the diamond spherical indenter (P) decreased in value as in the previous cases (table 4 and 5), and the work spent on elastic-plastic deformation Fe-Ni composite coatings decreased from 37.4×10^{-3} to 30.4×10^{-3} (N×mm). As in previous cases (table 4 and 5) with increasing temperature electrolysis (T), hardness (Hh), dynamic hardness (Hh), the load on the spherical indentation diamond indenter (P) and the work spent on elastic-plastic deformation of Fe-Ni composite coatings is experimental.

One of the problems of engineering prediction of wear resistance of materials. In this sense, the test method for hardness macro volume treat micromechanical testing, allowing the most justified approach this material characteristics.

The obtained dimensions of the Hh, Hd, P, A have a good correlation to the intensity of wear of the iron -nickel composite coating.

Thus, the parameters Hh, Hd, P, A can be used in the future to clarify the description of the wear rate of materials. Depending on the choice of the wear rate on these parameters based on the notions of additive contributions of these structural indicators [1].

Research results have shown that the parameters Hh, Hd, P, A taking into account the elastic-plastic properties Fe-Ni composite coatings have extreme character as the wear rate with changing conditions electrolyze (Dk, T).

3. CONCLUSION

Established not restored hardness (Hh) and the dynamic hardness (Hd), the work spent on elastic-plastic deformation (A) have extreme character changes in the conditions of electrolysis (Dk, T) for the study of iron-nickel composite coatings.

Experimental values not restored hardness (Hh), dynamic hardness (Hd), indentation load diamond spherical indenter (P), the work spent on plastic (Ap) and elastic-plastic deformation (A) coincides with our earlier recommendations for iron-nickel composite coatings with the point of view of their optimum durability.

Physical and mechanical characteristics (Hh, Hd, P, Ap, A) iron-nickel composite coatings have a good correlation with the intensity of wear of these coatings.

Physical and mechanical characteristics (Hh, Hd, P, Ap, A) can be used to refine the description of the wear rate of iron-nickel composite coatings.

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MEANING OF THE SENTENCE IN THE NATURAL LANGUAGE: SEMANTIC INSIGHTS

[1]S. Crețu, assoc.prof., dr., [2]A. Popescu, prof. dr. hab.
[1]E.S. Academy of Moldova,
[2]Technical University of Moldova

INTRODUCTION: THEORETICAL FRAMEWORK

The current study focuses on the development of certain techniques to accurately determine the meaning of phrases, be they written or spoken, in the natural language (NL). Complex phrases can be easily broken down into simpler sentences (syntactic units) and words (lexical units). Hence, the meaning of phrases could be extracted/derived from theirs four underlying components: 1. the lexical component; 2. the syntactic component; 3. the semantic component; 4. the pragmatic component.

The lexical component of a phrase refers to a vocabulary. A typical vocabulary comprises a set of lexical units, each having defined meanings (the meaning of the lexical unit).The syntactic component defines the order of the lexical and syntactic units within a sentence and phrase, respectively. Accordingly, the semantic component specifies the relation of the syntactic units (sentences) to a set of facts amenable to interpretation. The meaning of the lexical and syntactic units depends on additional factors: 1. timing (i.e., when the unit was written or pronounced); 2. location (i.e., where the unit was written or spoken); 3. modality (i.e., how the unit was written or spoken). These factors taken together constitute the pragmatic component of a phrase.

Although individual components (lexical, syntactic, semantic, pragmatic) can be readily determined, theirs relation to the overall meaning of the phrase is not straightforward. A common approximation (Frege's Principle of Compositionality) assumes a homomorphism between the syntactic and the semantic components of the phrase in the NL. However, this classical approach has several drawbacks [1]: 1. the way complex phrases in the NL are divided into syntactic units for analysis influences theirs overall meaning; 2. neglecting the pragmatic component of phrases in the NL leads to erroneous estimation of theirs meaning, especially in the case of non-assertive phrases (e.g., orders, directives); 3. the true emitter (author) of phrases in the NL cannot be accurately clarified (this is referred to as the "*game of the subjects*" conundrum). Here we propose an integrated theoretical framework aimed at defining intrinsic relations between both the lexical, syntactic, semantic components and the illusive pragmatic component.

1. COMPETENCE MODELS

To simply further analyses, the lexical, syntactic and pragmatic components of phrases in the NL were redefined as competences (Ch. Morris, N. Chomsky):

Definition 1.1: The syntactic competence refers to the ability of the speaker (emitter, author) to generate correct linguistic phrases with or without meaning**.**

Definition 1.2: The semantic competence refers to the ability of the speaker (emitter, author) to establish semantic relations between the lexical and syntactic units of phrases in the NL. There are several types of semantic relations: 1. inclusion relations; 2. reference relations; 3. consistence relations; 4. coherence relations.

Definition 1.3: The pragmatic competence refers to the ability of the speaker (emitter, author) to apply correct linguistic phrases in a proper syntactic-semantic context.

The relations between the competences are unclear and poorly defined. As a simplification, a hierarchical model has been postulated: 1. the syntactic competence constitutes a prerequisite for the other two competences; 2. the semantic competence with its underlying connections "charges" the emitted linguistic phrases with meanings; 3. the pragmatic competence results from the integration of the syntactic and semantic competences with an *a priori* "experience" (prior to comprehension), presumably stored in a knowledge base. The semantic competence has a static-dynamic character. Thus, certain semantic relations (e.g., synonymy) can be stored in a vocabulary. Conversely, the pragmatic competence has a dynamic character and cannot be compiled in a vocabulary. This issue can be alleviated in two ways: 1. explicit definition of pragmatics; 2. construction of semantic networks.

Therefore, to model the ability of the speaker (emitter, author) to generate complex phrases in the NL bearing meanings, three competence models were generated: 1. a syntactic model, describing the employed syntax; 2. a semantic model, storing the semantic component; 3. a pragmatic model, defining and describing the pragmatic component. Each model functions independently, has its own formal language and relates hierarchically to the other two models using interpretation rules.

2. THE SYNTACTIC COMPETENCE MODEL

The syntactic competence model was developed using a categorial grammar [2], comprising the following categories: 1. N – proper nouns (singular); 2.CN – common nouns (singular, nominative case); 3. IV – intransitive verbs (infinitive); 4. TV – transitive verbs (infinitive); 5. VP – verbal phrases; 6. S – sentences. Having a clear lexical meaning, N, CN, IV and TV represent primary categories. For these categories, B was defined as the set of names of the basic categories:

$B=\{B_N, B_{CN}, B_{IV}, B_{TV}\}$

, where B_N, B_{CN}, B_{IV}, B_{TV} represent labels of the sets of the used proper nouns, common nouns, intransitive verbs and transitive verbs, respectively.

Conversely, the values of VP and S were derived only from the interpretation rules. The syncategorematic entities cannot be defined as categories (e.g., conjunctions). Thus, they were included in the syntactic rules, used to assemble linguistic phrases.

The employed syntactic rules were generated using the following formalism:

<construct> ::= <condition>, then <conclusion>

, where <condition> is a logical expression.

Thus, for a given sentence S (i.e., N-TV-CN) its corresponding syntactic rule can be constructed as:

S_n. $\alpha \in TV \wedge \beta \in CN, \text{ then } \alpha' \beta' \in VP$

S_m. $\chi \in N \wedge \delta \in VP, \text{ then } \chi\delta' \in S$

, where n, m $\in Z^+$, α, β, χ, δ – categories and the apostrophe " ' " – an inflection.

Example: Let "John hoists the flag" be a phrase to be modeled. In this case, its primary categories are specified as: B_N={John}, B_{CN}={flag}, B_{TV}={hoist}, and the corresponding syntactic rule is:

S1. "hoist" $\in$TV and "flag" $\in$CN, then "hoist flag'" $\in$VP.

S2. "John" $\in$N and "hoist flag'" $\in$VP, then "John hoists the flag" $\in$**S.**

The described above formalism can be conveniently simplified by the introduction of two additional operators: 1. the /(A,B) operator – specifying the rightward location of a given A category with respect to a given B category; 2. the \(A,B) operator – specifying the leftward location of a given A category with respect to a given B category. For sentence S (3) the TV category can be rewritten as \(N,/(CN,S)). This expression exactly posits the TV category within the S sentence: TV is located to the right of the N category (N is placed to the left of TV) and to the left of the CN category (CN is positioned to the right of TV). Therefore, the TV and, analogically, the VP categories can be precisely expressed using the N, CN and S categories and hence excluded from the defined basic categories. Thus we can conclude with a definition:

Definition 2.1. The categorial grammar **G**, defined for the **V** vocabulary, is a finite relation as follows:

$$G \subseteq V \times Cat(B)$$

, where the **V** is the vocabulary – a finite set with its elements representing the words of a NL, **B** – a countable set of categories, including a special S category (the set of the basic categories), Cat(**B**) – the algebra of the terms generated with the "/" and the "\" operators and containing the B set. **G** defines a single category for each element of the **V** vocabulary is considered to be a classical categorial rigid grammar [2].

Definition 2.2. I. For every **V** vocabulary of terminal elements two reduction rules can be applied to the definition 2.1:

1) FA (forward application) - /(A,B) A $\rightarrow$B.
2) BA (backward application) – A \(A,B)$\rightarrow$B.

II. In general, a set of categories from Cat(B) should be attributed to every element of the **V** vocabulary with the help of the "/" and "\" operators.

III. I. and II are necessary and sufficient to generate the L language:

$$L = \{c_1..c_n \in V^* | \forall i\{1,...,n\}, \exists A_i \in Cat(B) \wedge A_1..A_n \xrightarrow{FA,BA} S\}$$

Example: Let "John expertly hoists the flag" be a phrase to be modeled. The rigid classical categorical grammar (CCG) models this phrase is composed of :

1. The basic categories of the **B** set: **B**={N, CN, S}.
2. The **V** vocabulary: **V**={John, flag, expertly, to hoist}.
3. The rigid CCG:

G={<John, N>, <flag, CN>, <to hoist, \(N, /(CN, S))>, <expertly, \(\(N, /(CN,S)), \(N, /(CN, S)))>}.

Another kind of theory implied Lambek grammars [3] may be done.

3. THE SEMANTIC COMPETENCE MODEL

To efficiently interpret a sentence the NL sentence should be converted to a logical object. Conversion of a sentence from the NL to logical object relies on a specific logical language. The used logical language should be a typed one. That is, for each logical object we are to assign his type. In general, the type is a label refers to a subset of elements belonging to a set containing all the elements in use for interpretation. This universal set, usually, is named as Universe. For example, the vocabulary **V** containing all the NL words may be considered as Universe set.

Definition 3.1. The **Type** set is a minimal set which includes the following elements:

1. $e \in Type$. Element e denotes the individuals – the elements belong to Universe.
2. $t \in Type$. Element t denotes just only two values: true and false, also belonging to Universe.
3. If $a \in Type$ and $b \in Type$, then $\langle a,b \rangle \in Type$, where <a, b> - a function with its definition domain D_a (a set of the type a) and variation domain D_b (a set of the type b).

For example, the type expression <e, t> refers to a set of Universe's individuals and <<e, t>, t> is an expression denotes a second degree predicate.

The proposed logical language has two components: 1. the syntactic component; 2. the semantic component. The syntactic component comprises:

A. A set containing all the types for a given vocabulary as Universe (definition 3.1);
B. A set of all non-logical constants - Con (e.g., Con_a - the set of the constants of the type a);
C. A set of all the variables - Var (e.g., Var_a – the set of the variables of the type a).
D. A set of all the expressions of the type a ME_a
E. The following syntactic rules are available:

1. If a is a variable of the type a, then $v_a \in ME_a$.
2. If a is a constant of the type a, then $c_a \in ME_a$.
3. If $\alpha \in ME_b$ and $v \in Var_a$, then $\lambda v \alpha \in ME_{<a, b>}$.
4. If $\alpha \in ME_{<a, b>}$ and $\beta \in ME_a$, then $\alpha(\beta) \in ME_b$.
5. If $\alpha, \beta \in ME_a$, then $\alpha = \beta \in ME_t$.
6. If $\varphi \in ME_t$ and $\psi \in ME_t$, then $\neg\varphi, [\varphi \wedge \psi], [\varphi \vee \psi], [\varphi \rightarrow \psi], [\varphi \leftrightarrow \psi] \in ME_t$.
7. If $\varphi \in ME_t$ and $u \in Var$, then $\forall u \varphi \in ME_t$.
8. If $\varphi \in ME_t$ and $u \in Var$, then $\exists u \varphi \in ME_t$.

The semantic component embodies:

A. A model M interpreting the syntactic rules: M=<I, F, g>, where I – a non-null set of elements form the Universe, F – a function attributing values of the type a to every single constant from the Con_a set, g - a function attributing values of the type a to every single variable from the Var_a set
B. The following semantic rules:

1. If α is a constant, then $|\alpha|^{M,g} = F(\alpha)$.
2. If α is a variable, then $|\alpha|^{M,g} = g(\alpha)$.
3. If $\alpha \in ME_{<b, a>}$, and $\beta \in ME_b$, then $|\alpha(\beta)|^{M,g} = |\alpha|^{M,g}(|\beta|^{M,g})$.
4. If $\varphi \in ME_t$, then $|\neg\varphi|^{M,g} = 1$, if and only if $|\varphi|^{M,g} = 0$ or the other way around.
5. If $\varphi \in ME_t$ and $\psi \in ME_t$, then $|\varphi \wedge \psi|^{M,g} = 1$ if and only if $|\varphi|^{M,g} = 1$ and $|\psi|^{M,g} = 1$.
6. For $\vee, \rightarrow, \leftrightarrow$ similar to 5.
7. If $\varphi \in ME_t$ and $v \in Var_a$, then $|\forall v \varphi|^{M,g} = 1$, if and only if $\forall$ e $\in D_a$, where D_a- a domain of the type a, $|\varphi|^{M,g,v/e} = 1$ and v/e - substitution.
8. If $\varphi \in ME_t$ and $v \in Var_a$, then $|\exists v \varphi|^{M,g} = 1$, if and only if $\exists e \in D_a$ $|\varphi|^{M,g,v/e} = 1$.

Comment: The λ- sign represents the λ- operator from λ- calculus. For example, the expression λ p[$\forall$ xp(x)] is of the <<e, t>, t> type and denotes the set of characteristics (of second degree predicate) of the elements from the adopted Universe. Conversely, the λ x[p(x)] expression is of the <e, t> type and specifies the elements of the Universe having the p as predicate.

4. INTERPRETATION OF THE LINGUISTIC PHRASES.

To accurately interpret the linguistic phrases generated with the rigid CCG approach in the context of the proposed logical language a correspondence between the syntactic categories and the semantic has to be defined.

Definition 4.1. I. For the basic grammar categories (definition 2.1) a morphism f should be parsed as follows:

1. N $\rightarrow e$, proper nouns are associated with the elements of the V vocabulary;
2. S $\rightarrow t$, sentences are associated with the t element (true, false) from Universe;
3. CN $\rightarrow \langle e,t \rangle$, common nouns are associated with the first degree predicates;

II. For the other categories of the Cat(**B**) set the following relation should be defined: f(\(A, B))= $\langle f(A), f(B) \rangle$ and f(/(A,B))= $\langle f(A), f(B) \rangle$, where A and B $\in$ Cat(B).

Example: Let “John expertly hoists the flag” be a phrase to be interpreted. Using the morphism f, described above, it can be easily derived that:

<John, N> $\rightarrow e \rightarrow John''$

<flag, CN> $\rightarrow \langle e,t \rangle \rightarrow \lambda x[flag''(x)]$

<hoist,\(N,/(CN, S))>

$\rightarrow \langle e, \langle \langle e,t \rangle, t \rangle \rangle \rightarrow \exists x[flag''(x) \wedge hoist''(John'', x)]$

<expertly, \(\(N, /(CN,S)), \(N, /(CN, S)))> $\rightarrow \langle \langle e, \langle \langle e,t \rangle, t \rangle \rangle, \langle e, \langle \langle e,t \rangle, t \rangle \rangle \rangle \rightarrow$

$expertly''(\exists x[flag''(x) \wedge hoist''(John'', x)])$

Comments: 1. The transitive verb “to hoist” has been extensionally interpreted.

2. In the latter expression the following semantic rule was used: $|\alpha(\beta)|^{M,g} = |\alpha|^{M,g}(|\beta|^{M,g})$.

3. The elements followed by a double apostrophe represent translations of the words into the logical language.

The formulas in the logical language generated with the morphism f are limited by the analyzed sentence. However, they can be further generalized using the λ - operator. For example, the transitive verb “to hoist” can be described as:

$$\lambda N[\lambda A[\lambda D \exists x[D(x) \wedge A(N, x)]]]$$

5. NATURAL LANGUAGE: INTENSIONAL ASPECTS

The described model follows an extensional approach: it is assumed that the semantics of phrases in the NL can be derived from the interpretation of theirs components (words, sentences). However, this is only a simplification. In reality, a plethora of factors influence the semantics of phrases in the NL are: 1. contexts; 2. modal contexts; 3. temporal contexts; 4. intensional contexts. These factors taken together constitute some extra-linguistic objects. To support an intensional approach the proposed formalism [4] was extended as follows:

A. Definition 3.1 (extended). The Type set is a minimal set which includes the following elements:

1. $e \in Type.$
2. $t \in Type.$
3. If $a \in Type$ and $b \in Type$, then $\langle a,b \rangle \in Type$.
4. If a $\in$ Type, then <s, a> $\in$ Type.

, where <a, b> - a function with its definition domain D_a (a set of the type a) and variation domain D_b (a set of the type b**)**, s – the third object added to model the contexts. B. The syntactic rules of the logical language (extended):

1. If a is a variable of the type a, then $v_a \in ME_a$.
2. If a is a constant of the type a, then $c_a \in ME_a$.
3. If $\alpha \in ME_b$ and u $\in Var_a$, then $\lambda u \alpha \in ME_{<a, b>}$.
4. If $\alpha \in ME_{<a, b>}$ and $\beta \in ME_a$, then $\alpha(\beta) \in ME_b$.
5. If α, $\beta \in ME_a$, then $\alpha = \beta \in ME_t$.
6. If $\varphi \in ME_t$ and $\psi \in ME_t$, then $\neg\varphi, [\varphi \wedge \psi], [\varphi \vee \psi], [\varphi \rightarrow \psi], [\varphi \leftrightarrow \psi] \in ME_t$.
7. If $\varphi \in ME_t$ and u$\in$ Var, then $\forall u \varphi \in ME_t$.
8. If $\varphi \in ME_t$ and u$\in$ Var, then $\exists u \varphi \in ME_t$.
9. If $\alpha \in ME_a$, then $^\wedge\alpha \in ME_{<s, a>}$.
10. If $\alpha \in ME_{<s, a>}$, then $^\vee\alpha \in ME_a$.

C. The semantic rules of the logical language (extended):

1. If α is a constant, then $|\alpha|^{M,g}$ = F(α).

2. If α is a variable, then $|\alpha|^{M,g}$ = g(α).

3. If $\alpha \in ME_{<b, a>}$, and $\beta \in ME_b$, then $|\alpha(\beta)|^{M,g} = |\alpha|^{M,g}(|\beta|^{M,g})$.

4. If $\varphi \in ME_t$, then $|\neg\varphi|^{M,g} = 1$, if and only if $|\varphi|^{M,g} = 0$ or the other way around.

5. If $\varphi \in ME_t$ and $\psi \in ME_t$, then $|\varphi \wedge \psi|^{M,g}$ =1 if and only if $|\varphi|^{M,g}$ =1 and $|\psi|^{M,g}$ =1.

6. For $\vee, \rightarrow, \leftrightarrow$ similar to 5.

7. If $\varphi \in ME_t$ and $v \in Var_a$, then $|\forall v\varphi|^{M,g}$ =1, if and only if $\forall$ e $\in D_a$, where D_a- a domain of the type a, $|\varphi|^{M,g,v/e}$ =1 and v/e - substitution.

8. If $\varphi \in ME_t$ and $v \in Var_a$, then $|\exists v\varphi|^{M,g}$ =1, if and only if $\exists e \in D_a$ $|\varphi|^{M,g,v/e}$ =1.

9. If $\alpha \in ME_a$, then $|{}^{\wedge}\alpha|^{M,gw,t,g}$ is a function f with the domain $W \times T$, which satisfies the following : $\forall \langle gw', t' \rangle \in W \times T \rightarrow f(\langle gw', t' \rangle)\ is\ |\alpha|^{M,gw',t',g}$

10.If $\alpha \in ME_{<s,a>}$,then $|{}^{\vee}\alpha|^{M,gw,t,g}\ is\ |\alpha|^{M,gw,t,g}(\langle gw,t \rangle)$.

Comments: The s element permits to operate with extra-linguistic objects and to define the functions of the <s, a> type. The $D_{<s,a>}$ domain contains functions of this type and forms the domain of all possible senses (meanings of). These senses can be extracted with the ^ operator and have the general form <w, t>, where w – the index of the meaning and t – its temporal component [5]. The intensional of a linguistic phrase ${}^{\wedge}\alpha$ is a function applied to <w, t>.

The extended model M interpreting the syntactic rules comprises:
1. I – a non-null set of elements form the Universe;
2. F – a function attributing the intensional to every constant the Con set;
3. T – the non-null set of temporal components with the defined < relation;
4. W – the non-null set of all possible worlds (meanings of all extra-linguistic objects).

We have considered necessarily modifying the structure of possible worlds, because the structure of all possible worlds is a syntactical one. Therefore, this extended formalism permits modeling of extra-linguistic objects using categorial grammars: the index <gw, t> includes the categorial grammars gw.

Example. The type expression <s, e> denotes the individual concept, the expression <<s, e>, t>> refers to the properties of sets of concepts of individuals, but - <s, <e, t>> represents the properties of individuals. The properties of individuals may be express by the formula: ${}^{\wedge}\lambda x[P(x)]$ and, finally, the transitive verb "to hoist" from p.2 will be representing in logical language as:

$$hoist''(John'', {}^{\wedge}\lambda A \exists x[flag''(x) \wedge A(x)])$$

CONCLUSIONS AND PERSPECTIVES:

This study is aimed at developing systems for the interpretation of natural language texts. In fact, here was treated sentence interpretation - a particular case. Even at this level there are enough problems. The proposed approach allows to elaborate a system that would take into account the complexity of the problem. Many problems remain unresolved in theory. For example, it is important to investigate the structure of possible worlds, the relationship between the situation and the type of analyzed sentence: assertions, orders etc.

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THE EDUCATIONAL SYSTEM OF THE REPUBLIC OF MOLDOVA: NEW CHALLENGES AND OPPORTUNITIES

L. Bugaian, *dr.hab., univ. prof.*
Technical University of Moldova

The education system of the Republic of Moldova started its transformation process in the last decade of the XX century, accelerating the transformations together with the adherence at the Bologna process in 2005 by modifying and completing the Law on Education no. 547 of 21.07.1995. During this period the reform of the Moldovan university system has been oriented towards the following priority directions:

1. Changing the structure of the university system by organizing 3-cycles university studies, introducing the Diploma Supplement and the European Credit Transfer System (ECTS);
2. Organizing the internal and external quality evaluation and monitoring system by creating a Quality Assurance Agency, independent of the Government, as well as centers of quality management at each university;
3. The coordinating the university offers to market request by monitoring graduates' employment, cooperation with employers, professionalization of education [5].

In order to implement the respective priorities in the area of Higher Education several legislative reforms have been undertaken. Thus, on July 1, 2005 by the Ministry of Education a provision order of Framework-Plan for cycle I (later repealed) has been approved. It established general principles for organizing and conducting the educational process at cycle I, license. The Framework Plan provided that each student could create and follow an individual way of educational studies, consisting of study area subjects proposed within the curriculum for the relevant specialty. In February 2006 the National Education Credit System was approved and implemented. It aims both at outlining the study results and promoting students' mobility.

The Regulation on the organization of master studies, II cycle, was approved by Government Decision nr.1455 of 24.12.2007. On September 20, 2010 the Ministry of Education adopted by Order No. 726 the Regulation on the organization of higher education studies under the National Education Credit System. On June 3, 2011 the Ministry of Education Order No. 455 on the Framework-Plan for higher education has been adopted. The above-mentioned normative acts were the most important documents that regulate education reform by aligning to the European Bologna system.

Based on this review, we can state that out of several reform attempts, the main achievements are the following:

- The organization of cycle-based higher education starting with 1st of September 2005 and the development of new study programs (license studies lasting 3-4 years and master degree studies lasting 1-2 years);
- Develop and implement the Framework-Plan for cycle I (license studies from 2005);
- Institutionalization of study credits (ECTS) in all higher education institutions;
- Mandatory provision of the unique European model Diploma Supplement for license and master degree studies, which ensures transparency of qualifications and study documents [5].

The research results show that together with some achievements there are still many drawbacks. Among the most important there are the following:

- The Bologna education system was implemented only for cycle I, license, and cycle II, master degrees. The PhD remains to be determined in the new Education Code. Thus, science is still managed (especially financial part) by the Academy of Sciences of the Republic of Moldova.
- Another unsolved issue is students' mobility from one university to another, since there are differences in the structure of the curricula, which also requires students to pass the difference in subjects or the same subject at a different number of credits.
- External quality assessment is a contentious issue for a long time. A first step was made. Each university had created an internal quality management system. But at national level the Quality Assurance Agency remains a debt which will be settled up only after Parliament's approval of the Education Code.
- Optimizing the relationship between state involvement and academic autonomy is always in sight of discussions between state

institutions, especially ministries (Ministry of Education, Ministry of Finance, Ministry of Economy, Ministry of Labor and Social Protection) and universities. The limit of state influence and the extent of university autonomy are to be determined in the near future.

A modern university requires efficient educational process at universities, and, above all, the introduction of university autonomy in work, which in the European area was determined both by approving international documents (University Magna Carta in 1989, the Bologna Process in 1999, the Lisbon Declaration in 2007) and by the existing positive results in the European area. University autonomy is characterized by the following four components:

Organizational autonomy:

- independence to determine the structure, the governance and relations of subordination and responsibility.

Academic autonomy:

- independence and accountability of the university to develop their own programs of study,
- defining the structure and content of the academic curriculum,
- the responsibility for ensuring the quality of study programs and of the academic research,
- designing the selection procedures for student admission.

HR autonomy:

- independence to recruit and select qualified human resources,
- responsibility for signing work contracts,
- setting wage rates and salary increments to the value of human potential.

Financial autonomy:

- independence of the university in providing income and allocation of financial resources,
- decision of fees and charges for accommodation in dormitories, taxes on services,
- financing and co-financing of university research,
- use and storage of financial resources,
- using their transparent procedures regarding the efficient management resources.

The "Public Policy Proposals" project initiated by the Ministry of Education: „Developing managerial capacities of universities by expanding university autonomy", prepared by the Ministry of Education characterizes the current situation in higher education by the existence of partial autonomy, stressing that Moldova has been achieved some progress in this field.

University autonomy was declared by the Law on Education and other bylaws, as well as by the draft Education Code. In terms of organizational autonomy, universities have the right to determine their own organizational structure and to elect their own administrative bodies. In terms of human resources autonomy, universities enjoy the right to select the scientific, teaching and research staff, as well as the administrative and auxiliary staff. Regarding academic autonomy, universities have the right to approve the curricula and the scientific research plans.

In terms of financial autonomy, a degree of freedom was offered by Government Decision nr. Nr. 983 of 22.12.2012 that currently has applied two very important actions: each university has the right to open bank account and the balances at end of the year can remain on university bank account. Other measures provided by the Government Decision Nr. 983 of 22.12.2012 regarding the type of functioning of the institution of the higher education in condition of the financial autonomy. will be implemented starting with 2015.

According to the study developed by the Institute for Development and Social Initiatives (IDIS) ”*Viitorul*”, February 2012., currently most acute weaknesses in university autonomy in Moldova are the following:

Organizational component:

- Legal and organizational forms: budgetary institution;
- Deficit of decisional transparency;
- Lack of external actors in the management;
- Ineffective Student Governing;
- Non-transparent partial autonomy at university subdivision;
- Centralization of the admission process;
- Centralized student social aid system;
- Failure to implement to the full extent the Bologna process on the functioning of the three courses of study in universities;
- Bureaucracy on expanding educational activities.

Academic component:

- Lack of control structures and quality assurance at national level;
- Lack of mechanisms for implementation of performance indicators in universities;
- Inefficient mechanisms of interaction with business, labor, research, development and innovation areas at national and international level.

HR component:

- Crumbled and oversized university system as number of institutions;
- Lack of motivational conditions for human resource development;
- Low wages against major teaching loads;
- Low work experience of teachers in real economy sector.

Financial component:

- The existence of a centralized financial management mechanism;
- Budget Funding is based on historical costs, not per student;
- Budget Funding does not consider the shape, type and field of study;
- The budget is not apparent from the achievement of state order, or the needs of universities. The allocation is made based on the financial possibilities of the state.
- Special means are conditional on use of cash;
- The tuition fee is capped by the Government and is less than the actual cost of the education;
- High costs of maintaining dormitories, being covered improperly by the university;
- Existence of difficulties in using balances [5].

The character of a „*mass*” higher education felt the last few years, even if it is a challenge for higher education institutions, did not give the expected results. Budgetary funding based on the number of students, without considering the complexity of the various fields of studies in vocational training, without establishing academic performance indicators; the lack of funding for university research, etc. does not cause competition by increasing competitive academic advantage. Acceptance of completing quantitative approach - based only on the number of students - with qualitative approach - oriented towards quality of the education programs, knowledge and skills, all coordinated with economic and social environments requirements; monitoring of graduates’ occupations would ensure sustainable skills on the labor market. The implementation of qualitative and quantitative principles could provide real challenge to competition.

The “*Public Policy Proposals*” project initiated by the Ministry of Education: Developing managerial capacities of universities by expanding university autonomy" offers two options for implementing the university autonomy, one called partial, another one called enlarged. The first option provides partial liberalization of several positions within the four components of university autonomy. The option expects that there will remain certain limits imposed by the government on the organizational and financial component. Organizationally, the option provides the creation of a dual system of University management (the Senate and the Board) and some state intervention in the principal decisions on the quality of education system and student protection. Other limitations relate to the financial resources that will be managed by the Treasury (the ones from the state budget) and bank accounts (those from special funds) by the Government capping the maximum and minimum amount of the contract.

The one mostly preferred by universities is the wide autonomy; the conditions necessary to achieve this autonomy are the following:

- Quality assurance of education by the state by applying external evaluation mechanisms by an independent agency;
- Follow-up of the professional career of graduates;
- Allocation of budget based on academic performance;
- State budget allocated to universities depends on the state order, the calculation is carried out according to student academic performance based on an aggregated formula that applies coefficients dependent on the form, type and field of study;
- Limit the total number of students based on university capacity as infrastructure and teaching body;
- University independence in establishing scholarships and social benefits out of state funds and special funds;
- The possibility of fee-based study alternation on budget place depending on academic performance;
- Liberalization of the contract amount in accordance with the specific costs;
- Liberalization of salary level of the academic staff;
- Independence on the management of financial resources from the state budget transfers and special means;
- The university right to request accreditation of study programs / cycles;
- A prerequisite for both options is the establishment of the Quality Assurance Agency as well as of a body responsible for university ethics and management [5].

Of course, any improvement takes time and effort. The Bologna process requires educational efficiency and effectiveness, quality of the education process, involvement of the entire academic community, results associated with traditions and previous achievements, thus contributing to strengthening the image of modern university.

The whole global education system is in the transformation process. Higher education faces the challenge to find ways and solutions to survive on a competitive market that passes through a knowledge and information revolution. The trend of the educational market dynamics shows that change is irreversible and the choice of universities can be - adapting and developing competitive advantages - or opposing and staying alert in the future.

Higher education reform can be achieved only by the ability and capacity to adapt to the European University development trends. National culture, education and values can be capitalized and promoted effectively only in a European context. The unique opportunity and the right choice is to become a high performance organization and tend to the excellence level of the best European universities, based on active students, competent and dedicated teaching staff and efficient management. Conservative, traditional, passive, waiting-based approach will fail in the current environment of quick change and society development.

Traditional educational institutions are challenged by forces that characterize the global economy: competitive markets, demographic change, increasing ethnic and cultural diversity, technology. Universities must be responsive to the needs of the environment, to promote policies and educational strategies appropriate to the labor market, both opportunity and challenge for the educational environment being felt. Prosperity and well-being of a nation in a global knowledge-based economy will require educated citizens. The environment will require institutions with the ability to discover new knowledge and to transfer them on the market through economic activities. Cooperation between scientific research and economic development requires practical application of research results and technology transfer methods. Orientation to the needs of the environment must reshape higher education research and restore education programs.

Following the challenges of the Bologna process, which set out guidance and promotion of education development and research to integration into a common area of education and research, higher education institutions must take into account the following requirements:

1. To promote teaching and research in accordance with the requirements of a knowledge-based society and lifelong learning, embedded in a European and global context;
2. To contribute to active participation in local, regional and national development in social, economic, cultural and political terms;
3. To contribute and provide original systematic knowledge for the major areas of science and technology, associated with flexible, comprehensive, interactive and permanent studies;
4. To promote and support the quality of public institution at national and international levels to develop a culture of proactive and participatory attitude, of personal development and integration of diversity and globalization;
5. To be open to interaction with economic, social and academic communities at national and international level, etc. [8]

In this context of principles the capitalization of scientific research is required, by initiating new relationships with the socio-economic environment, diversification of study programs, and realization of joint projects that will help transform universities from traditional, conservative institutions, in new, entrepreneurial institutions. An educational institution is an entrepreneurial university when teaching and administrative staff unite their efforts for the institutional development, providing resources for a properly function, which will help develop a dynamic university character. As a result, university graduates acquire skills consistent with labor market structure [6].

Changing the vision from traditional to entrepreneurial was triggered by decreased public funding of the education system, therefore, all business activities are meant to balance this financial decline. Implementation of academic entrepreneurial approach requires:

- development of an entrepreneurial culture;
- further development of Training Centers for technology transfer and innovation;
- creation of an entrepreneurial vision and initiative to encourage the creation of spin-off companies;
- promotion of technology parks development, participation in public-private initiatives and partnerships;
- creation of the requirements and facilities for lifelong learning [7].

By definition, the academic entrepreneurship must create conditions for new organizational structure, oriented towards independent activities. That kind of universities are actively involved in social and economic development of the region, creatively using the existing resources, reorganizing education in order to adapt graduates to environmental requirements, teaching them to work in conditions close to real environment, considering the cost and profit indicators. The defining characteristic of the entrepreneurship is to strengthen, expand and renew university's relationship with business community in particular and society in general, which has a positive impact on the rhythm of sustainable economic development.

Strengthening academic partnership with the company leads to sustainable adaptation of university services, study and research programs, entrepreneurial approach deserves special attention because of its potential to make a university more active and deeply committed to social development accompanied by an institutional management, capacity for self-governance and managerial values required by the labor market requirements. Therefore, it is imperative to develop a modern, flexible and efficient management, which is continuously looking for solutions to environmental problems, with a vision and clearly defined academic mission and objectives-oriented strategy. This type of management should be oriented to identify appropriate solutions to a variety of challenges to benefit and empower the university as a promoter of progress. In this context, it is essential to identify various sources of funding (European programs, grants and research contracts, exploitation of intellectual property rights, consulting services, etc…) [7].

The state cannot be indifferent on financing public educational institutions, as economic and social significance of the whole educational system is too important for the society. Good practice of European universities show that for a more appropriate financial management of the market situation it is necessary for the state to pass from strict inspection methods to surveillance methods. The state does not disappear; it undertakes new approaches realized by introducing various steering and financial supervision committees. The state must "*resist*" [4].

A high performance educational system requires complex reform aimed to develop a clear concept, developed in a code of education, adequate funding, optimal working conditions and facilities, prestige, a system able to recruit the best qualified, talented and committed teacher, dynamic curricula geared to market needs, transnational cooperation and regular mobility, continuous development, etc.

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PECULIARITIES OF AROMATIC COMPOSITION OF THREE WINES MADE FROM WHITE GRAPE VARIETIES SELECTED IN MOLDOVA

N. Furtuna, drd., lect.univ.
Universitatea Tehnică a Moldovei

INTRODUCERE

Wine is one of the most complex alcoholic beverages, and its aroma substances are responsible for much of this complexity. Wine flavor can be classified into three groups: varietal, fermentative and wine ageing aroma. Describing the aroma of wines is not a simple task for researchers, because more than 800 aroma compounds such as alcohols, esters organic acids, aldehydes, ethers, ketones and terpenes, etc., have been identified in them, with a wide concentration range varying between hundreds of mg/L to the µg/L or ng/L levels, and their combinations form the character of wine and differentiates one wine from another [1].

The gas chromatography-olfactometry (GC-O) is an analytical method that combines the gas chromatography and sensory evaluation, using the human nose to assess odor components. The human nose has odor detection limit of about 10^{-19} moles [2], therefore GC-O is an extremely valuable and sensitive tool for odor detection.

1. THEORETICAL ISSUES

Chromatography is a method used to decompose complex mixtures of chemicals into their constituents. In essence, the method entails the forced transfer of chemical components along an adsorptive or dissolvent material, which usually is packed in a column or which constitutes the inner lining of a column.

A better estimation of each component's contribution to the aroma may be obtained by sensory evaluation of the separated constituents. Thus, by replacing the flame ionization detector (FID) with a sufficiently large panel of subjects that sniff the effluents of the gas chromatograph with the purpose to detect and characterize the odor-active chemicals.

After injection, the content of the sample is separated by the chromatographic column. Before leaving the column (figure 1), the effluent is divided into two parts: the smallest is directed to the instrumental detector, usually a FID; the largest part is directed to a smelling device (sniffing port) placed at the evaluator's nose height. This method provides simultaneously two signals: the chromatogram of the extract and the recording of odor events perceived by assessors [3].

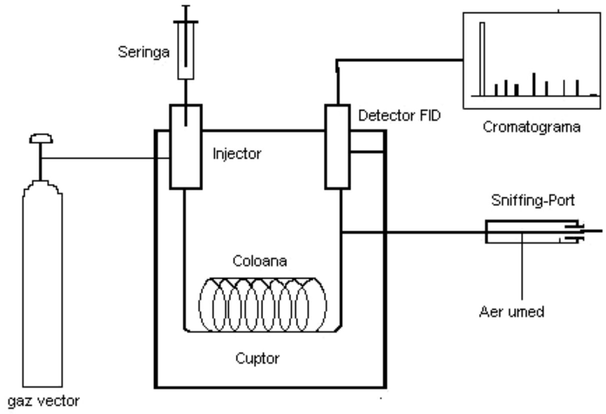

Figure 1. The operating principle of GC-O

Each assessor must perceive the beginning and the end of the flavor and describe it. The individual aromagrams are summed, yielding the global aromagram where frequency of detection is represented in dependence on time or retention index. The olfactometric indices can be used for ranking odorant areas according to their olfactory impact [4].

The odorant areas obtained via GC-O are characterized by three parameters: olfactometric index, average linear retention index (LRI) or LRI interval and flavor descriptors. All this information is used later in the identification of compounds [5].

2. MATERIAL AND METHOD

For analysis were used wines made from Moldavian local grape varieties: Startovyi, Hibernal and Muscat of Ialoveni (harvest 2010) produced at the Practical Scientific Institute of Horticulture and Food Technology from Chişinău.

In order extract aromatic compounds was used the dichloromethane extraction, based on the method proposed by Moio [6].

The olfactometric analysis was performed on 3 extracts by 7 assessors selected in advance and informed that they will analyze three white wines, but no other detail has been specified. The extracts were analyzed by the participants in a different and balanced sequence. The total length of a session was 45 minutes. After injection of the solution into chromatograph column, in order to avoid inhalation of the solvent, the assessor was asked to wait 5 minutes before approaching the nose to the sniffing port (figure 2).

Figure 2. Sniffing-port (with the glass mold of the nose), button and microphone for recording.

The gas chromatograph Hewlett-Packard 5890 was equipped with split/splitless injector and DB-1701 capillary column. Simultaneous processing of both signals was performed using EZchrom Elite (Agilent Technologies) and AcquiSniff ® (© INRA).

Linear retention indices (LRI) of chromatographic peaks and odorant events were calculated using a daily injection of a solution of 13 n-alkanes (from C_7 to C_{19}), analyzed under the same chromatographic conditions as the extracts.

The results of each individual data processing were presented in Excel tables where the LRI peak, the assessor codes, the extract codes and their respective descriptors were indicated. Therefore, 21 tables with olfactometric data were obtained, that subsequently were submitted to mathematical processing. Mathematical processing of olfactometric data was performed using Matlab ® (The Mathwork Inc.), which implements an iterative mathematical function to get a table that contains the number of detections for each tandem wine/odorant area.

3. RESULTS AND DISCUSSIONS

Initially the wines were submitted to sensory analysis sessions. Though considerable dispersion of responses, it was achieved conclusive data and a diagram of sensory profile. The intensity of wine aroma was appreciated with values within a range from 62.5 to 75 pts out of 100.

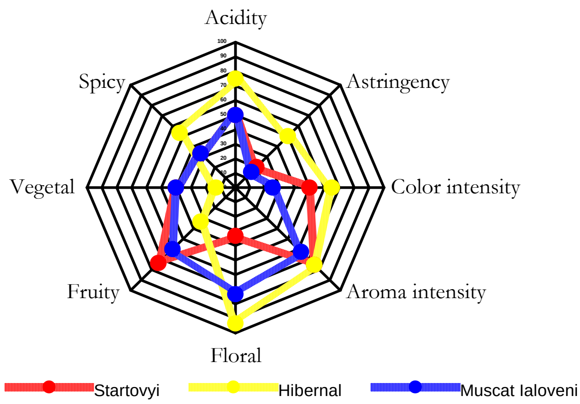

Figure 3. Sensorial profile of studied wines.

On the axes of radar type diagram (figure 3) are set the values and the sensory characteristics for each wine. Descriptors are presented according to the free expression of assessors (table 1).

Table 1. Descriptors set out by the assessors.

The wine	Types of aromas			
	Floral	*Fruity*	*Vegetal*	*Spicy*
Startovyi	Honey	Pear, lemon	Freshly cut hay	Pepper, coconut
Hibernal	Basil, thyme	Pomelo, grapefruit	Grass	Laurel, paprika
Muscat Ialoveni	Acacia flowers	Citrus, pineapple	Celery	Nutmeg

The olfactometric study, using frequency detection, generated 21 individual aromagrams. The number of odorant events related to each wine is situated between 228 (Muscat of Ialoveni) and 238 (Hibernal), meaning that for three wines, seven assessors had spotted 697 events (table 2).

Table 2. Global data of olfactometric analysis.

The wine	*Total odor events*	*Total descript.*	*Events without descript.*	*% Events without descript.*
Startovyi	231	259	22	8,5 %
Hibernal	238	272	26	9,5 %
Muscat Ialoveni	228	250	31	12,4 %
Sum 3 wines	697	781	79	10,1 %

In order to process data obtained by using Matlab® software, it was previously set an eliminatory threshold. This corresponds to the value of first quartile of distribution, i.e., to consider an odorant area as representative it must contain at least 5 odor events. From the totality of 697 odor events, 565 (81%) were distributed within 45 odorant areas that contain at least 5 events per area (figure 4). Consequently, the areas with the number of events lower than the eliminatory threshold have been removed.

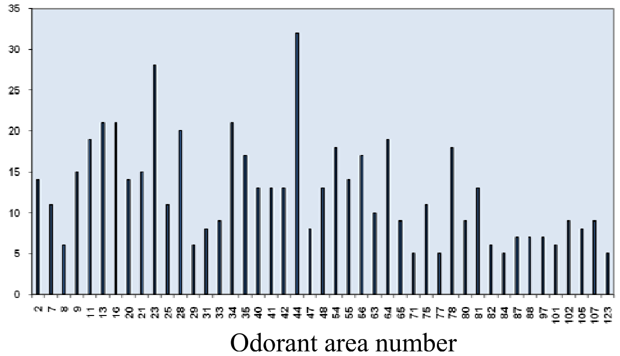

Figure 4. Global aromagram of studied wines.

It can be observed that the odorant areas have well separated peaks (odor events), except the odor events of compounds with a perception threshold inferior to the sensorial capacity of assessors, as well as differences between their ability to recognize a flavor.

The results obtained by GC-O analysis were summarized in table 3.

Table 3. Characteristics of representative odorant areas for studied wines.

Area number*	**LRI ****	**Detection frequency**	**Odorant area description**
2	695	14	Yoghurt, cream, butter
7	766	11	Fruity, solvent
8	770	6	Vinegar, pungent
9	778	15	Fruity, brandy
11	816	19	Fruity, strawberries, pineapple
13	845	21	Cocoa, chocolate, yeasty
16	862	21	Tutti frutti, strawberries, raspberries
20	906	14	Fruity, kiwi, pineapple
21	912	15	Fruit candy, linden, verbena
23	938	28	Peanuts, roasted, banana, pear
25	957	11	Cheese
28	1009	20	Cheese, rancid
29	1014	6	Apple, cheese
31	1027	8	Dried herbs
33	1053	9	Cooked potatoes, gnocchi
34	1060	21	Fruit candy, apple, citrus
35	1074	17	Black currant buds
40	1149	13	Flowers
41	1154	13	Sulfurous, plastic
42	1174	13	Fruity, balsamic
44	1194	32	Lily of the valley, lavender, citrus, marshmallows
47	1235	8	Caramel, chocolate
48	1240	13	Cotton candy, caramel
54	1284	18	Honey, rose, lilac
55	1292	14	Flowers
56	1305	17	Caramel, cotton candy
63	1350	10	Cheese, smoky, dusty
64	1357	19	Spicy, curry, fennel
65	1371	9	Bergamot, citrus
71	1432	5	Licorice
75	1473	11	Floral, herbaceous
77	1489	5	Chemical, pharmaceutical
78	1494	18	Balsamic, clove, curry
80	1508	9	Polyfloral honey
81	1512	13	Prune, floral, smoky
82	1518	6	Clove
84	1529	5	Spicy
87	1545	7	Mineral
88	1550	7	Floral, herbaceous
97	1619	7	Fruity, vegetal
101	1644	6	Sulfurous, fermented
102	1662	9	Vanilla
105	1728	8	Mulled wine, balsamic
107	1748	9	Coconut
123	1909	5	Fruity, berries

* *Odorant areas that contain at least 5 events ;*

** *Average LRI in DB-1701 capillary column (30 m x 0.32 mm x 1 µm).*

CONCLUSIONS

Olfactometry analysis (GC-O) allows the selection of odorant compounds using human analyzer, sequentially combining gas chromatography (instrumental analysis) and sensory perception (subjective analysis), thus being a very precious technique for detection of compounds with higher detection threshold than their concentration in wine, and thereby solving some problems in the aroma analysis.

The study presented here has shown that the wines made from white grapes varieties from Republic of Moldova selection (Startovyi, Hibernal and Muscat of Ialoveni) posses a large amount of odorants detectable by olfactometric studies.

The central method of this research was the olfactometry analysis by using the detection frequency method to generate 21 individual aromagrams, which were later summed into a global aromagram for all three wines.

According to mathematical processing of experimental data using Matlab® software, it was established that out of 697 odor events spread in 123 odorant areas, 565 (81%) were distributed within 45 odorant areas that contain at least 5 events per area.

By analyzing the global aromagram, it can be concluded that the odorant areas have well separated peaks (odor events), except the odor events of compounds with a perception threshold inferior to the sensorial capacity of assessors, as well as differences between their ability to recognize a flavor.

In spite of some limitations, The GC-O approach used in the study arises as a valid tool for determining the existence of intense odorants of wine.

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THE IMPACT OF REGULATIONS ON ELECTRICITY SECTOR - SECURITY, RELIABILITY, EFFICIENCY

V. Gropa, N. Mogoreanu, PhD,assoc.prof.
Technical University of Moldova

I. INTRODUCTION

Undeniable that sub-legislative acts elaborated by the National Energy Regulatory Agency (NERA) in accordance with the Regulation [1] promote the concepts of these laws to a large extent determining the economic development of the country, the safe operation of the National Power System, supply reliability and other issues related to the effectiveness of the electricity "*production – consumption*" couple. With the liberalization of the electricity market an important role is on account of electricity networks that have a multiple technical and commercial role:

- it is the physical environment of electricity transmission in the geographical area;
- provides access to the network and the market;
- provides electricity at the security and quality standards required by both the user - the client, and the system operation.

Starting point: An investor has obtained land to start a business related to production. To organize production it is necessary to have a building or group of buildings. To put it into operation, the object has to be connected to the network of the distribution operator. Depending on the distance to the operator's network, connection can be achieved only by **connecting**, or, in the case of long distances, by **extending** the operator's network with subsequent **connection** to it.

Let us see what are the provisions of the national legislation to achieve these important investment components?

According to [2]**:**

1. ***Electricity distribution network expansion*** - increasing the capacity of existing electricity distribution network or construction of new electricity networks or portions of electricity distribution networks, actions performed by the distribution network operator to meet electricity demand of individuals and legal entities that require connection to the network;

2. ***Connection*** - performing a permanent electrical connection between the usage facility and the electricity network by the distribution network operator;

3. ***Article 40*** [1]. Distribution network operators perform network expansion in relation to increasing electricity demand, so as reliability and continuity of electricity supply to consumers to be ensured, according to a regulation developed and approved by the Agency.

4. In [1] provisions on procedures for accomplishing the connection to the electricity network are missing.

2. ELECTRICTY DISTRIBUTION NETWORK EXPANSION

Let us analyze the mechanism and steps for undertaking the process of electricity network expansion regulated by [3]:

1. The local public authority is responsible for the design of the new electricity distribution network - p.12 [3];

2. The local public authority or investor shall submit the operator an application for the expansion project inclusion in the work plan of the operator. Within 15 days of receipt of the application, the operator is obliged to inform the local public authority or investor about project acceptance for review – p. 13;

3. If the application for inclusion of the expansion project is submitted until September 30 this year, the operator shall examine the application and, where applicable, includes the projects in the work plan for the coming year – p. 14;

4. If the public authority or investor requests the extension of the new network within more limited time than the one established in the investment plan, the operator is entitled to refuse the request or to propose the applicant to fund the new network expansion. To this end the local authority or the investor will conclude a contract with the operator where the allocated amount, terms and reimbursement conditions will be stipulated – p. 21.

Comments:

1. Provision 12 [3] is contrary to the provisions of Art. 40. (1). [2] by which "*Distribution network operators perform network expansion ...*", the design being part of the expansion process;

2. Provision 14 [3] is bureaucratic and discriminatory (acceptance / rejection, up to September30) and can cause corruption;

3. According to provision 21 [3], network expansion will be made by crediting the operator by applicants: the applicant obtains a loan from the commercial bank in the amount of 2-3 million lei (one kilometer connection to a substation of 250 kVA in the conditions of the Republic of Moldova costs about 1.5 million lei). In principle, this is a provision which is contrary to financial and banking legislation. The reimbursement of the "loan" by the operator may take more time than stipulated in the contract which will cause significant additional costs to the applicant. It can cause corruption.

4. From the investment point of view no investor will accept the "*speeding*" of the expansion through the proposed mechanism. However, the credit line being open, he cannot wait a year or more for network expansion, the connection to which will last 3-4 months.

Conclusion:

Most likely the investor will abandon the investment. The economy will lose jobs, investment image will diminish and electricity consumption will not increase.

Romanian Law [4] does not use the term "*expansion*". According to Article 45 (1) [4], the "*distribution operator has the following main tasks*:

c) carries out development works of electricity distribution networks through ***programs*** *and their optimal* ***development plans*** *based on prospective studies, in consultation, where appropriate, with the transmission and system operator ...* ".

Article 3 [4]: "***Development plan*** *– long term planning document of the investment needs in distribution capacities in order to cover the electricity demand of the system and to ensure delivery to customers*".

3. CONNECTION TO THE ELECTRICTY NETWORKS

Connection to the electricity networks is a very important procedure, regardless of user nature - residential or industrial. The importance of this procedure is also confirmed by art. 3.3 of the Directive 2009/72/ EC [5] "*... Member states shall impose on distribution companies an obligation to connect customers to their network under some established conditions and tariffs, in accordance with the procedure stipulated in Article 37.6 ...*".

The provisions of Article 37.6 share responsibilities: "*The regulators are responsible for fixing or approving, sufficiently in advance of their entry into force, at least the methodologies used to calculate or establish the terms and conditions for:*

a) connection and access tariffs to national networks, including transport and distribution tariffs".

The complexity of the procedure for connection to electricity networks is determined by the diversity of possible situations, which is confirmed by the legislative and regulatory acts package of **Romania**:

1. Law on electricity and natural gas;
2. Regulation on the connection of users to public electricity networks, approved by the Government Decision;
3. Documents approved by the National Energy Regulatory Authority:

- Technical Code of Electricity Distribution Networks;
- Regulation on the establishment of solutions for the connection of users to public electricity networks;
- Methodology for setting tariffs for the connection of users to the electricity distribution networks of medium and low voltage;
- The procedure of solving the disagreements on connection of users to public electricity networks and issuing location permits;
- The procedure on the connection of users to the electricity networks in the vicinity of the boundary of the activity area of distribution operators.

According to Article 25 (1) [4] (RO), "*The licensee and the client have regulated access to public networks. Access to public networks is a mandatory service, under regulated conditions, which the transportation operation and distribution operator have to meet*".

In case of connection to the electricity network Article 26 [4] provides the conclusion by the applicant of the connection contract with the distribution operator. The connection procedure is determined by [4] and is carried out by performing the following steps:

1. **Applying for connection.** The connection solution is determined by the network operator through the solution sheet or solution study, as appropriate. The costs related to drafting of the solution sheet are included in the tariff for issuing the connection technical approval.
2. **Issuing the connection technical approval**;
3. **Conclusion of the connection contract.** After the conclusion of the connection contract, the

network operator provides: **design, construction and commissioning of the connection plant;**

4. **Powering the plants.**

The work cost is paid by the applicant in several stages on the extent of work performance.

The Regulation [6] contains a very important provision for both the distribution operator and the consumer: Article 40 (2) "*These plants shall remain in the property of the network operator and can be used for connecting other users ...*"

In the case of the **Republic of Moldova** the basic legislative act [2] does not contain conceptual provisions, which would determine the procedure for connecting to the electricity network.

The mechanism of connecting to the operator's network is determined by 23 provisions (three pages) of **Section 6** [7] ***„Connection of the applicant's installation to the electricity network***" and involves the following steps:

1. **p. 55**. "*The network operator is obliged to provide the applicant no later than 15 calendar days the connection approval*".

Comment: Typically, the procedure can last 2-3 months due to the lack of capacity of the distribution operator in the area or the refuse of the network owner, which the operator appealed to. For these reasons the length of the connection network can reach 0.7 to 1.5 km.

2. **p. 61**. "*At the request of the applicant, the network operator performs the design and mounting of the connection installation. Connection work is carried out after concluding the contract on the mounting of the connection installation and after paying these costs by the applicant*".

Comment: "*... the network operator performs the design and mounting of the connection installation*" which means that there appears an intermediary, because the operator (in the case of Moldova) has no design office and capabilities that would undertake the design and mounting of the connection installation.

3. **p. 67**. "*Once the conditions included in the connection approval are met, the applicant addresses to the network operator for drawing up and signing of the demarcation act*".

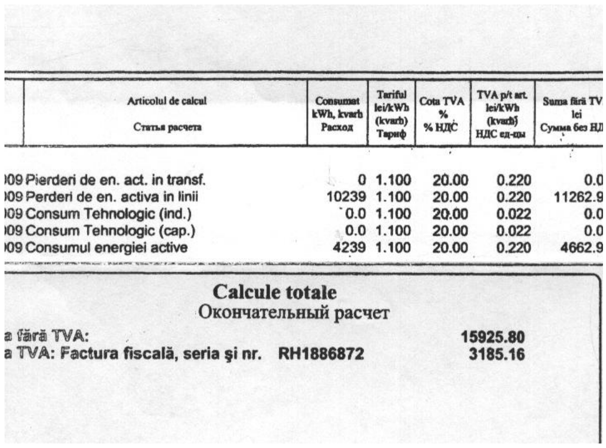
Comments: According to **p. 76 and 77** [7], "*The **property** demarcation point is set to a physical element ... . For industrial consumers, the demarcation point is determined based on the agreement between the industrial consumer and operator ...* ". This is a camouflaged provision, but due to the presence of the word "*property*" the connection point is also the demarcation point. Once becoming the owner of the connection installation, the user will incur additional costs because it will be obliged:

- to conclude a contract on the maintenance of the connection installation with an authorized company or the distribution operator;
- under provision 114 [7], "*In case the measuring equipment of the industrial consumer is not installed at the demarcation point, the loss of active and reactive power in the network elements comprised between the two points is added to the amount of energy registered by the measuring device, calculated in accordance with the Instruction on the calculation of active and reactive power losses in the network elements which are at consumer's account ...* ". This is a provision used by the operator to obtain additional income as calculation methods are complicated for users. Frequently, cases are detected when power losses, without transformation stage, reached 25 - 50% and even 100% (Annex 1, Fig. 1). In these calculations, the reactive power costs as if it is active;
- the distribution operator connects other users to the connection installation without informing the owner of the network;
- it is not clear how the electricity market will be liberalized under these situations.

4. **p. 72.** "*The network operator may refuse argued the issuance of the connection approval to the applicant, potential final consumer, if facing a lack of capacity, including on the grounds that there is no electricity network or that the existing electricity network is not able to meet the electricity requirements of the applicant*".

Comment: This is a discriminatory provision which contravenes the concept promoted by art. 3.3. [5] even if in the law preamble there is the phrase "*this law sets the framework necessary for the application of the Directive 2003/54/EC ....*".

ANNEX 1



Articolul de calcul / Статья расчета	Consumat kWh, kvarh / Расход	Tariful lei/kWh (kvarh) / Тариф	Cota TVA % / % НДС	TVA p/t art. lei/kWh (kvarh) / НДС ед-цы	Suma fără TV lei / Сумма без НД
)09 Pierderi de en. act. in transf.	0	1.100	20.00	0.220	0.0
)09 Perderi de en. activa in linii	10239	1.100	20.00	0.220	11262.9
)09 Consum Tehnologic (ind.)	0.0	1.100	20.00	0.022	0.0
)09 Consum Tehnologic (cap.)	0.0	1.100	20.00	0.022	0.0
)09 Consumul energiei active	4239	1.100	20.00	0.220	4662.9

Calcule totale
Окончательный расчет

a fără TVA: 15925.80
a TVA: Factura fiscală, seria şi nr. RH1886872 3185.16

Figure 1.

According to Article 25.(2) [4], "***The access to the network can be restricted only if the connection affects the safety of the Electric Power National System***...".

4. CONCLUSIONS

1. In reality, under the connection pretext, the extension (development) of electricity distribution networks occurs. At the same time, a considerable technically and economically unjustified financial flow is directed to the operator;

2. Network development, having a character of solving concrete situations (isolated fragments), caused by private interests, for the moment, affects the geometry of distribution networks, and is of chaotic nature. As a result, protection systems are getting complicated, especially future network monitoring and equipment with SCADA elements, reduces efficiency, service level and service quality;

3. If the current conception of the connection procedure continues, the share of private/personalized electricity networks will increase, which will lead to the complication of relationships on the electricity market;

4. The very important and difficult procedure (which is actually confirmed through the acts package of Romania) - connection to the electricity network, in Moldova it is regulated only by 20 provisions of the act, which is intended only for the supply procedure. Obviously, it is an imperfect mechanism that causes proactive treatments and irregular "*supplier-consumer*" relations, which disadvantages domestic and foreign investors;

5. **In both the current Law on electricity and in the proposed amendments, there are not included the provisions of preamble 45, Art. 3 (3) and 37 (6)** of [5]: "*There should be taken actions to ensure transparent and non-discriminatory tariffs for the access to the network. These tariffs should be applicable to all system users on a non-discriminatory base*".

"***The main obstacles to reach an internal market, fully functional and competitive, relate, inter alia, to <u>issues of access to the network</u>*** **...** "[5].

Through concrete examples, it was demonstrated that the analyzed documents contain deviations from European standards, do not stimulate and do not require operators to upgrade the components of the power system, to ensure efficient operation and to increase *safety, reliability and quality*.

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PRECESSIONAL TRANSMISSION SOUND REASEARCH

Iu. Malcoci, PhD student
Technical University of Moldova

1. BASIC PARAMETERS OF SOUND

Sound measurement and analysis are required to determine what sound is typically generated and what sound is undesired noise. This analysis is accomplished by the use of a sound analyzer. A sound analyzer is an instrument which displays sound waves in the rms levels at various frequencies or frequency bands. Using an analyzer will help separate undesired frequencies from the sound spectrum and contribute to an accurate interpretation of sound data. The sounds generated during gear unit operation can be from one or more of the following major sources: gear dynamics; bearing dynamics; coupling noises; system resonance or critical speeds; accessories such as funs, lubrication systems, etc.

Sound may be defined as any pressure variation (in air, water or other medium) that the human ear can detect. Just like dominoes, a wave motion is set off when an element sets the nearest particle of air into motion. This motion gradually spreads to adjacent air particles further away from the source. Depending on the medium, sound propagates at different speeds. In air, sound propagates at a speed of approximately 340 m/s. In liquids and solids, the propagation velocity is greater – 1500 m/s in water and 5000 m/s in steel [8].

In the other hand sound is such a common part of everyday life that we rarely appreciate all of its functions. It provides enjoyable experiences such as listening to music or to the singing of birds. It enables spoken communication and it can alert or warm us – for example, with the ringing of a telephone, or a wailing siren. Sound also permits us to make quality evaluation and diagnoses – the chattering valves of a car, a squeaking wheel, or a heart murmur.

In many cases in our modern society, sound annoys us. Many sounds are unpleasant and unwanted – these are called **noise**. However, the level of annoyance depends not only on the quality of the sound, but also our attitude towards it. The sound of his new jet aircraft taking off may be music to the ears of the design engineer, but will be ear-splitting agony for the people living near the end of the runway. A creaking floor, a scratch on a record, or a dripping tap can be just as annoying as loud thunder.

Worst of all, sound can damage and destroy. A sonic boom can shatter windows and shake plaster of walls. But the most unfortunate case is when sound damage the delicate mechanism designed to receive it – the human ear.

The level of sound is normally described in terms of either sound pressure level at a given distance from the source or sound power level. In each of these, the desired quantity (pressure or power) is expressed in the numerator of a ratio with the reference level as the denominator. Because of the extremely wide range of levels measured (very small to extremely large) in everyday environments, both pressure and power ratios are expressed by logarithmic scale.

Sound pressure level, $\boldsymbol{L_p}$, expressed in decibels, is 20 times the logarithm to the base 10 of the ratio of the sound pressure being measured to the reference sound pressure [1,3]:

$$L_p = 20\log_{10}\frac{p}{p_0},\ [dB] \quad (1)$$

where, p – is sound pressure being measured, $\mu N/m^2$, p_0 – is reference sound pressure 20 $\mu N/m^2$. The reference sound pressure, p_0, is internationally accepted as 20 microNewton/meter squared, which is about the threshold of normal hearing at a frequency of 1000 Hz. All sound measuring instruments respond to sound pressure.

Example: The sound pressure near a punch press is measured as being 0,0025 psi. What is the sound pressure 20 $\mu N/m^2$ in dB?

Since 1,0 psi = 6890 N/m^2, then 0,0025 psi = 17,225 N/m^2.

$$L_p = 20\log_{10}\left(\frac{17{,}22 N/m^2}{20\mu N/m^2}\right) = 118{,}7dB$$

So we would commonly say the noise of the punch press is 119 dB.

The second main quantity used to describe a sound is the size or *amplitude* of the pressure fluctuations. The weakest sound a healthy human ear can detect has an amplitude of 20 millionths of a Pascal (20 μPa) – some 5000000000 times less than normal atmospheric pressure. A pressure change of 20 μPa is so small that it causes the eardrum to deflect a distance less than the diameter of a single hydrogen molecule. Amazingly, the ear can tolerate sound pressures more than million times higher. Thus, if we measured sound in Pa, we would end up with some quite large, unmanageable numbers. To avoid this, another scale is used – the *decibel* or dB scale.

2. GENERTION OF SOUND IN GEAR UNITS

The differentiation between sound and noise can be defined simply: sound is a variation in pressure; noise is undesired sound. Noise also implies undesired frequencies which tend to mask useful information, causing possible misrepresentation of actual sound characteristics. Examples of noises extraneous to gear sound measurement are lubrication pump noise, air-drill noise, instrumentation, electrical noise, etc.

Sound measurement and analysis are required to determine what sound is typically generated and what sound is undesired noise. This analysis is accomplished by the use of a sound analyzer. A sound analyzer is an instrument which displays sound waves in the rms levels at various frequencies or frequency bands. Using an analyzer will help separate undesired frequencies from the sound spectrum and contribute to an accurate interpretation of sound data. The bandwidth of the analyzer governs the amount of useful data displayed for analysis. The narrower the bandwidth, the more discrete frequency information available, the easier it becomes to identify extraneous noise frequencies from the other generated sound in a gear driven system.

In all possible cases, the elimination of unwanted noise in the area under investigation should be carried out before proper gear sound analysis is initiated. This will make the engineer's job of analyzing the data much easier and will enable him to give better results.

The sounds generated during gear unit operation can be from one or more of the following major sources:

- gear dynamics;
- bearing dynamics;
- coupling noises;
- system resonance or critical speeds;
- accessories such as funs, lubrication systems, etc [3,8].

Sound generation in gears is related to design tolerances and operation. The mating accuracy of a gear set must be maintained, commensurate with the desired operation. Gear sound is often generated by the mesh action of the teeth. If the teeth have irregularities in their profile or spacing, noise may be generated at the frequency of the irregularities. One must understand that a 100% accurate theoretical tooth profile will still generate sound due to the dynamics of gear mesh. Improper lubrication may allow noise to be generated in the mesh. The sounds generated will often be at the mesh frequency (i.e., the frequency or rotation times the number of teeth on the rotor), harmonics of mesh frequency, or at sideband frequency (mesh frequency plus and minus pinion or gear rotational frequency).

Sound in ball and roller bearings can be generated by the irregularities in the bearing elements, friction, deflections under load, misalignments, loose cages and races, windage, roller skewing and/or skidding, etc. Misalignments and deflections under load are the major causes of antifriction bearing noise.

System resonances and critical speed generate sound in gear units. The structural resonant frequencies of the casing and the baseplate can be excited by internally generated frequencies (tooth mesh) to produce noise. Care must be taken to determine the natural frequencies if support structures to ensure that the rotational frequency and other generated frequencies are not coincident to, or a multiple of, natural frequencies. Likewise, lateral and torsionale natural frequencies in the rotating system may be excited to produce noise if they are too close to a generated frequency or its harmonics.

Often, other equipment is required for proper operation of a gear unit. Accessories such as cooling fans and lubrication systems (pumps, motors, relief valves, etc.) can be sources of noise which may appear to be generated by the gear units.

Measurements of sounds provide definite quantities which describe and rate sounds. These measurements can provide benefits such as improved building acoustics and loudspeakers, thus increasing our enjoyment of music, both in the concert hall and at home.

Sound measurements also permit precise, scientific analysis of annoying sounds. However, we must remember that due to the physiological and psychological differences between individuals, the degree of annoyance cannot be scientifically measured for a given person. But the measurements do give us an objective means of comparing annoying sounds under different conditions.

Sound measurements also give a clear indication of when a sound may cause damage to hearing and permit corrective measures to be taken. The degree of hearing damage can be determined by *audiometry* which measures a person's hearing sensitivity. Thus, sound measurements are a vital part of hearing conservation programmes.

Finally, measurement and analysis of sound is a powerful diagnostic tool in noise reduction programmes – from airports, to factories, highways, homes, industrial areas and recording studios. It is a tool which can help to improve the quality of our lives.

All of these sources as well as extraneous noise from the surrounding environment (background noise) add up the overall sound level in the area of the gear unit. The interrelationship between them helps to define the sound level. The overall level is determined by the addition of different generated levels by the following expression [1,2]:

$$L_p = 10\log_{10}\sum_{i=1}^{N}10^{(0,1\cdot a_i)} \qquad (2)$$

where: L_p – is sound pressure level, dB; a_i – is sound pressure level from a single source or octave; N – is number of single levels investigated.

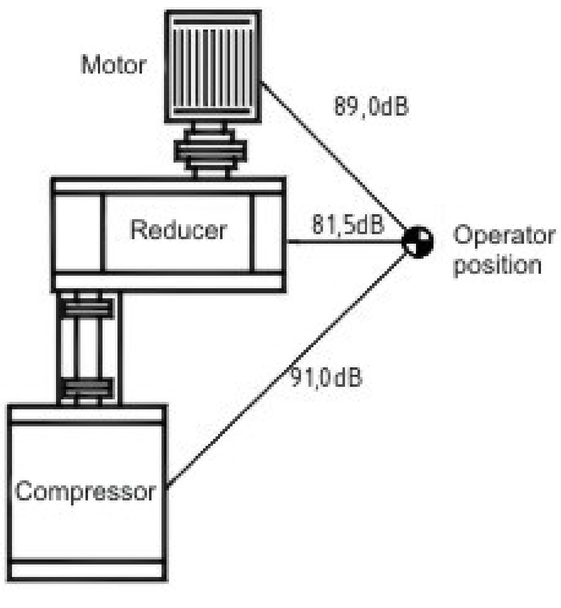


Figure 1. Calculation for expected sound level.

In an octave band analysis, N is the number of octaves.

Example 1: The installation in figure 1 shows a motor, reducer and a compressor in an industrial plant environment. The sound of each piece of equipment was measured by its manufacturer to have the listed sound levels at the operator location shown in figure 3. Totalling the levels by the formula (2) gives an expected level at the operator of 93,4 dBA.

$$L_p = 10\log_{10}\left[10^{8,9} + 10^{8,15} + 10^{9,1}\right] = 93,4\left[dB\ A\right].$$

Therefore, a means of adding or subtracting sound generated from different sources is also available. Any school student will tell you that (82+88=89) is an invalid equation. However, if we state that in the same environment 82 dB + 88 dB = 89 dB we would be correct.

3 EXPERIMENTAL MEASUREMENTS

3.1 Experimental stands

For experimental measurements we use experimental stand as shown in figure 2 with sound level meter Brüel & Kjær 2250 Light with following setup : **Diffuse-Field** for *Sound Field Correction*, **A** for *Frequency Weightings*, **Automatic** for *measurement Mode* and **10 minutes** for *Preset time*. The experimental stand is composed like is shown in figure 3 by: 1-electromotor; 2- precessional reducer; 3 – brake; 4 – rev-meter; 5 – sound level meter Brüel & Kjær Type 2250 Light.

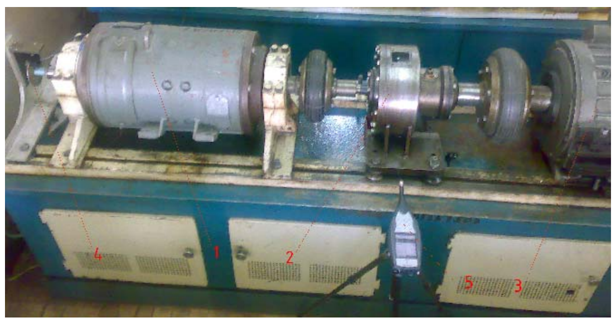


Figure 2. Experimental stand.

The 2250 Light has been developed specifically for measuring occupational, environmental and product noise, while complying fully with all the relevant national and international standards. Extensive user studies have been paired with state-of-the-art technology to make this analyzer a robust, effective and elegant tool for those applications.

3.2 Sound Level Meter 2250 light

Analyzer 2250 Light shown in figure 3 has been developed specifically for measuring occupational, environmental and product noise, while complying with all the relevant national and international standards.

Using the large, high contrast, touch screen interface, the analyzer can easily be set up to display and measure just what is needed from the extensive list of parameters provided by the analyzer.

Figure 3. Sound Level Meter Type 2250 Light.

2250 Light have installed Spund Level Meter Software, measuring all parameters simultaneously within its wide 120 dB dynamic range. For frequency analysis, the sonometer have installed 1/1 and 1/3 – octave software module.

Back in the office, USB connectivity lets us use the PC to archive, manage, view or even control 2250 Light, as well as export our results to software packages such as Microsoft® Excel and Bruel & Kjaer Types 7815, 7820 or 7825 for post-processing and reporting.

Uses and features of 2250 Light:

- environmental noise assessment, monitoring and complaints;
- occupational noise evaluation, selection of hearing protection;
- noise reduction, product quality control, general purpose Class 1 sound measurements;
- real-time analysis of sound 1/1 and 1/3 – octave bands;
- large, high-resolution touch-sensitive screen;
- plug-in rechargeable Li-ion battery;
- data storage on plug-in memory cards;
- 120 dB dynamic range – up to 140 dB;
- robust and environmentally protected (IP 44);
- upgrade to Type 2250 on exchange basis.

2250 Light combines renowned Bruel & Kjaer measurement excellence and the Type 2250 platforms ease of use, in an efficient and versatile sound measurement instrument. This analyzer was developed with special interest for the measurements of workplace noise. The comfortable and secure design feels in our hand. With the display located relatively close to us, the buttons fall precisely where they need to be for a one thumb operated Start, Stop and Save. The "*Trafic Light*" indicator surrounding the Start/Pause pushbutton gives us an immediate visual indication of measurement status – even in the brightest sunshine. The large, high contrast, touch screen/display, lets us select parameters on the display, and 2250 Light can memorise those setups for our next measurements [7,9].

As for occupational health noise parameters, nothing was left out. 2250 Light can measure Fast and Slow, A-weighted and C-weighted SPLs simultaneously, along with a separately weighted peak detector, so that the values we need to specify hearing protection are immediately on the display. Parallel analysis allows us to compare a 3 dB exchange rate average measurement with a selectable alternate 4,5 or 6 exchange rate, including separate dose, expected dose and exposure values.

2250 Light also offers three independent threshold peak event counters, along with simultaneous Fast, Slow and Impulse RMS detectors, to assess impulsive noise.

With the 1/1 octave frequency analysis software option, we are ready to instantly assess noise control and detailed hearing protection requirements for a surveyed location. With 2250 Light there is no filter switching, or range changing, all the octaves are measured at the same instant, along with the broadband A- and C-weighted values. For even more detail, add 1/3-octave frequency analyses option. Instantly see the maximum and average levels across 31 frequency bands spanning three decade from 12.5 Hz to 16 kHz [7].

2250 Light can be used as a hand-held device for easy portability, or it can be operated using our Windows® PC as an on-line USB controlled device in our laboratory. The user-defined templates make switching between applications easy [7].

But for more involved environmental applications, we will need to add the logging option. With this option we can set the instrument to record all, or up to ten selected measurement results at intervals from one second to one day, for a duration only limited by size of the CF or SD memory card used in the external memory slots. The display offers two simultaneous views, one of the complete profile and a "zoomed-in" 100-second "*window*", that are intuitively linked by the cursor.

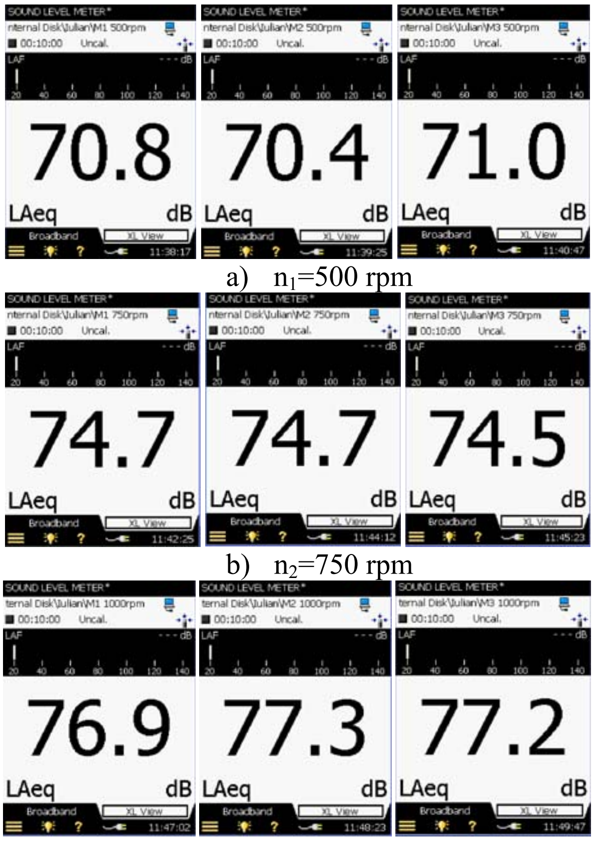
The wide 120 dB dynamic range of 2250 Light eliminates concern for overloads, and we can set a preset measurements time to add consistency to our measurements. Use the built-in headphone style (3.5 mm) output jack to send the signal out to other measurement instrumentation. The included utility program makes it easy to keep track of results in an organised, archive structure. And, of course, there is the Class 1 precision and reputation of Bruel & Kjaer, giving us and our customers complete confidence in our measurements, while adding value to our products.

For comprehensive data management and post-process reporting, consider using 2250 Light data together with Type 7815 Noise Explorer, which supports a wide range of user-definable graphic and tabular displays.

In all configurations, Type 2250 offers a variety of the same measurement. These views have no impact on the measurement, but they allow us what we want. [9].

3.3 Data calculating

The measured noise parameter is $\mathbf{L_{Aeq,T}}$, where the letter "**A**" denotes that the "A-weighting" has been included and **"eq"** indicates that an equivalent level has been calculated. Hence, L_{Aeq} is the A-weighting-equivalent continuous noise level, and **T=10 min** is preset time for measurement.



a) n_1=500 rpm

b) n_2=750 rpm

c) n_3=1000 rpm

Figure 4. *a)-three measurement for* ***n_1=500 min^{-1}*** *b)-three measurement for* ***n_2=750 min^{-1}*** *c)-three measurement for* ***n_3=1000 min^{-1}***

In our case we made 3 different measurements for 3 different cases, when precessional reducer is minimum filled with lubricating cooling fluid. First case for revolution speed **n_1=500 min^{-1}**, second case for revolution speed **n_2=750 min^{-1}** and third case for revolution speed **n_3=1000 min^{-1}.** For each case we obtained 3 different results like in figure 4.

3.4 Average noise level

If we have 3 different result and you need an average result you can use following formula:

$$L_{ptot} = 10\log_{10}\frac{1}{N}\sum 10^{0,1\cdot a_i} \qquad (3)$$

First case when n_1=500 min^{-1}

$$L_{ptot} = 10\log_{10}\frac{1}{3}\left(10^{7,08} + 10^{7,04} + 10^{7,10}\right) = 70,7\,[dB]$$

Second case when n_2=750 min^{-1}

$$L_{ptot} = 10\log_{10}\frac{1}{3}\left(10^{7,47} + 10^{7,47} + 10^{7,45}\right) = 74,6\,[dB]$$

Third case when n_3=1000 min^{-1}

$$L_{ptot} = 10\log_{10}\frac{1}{3}\left(10^{7,69} + 10^{7,73} + 10^{7,72}\right) = 77,1\,[dB]$$

4. CONCLUSIONS

Noise specification are written by governments, standards organizations, users, manufacturers and trade associations.

The most significant governmental noise specification has been the Occupational Safety and Health Act (OSHA) Regulations (US Standard – 29 CFR, Occupational noise exposure – 1926.52). OSHA placed limitations on the maximum sound level and exposure times to which an employee may be subjected at his working station without personal protective equipment. Protection against the effects of noise exposure shall be provided when the A-weighted sound pressure level exceeds those shown in table 1 [2].

See AGMA 914-B04, *Gear Sound Manual*: *Part II - Sources, Specifications and Levels of Gear Sound*, published by the American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314, http://www.agma.org.

When employers are subjected to sound levels exceeding those in table 1, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipments shall be provided and used to reduce sound level within the levels of the table.

Table 1. Occupational noise exposure.

Duration per day, hours	**Sound Level dBA slow response**
8	90
6	92
4	95
3	97
2	100
1,5	102
1	105
0,5	110
0,25 or less	115

NOTE:
When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effects should be considered, rather than the individual effect of each. Exposure to different levels for various periods of time shall be computed according to the following formula:

$$F(e)=\frac{T(1)}{L(1)}+\frac{T(2)}{L(2)}+...+\frac{T(n)}{L(n)}$$

$F(e)$ is equivalent noise exposure factor;
T is period of noise exposure at any essentially constant level;
L is duration of the permissible noise exposure at the constant level.

Example: A sample computation showing an application of the above formula is as follows. An employee is exposed at the levels for the following periods:
110 dBA for 0,25 hour
100 dBA for 0,5 hour
90 dBA for 2 hours

$$F(e)=\frac{0{,}25}{0{,}50}+\frac{0{,}5}{2}+\frac{2}{8}=0{,}5+0{,}25+0{,}25=1{,}000$$

Since the value of $F(e)$ does not exceed unity, the exposure is within permissible limits.

If the variations in noice level involve maxima at intervals of 1 second, or more, it is to be considerate continuous.

In all cases where the sound levels exceed the values shown, a continuing, effective hearing conservation program shall be administrated.

In conclusion we can mentioned the fact that the results of researches have shown that the noise levels, emitted by the non-loaded reducer K-H-V considerably less norms regulated by the branch standard OST 2.N89-5-79 for planetary reducers and cylindrical double-reduction gears with appropriate capacity and OSHA Regulation (US Standard 29 CFR) shown in table 1 [2].

Future research steps will be focused on analyzing and researching the acoustic behaviour of precessional reducer filled to maximum oil capacity and comparison with the minimum oil level.

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QUANTIFICATION OF FOOD PRODUCTION DIVERSIFICATION WITHIN AGRICULTURAL ENTERPRISES IN THE REPUBLIC OF MOLDOVA

S. Zaharco, PhD, B. Corețchi, PhD student
State Agrarian University of Moldova

INTRODUCTION

The diversification strategy was applied in the 60s in order to ensure the development of many enterprises. They started with the assumption that a good manager can run many businesses, even if they have nothing in common. In the 70s the diversification was viewed as the cash flow produced by each activity, aiming to ensure the financial stability of the company. The 80s were marked by the enterprise restructuring, giving up the activities that had nothing in common; they were focused on a more limited range of activities. The 90s were marked by a renewed interest in diversification, but this time to ensure the development of related activities [6].

Diversification implies the presence of two or more activities within an enterprise, each of them being a unique activity of some specialized enterprises. An enterprise is diversified when it gets engaged in the production of new products without renouncing its old production activities. The new products are differentiated enough thanks to the existence of some significant differences in production or distribution. Diversification involves participation in various markets. As businesses grow, they naturally tend to diversify.

The diversification strategy can be achieved in two ways: concentric and conglomerate diversification. The diversification that refers to the enterprise portfolio supplementation with products of the same type and similar managerial skills is called a concentric diversification. If the diversification completes the company's portfolio with unrelated activities to maximize the return on investment and profitability, then we deal with the conglomerate diversification [6].

1. WAYS TO QUANTIFY THE LEVEL OF FOOD PRODUCT DIVERSIFICATION

Food consumption is determined by the structure of the agro-industrial complex and vice versa. Modernization and improvement of production technologies, enlargement of the product, and increase of the new products share in the total production is one of the main directions for update, multiplication of the demand at both domestic and foreign markets.

Moldova's economic development is conditioned by the transformation of the current economic structure to another one that corresponds to the country's demand and potential possibilities. Modernization and diversification of food products implies [3, p. 14]:

1. enhanced participation of the Republic of Moldova in the world economy circuit;
2. increased share of original products that are fundamentally new in GNP;
3. aspiration of some branches development, propulsion of some ideas, technologies, a technique in productivity growth of food products (x_1);
4. employment and priority use of human and natural-material resources in sectors with the highest productivity (x_2);
5. harmonization of socio-economic development of all communes and districts of the country, improvement of working conditions (x_3);
6. increasing technical equipment work, each job (x_4) ;
7. stimulation and motivation of creative activities, those that design new products and technologies (x_5);
8. study of domestic and foreign markets regarding the demand of food products (x_6);
9. training specialists in the processes of current structure analysis of food production (x_7);
10. development of a standard structure (x_8);
11. creation of mechanisms to motivate in convergence processes of these two structures (x_9);

The complexity of the listed problems leads to the idea to systematically treat diversification processes of agricultural products.

So, modernization and diversification of food products can be considered as a function F which depends on variables x_1, x_2, ... x_9 . In its turn, each of the listed variables evaluates in time. Formally speaking $F\left(x_1(t), x_2(t), \dots, x_9(t)\right)$ is a diversification function of agricultural products. Elements, variables $(x_1(t), x_2(t), \dots, x_9(t))$ are constantly interacting. The change of some factors over time generates the modification of other factors and, therefore, of the structural diversification:

$$\Delta F(x_1(t), x_2(t), \dots x_9(t)) = \frac{\partial F}{\partial x_1} \times \frac{dx_1}{dt} \Delta t + \frac{\partial F}{\partial x_2} \times \frac{dx_2}{dt} \Delta t + \dots + \frac{\partial F}{\partial x_9} \times \frac{dx_9}{dt} \Delta t \quad (1)$$

The evolution of the current structure in relation to the standard may be either divergent or convergent. The problem is formally about creating the diversification function F^* and motivation systems in the processes to which asymptotically tends the current function $F(x_1(t), \dots, x_9(t))$. The economic development of the Republic of Moldova actually means the diversification of the economic structure, appearance and removal of some branches, products and technologies.

Structural changes of food products are determined by: the pace of economic growth, the development level of productive forces, economic policies of the state, the labour productivity, natural and geographical conditions, the creativity level of research institutions and scientific analysis, technical possibilities of the production, possibilities for improvement, adaptation of agricultural products manufacturing technologies, the efficient use of natural, human and capital resources, the division of labour, the increasing volume and efficiency of foreign economic exchanges, effects of natural economic circumstances, the division of labour at the national level, the level of labour qualification, the work organization. Each of the listed factors, in its turn, is subject to structural changes. The Republic of Moldova has the economy characterized by a small number of branches, preponderance of agriculture, weak ties between branches, thus, this is an underdeveloped country. Labour productivity in agriculture in the Republic of Moldova is lower than that of the European Union countries. The share of energy resources in the structure of productive expenditures is great; the share of labour is reduced. Consequently, agriculture producers usually cannot make any profit. There are also monopolistic policies of external business partners: a Moldavian farmer is disappointed with both selling and buying. Thus, the Republic of Moldova is forced to restructure its final products and foreign economic relations, to expand exports to Arab countries, to start stock exchange with Turkmenistan and other energy exporting countries [3, p. 15].

Hence it is necessary to practice some oligopolistic policies in relatively sophisticated industries such as the wine industry, the industry of fresh and dried fruit production for export, the sugar production industry, the tobacco industry, the production of organic products (ecologically pure) at the government level in order to ensure a national competitive advantage in the context of international economic relations [5, p. 267-268].

The system of agricultural production has a complex structure. It (complexity) makes people use some systematic methods in the process analysis. The diversification of agricultural products is identical to the substitution of a vector with another one; it starts with the identification of parties and structural units. There appears a problem in the process of agricultural products diversification: the measurement (quantification) of the diversification. There may be various methods of diversification analysis. Further we will use vector methods to analyze the structure of the final process. The diversification of agricultural products is equivalent to the increase of the coordinate number of the vector that consists of final products. Starting from the assumption that the final product in the agro-industrial complex is $Y = (Y_1, Y_2, \dots Y_9)$, then the module of this vector will be $(Y)\sqrt{\sum_{i=1}^{n} Y_i^2}$. To be more convincing about the contents of this economic indicator, let us analyze its variation domain. Suppose that the number of the vector Y coordinates is n. Accordingly, for example, if n = 2, the length (module) of the vector Y is $|Y| = \sqrt{Y_1^2 + Y_2^2}$.

The final product $Y = Y_1 + Y_2$. We solve the problem:

$$|Y| = \sqrt{Y_1^2 + Y_2^2} \rightarrow min \quad (2)$$

If $Y_1+Y_2=Y$, we develop the Lagrange function:

$$L = \sqrt{Y_1^2 + Y_2^2} + \Lambda(Y - Y_1 - Y_2) \quad (3)$$

$$\begin{cases} \frac{\partial L}{\partial Y_1} = \frac{1}{2\sqrt{Y_1^2+Y_2^2}} \times 2Y_1 - \Lambda = 0 \\ \frac{\partial L}{\partial Y_2} = \frac{1}{2\sqrt{Y_1^2+Y_2^2}} \times 2Y_2 - \Lambda = 0 \end{cases} \quad (4)$$

from which we learn that Y1 = Y2.

The module of the vector Y is minimal when $Y_1 = Y_2 = \frac{Y}{2}$, the final product diversification is maximum, the length of the vector Y is maximum when Y_1 or Y_2 is zero, when the whole mass of the final product is concentrated in a single coordinate Y2 = Y or Y1 = Y, the final product diversification is minimal. So one of the possible indicators that can be used to quantify the level of food products diversification is the module (length) of the final product vector $Y = Y_1 + Y_2 + \cdots + Y_n$. In reality the number of the vector Y components is very big (there can be hundreds of thousands of final products). Therefore, there is a need for aggregation and disaggregation of the structure of the final product vector. Operations of aggregation and disaggregation logically change the vector module. The statement can be illustrated if the final product is aggregated into a single group $(Y_1 + Y_2 + \cdots + Y_n)$, then the module of the vector Y will be $|Y| = \sqrt{(Y_1 + Y_2 + \cdots + Y_n)^2} = Y_1 + Y_2 + \cdots + Y_n$; if each component of the final product Y will be a coordinate of the vector Y of equal size $Y_i = Y_{i+1} = \frac{Y}{n}, i = 1,2, \ldots, (n-1)$, then the vector length will be:

$$|Y| = \sqrt{\left(\frac{Y}{n}\right)^2 + \left(\frac{Y}{n}\right)^2 + \cdots + \left(\frac{Y}{n}\right)^2} = \frac{Y}{\sqrt{n}} = \frac{Y_1+Y_2+\cdots+Y_n}{\sqrt{n}}$$

the final product structure is much more diversified, with no concentration, i.e. for each product the volume will be $\frac{Y}{\sqrt{n}} = \frac{Y_1+Y_2+\cdots+Y_n}{\sqrt{n}}$ (arithmetic average) [3, p. 16-17].

The diversification of food products will be limited when $\frac{Y}{n} = 1$, the module $|Y| = \sqrt{1^2 + 1^2 + \cdots + 1^2} = \sqrt{n}$. So, one of the possible criteria that would allow assessing the level of agricultural products diversification is the module of the food products vector.

2. QUANTIFICATION OF THE DIVERSIFICATION LEVEL OF FINAL PRODUCTS: DIVERSIFICATION INDECES

Success and failures of an agricultural enterprise are determined by the diversification level of potential productive activities. Strategic management is efficient only if it is based on the principle of potential activities diversification in a company.

The diversification of activities can be treated according to different criteria. Generally speaking, diversification is acceptable to evade some risks, grabbing of some new markets, insurance of financial stability, increase of the company's competitiveness at internal and external markets. The use of resources available to the firm in only one direction (specialty) can provide significant profits to the company, especially when the company's activities are diversified. But more likely, the company may go bankrupt [2, p. 224].

The process of activity diversification is accepted by practitioners not because it is better, more successful and profitable from the economic point of view, but because it is safer. The diversification can be either international or national. Further we will orient the estimates towards the diversification of agricultural products from the Republic of Moldova. Thus, it is necessary to make some remarks: What is diversification? How can diversification be measured? What is the diversification methodology? How can the effectiveness of diversification be studied and investigated? Different authors differently state the notions of the economic activities diversification. Some authors [4, p. 111], reduce the diversification of activities to the diversification of markets. In other words, the economic agent schedules his activities, based on the demand of markets rather than production capacity, markets should be more diversified. Other authors identify diversification as the number of industries in which the economic subject works [1, p. 268]. We consider that this point of view is questionable.

The branch is an aggregate of activities, diversification can exist within a single branch; it may be missing in a few branches. Diversification here means the diversification of final products demanded by the market; the diversification of ways used to produce final products; the increased number of final products and production technologies [2, p. 225].

Therefore, we state the final product volume i by $V_i, i = 1, 2, \ldots, m$. The total capacity is $\sum_{i=1}^{m} V_i$.

The total share of the product i is $P_i = \frac{V_i}{\sum_{i=1}^{m} V_i}$; the share of the volume of potential capacities after the product i has been produced is $(1 - P_i)$, $i = 1,2, \ldots, m$. The potential $(1 - P_i)$ is involved with the share P_i, the average share, therefore, is $P_i(1 - P_i)$; the entire potential of the company's activities diversification is:

$$\sum_{i=1}^{m} P_i\,(1 - P_i) \qquad (5)$$

We determine:

$max \sum_{i=1}^{m} P_i\,(1 - P_i)$ unde $\sum_{i=1}^{m} P_i = 1$.

We develop the Lagrange function

$$L = \sum_{i=1}^{m} P_i(1 - P_i) + \Lambda(1 - \sum_{i=i}^{m} P_i) \qquad (6)$$

Under the necessary conditions:

$\frac{\partial L}{\partial P_i} = 0, i = 1,2,\dots,m$; $\frac{\partial L}{\partial P_i} = 1 - 2P_i - \Lambda = 0$;

$P_i = \frac{\Lambda-1}{2}, i = 1,2,\dots,m$ (7)

Thus, the diversification is maximum when all the company's products have the same share in the total production capacity, $P_i = P_{i+1} = P = \frac{1}{m}$.

Diversification indices are:

$\sum_{i=1}^{m} P_i(1-P_i) = \sum_{i=i}^{m} \frac{1}{m}\left(1-\frac{1}{m}\right) = m \times \frac{1}{m} - m \times \frac{1}{m^2} = 1 - \frac{1}{m}$ (8)

The diversification evolution depending on the potential number of activities can be graphically interpreted in Figure 1.

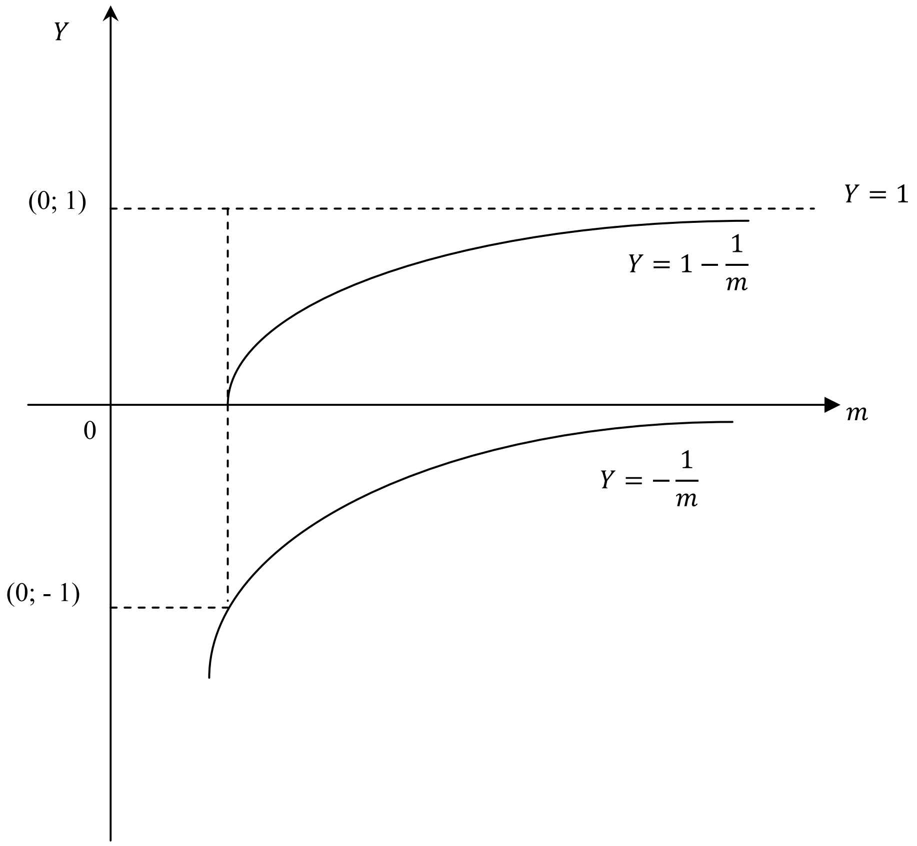

Figure 1. The diversification evolution.

The Source: *developed by the authors*

For example, we assume that the firm can potentially produce four products in the volume of

a) $V_1 = 1;\ V_2 = 2;\ V_3 = 3;\ V_4 = 4.$
b) $V_1 = 0;\ V_2 = 2;\ V_3 = 3;\ V_4 = 0.5.$
c) $V_1 = 0;\ V_2 = 0;\ V_3 = 3;\ V_4 = 7.$
d) $V_1 = V_2 = V_3 = V_4 = 2.5.$

Then diversification indices will be:

$Y_a = 0.1(1-0.1) + 0.2(1-0.2) + 0.3(1-0.3{+}0.41{-}0.4{=}1{-}0.3{=}0.7$

$Y_b = 0(1-0) + 0.2(1-0.2) + 0.3(1-0.3) + 0.5(1-0.5) = 1 - 0.38 = 0.62$

$Y_c = 0(1-0) + 0(1-0) + 0.3(1-0.3) + 0.4(1-0.7) = 1 - 0.58 = 0.42$

$Y_d = 0.25(1-0.25) \times 4 = 1 - \frac{1}{4} = 0.75.$

Starting from $m = min\{m_1 + m_2\}$ where: m_1 is a market demand; m_2 is the potential number of final products that can be created by an enterprise, it is easy to determine the maximum level of diversification $Y_{max} = 1 - \frac{1}{m}$. If a company, for certain reasons, excludes a product from its activities, then the diversification is reduced from $(1 - \frac{1}{m})$ to $\left(1 - \frac{1}{m-1}\right)$, i.e. by $1 - \frac{1}{m(m+1)} \times 100\%$; if we exclude *k* products, the diversification is reduced by $\frac{k}{m(m-k)} \times 100\%$. Depending on the current production structure of a company, various final products differently influence the diversification evolution (Table 1).

For the volume V_i with the share P_i in the total $\sum_{i=1}^{m} V_i$ the current diversification is $P_i(1 -$

P_i); the maximum diversification (for $P_i = \frac{1}{m}$) is $\frac{1}{m}\left(1 - \frac{1}{m}\right)$; the gap is $\frac{1}{m}\left(1 - \frac{1}{m}\right) - P_i(1 - P_i) = \left(\frac{1}{m} - P_i\right)\left(1 - \frac{1}{m} - P_i\right)$ [2, p. 26].

The diversification of economic activities can generate some positive and negative effects. In the short run, diversification is not apparently justified. The company's specialization in one activity helps to increase labour productivity. In the long run, the company may go bankrupt, being negatively influenced by the market. When activities are varied, then some final products generate losses, others - profits. The algebraic sum is positive. Diversification is not necessary to increase profits, diversification is necessary to enhance financial stability. The quantification of the diversification level of agricultural products was based on the statistical data from "*Nistru-Olanesti*" JSC, district Stefan Voda, the obtained results are shown in Table 2.

Table 1. The quantification of the product diversification level within an enterprise.

Nr.	**The volume of the product *i***	**The total share of the volume of the product *i***	**The share of the volume of potential capacities after the product *i* has been produced**	**The share of the volume of potential capacities after the product *i* has been produced with the share *P_i***	**The total of identical shares of products *i*, $P_i = \frac{1}{m}$**	**Potential shares of a company's products diversification**
1	V_1	$\frac{V_1}{\sum_{i=1}^{m} V_i} = P_1$	$1 - P_1$	$P_1(1 - P_1)$	$P_1(1 -$ *P1=1m1−1m*	$\frac{1}{m}\left(1 - \frac{1}{m}\right) - P_1(1 - P_1) = \left(\frac{1}{m} - P_1\right)\left(1 - \frac{1}{m} - P_1\right)$
2	V_2	$\frac{V_2}{\sum_{i=1}^{m} V_i} = P_2$	$1 - P_2$	$P_2(1 - P_2)$	$P_2(1 -$ *P2=1m1−1m*	$\frac{1}{m}\left(1 - \frac{1}{m}\right) - P_2(1 - P_2) = \left(\frac{1}{m} - P_2\right)\left(1 - \frac{1}{m} - P_2\right)$
⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	V_i	$\frac{V_i}{\sum_{i=1}^{m} V_i} = P_i$	$1 - P_i$	$P_i(1 - P_i)$	$P_i(1 -$ *Pi=1m1−1 m*	$\frac{1}{m}\left(1 - \frac{1}{m}\right) - P_i(1 - P_i) = \left(\frac{1}{m} - P_i\right)\left(1 - \frac{1}{m} - P_i\right)$
⋮	⋮	⋮	⋮	⋮	⋮	⋮
m	V_m	$\frac{V_m}{\sum_{i=1}^{m} V_i} = P_m$	$1 - P_m$	$P_m(1 - P_m)$	$P_m(1 -$ *Pm=1m1−1m*	$\frac{1}{m}\left(1 - \frac{1}{m}\right) - P_m(1 -$ *Pm=1m−Pm1−1m−Pm*
The total	$\sum_{i=1}^{m} V_i$	1	$\sum_{i=1}^{m}(1 -$ *Pi*	$\sum_{i=1}^{m} P_i(1 -$ *Pi*	$1 - \frac{m1}{m^2} = 1 - \frac{1}{m}$	$\sum_{i=1}^{m} P_i{}^2 \frac{1}{m}$

The Source: developed by the authors

Having analyzed the data, we can mention that the company "*Nistru-Olanesti*" JSC has a range of vegetation products that are diversified enough, taking into account the total number of collected products. Moreover, we should note that the potential share of the enterprise's business diversification, in the plant products profile of the analyzed company, only 6 out of 8 product categories register the potential diversification share as "*positive*".

It should be also mentioned that the analyzed company 's basic activity is directed towards achieving the lowest costs of production and distribution, so that the prices of products are lower than by its competitors and ensure getting a bigger market share. This strategy is based on the experience curve. The company "*Nistru-Olanesti*" applies such a strategy because it has a potentially technological, production, supply and logistics environment. To improve the situation in the company it is necessary to attract investments for modern production equipment, an aggressive sales policy, which ensures a larger share both at the national and international market.

In this context, "*Nistru-Olanesti*" will focus on getting the superior performance that will guarantee the leading position in the sector, in terms of one of the following attributes: the quality of the offered products, after- sale services and facilities proposed to customers, the used technology, product originality, delivery time compliance, ability to adapt to environmental changes and customer requirements, etc.

Table 2. The quantification of the agricultural product diversification level within the company "*Nistru–Olanesti*", the village of Olanesti, district Stefan Voda.

Nr	**The name of the product**	**The volume of the product i, q**	**The total share of the volume of the product i**	**The share of the volume of potential capacities after the product i has been produced**	**The share of the volume of potential capacities after the product i has been produced with the share P_i**	**The total of identical shares of products $i, P_i = \frac{1}{m}$**	**Potential shares of a company's products diversification**
1.	**Vegetation products**						
2.	Cereals and leguminous plants – the total	56536	0.732977234	0.267022766	0.195721609	FALSE	TRUE
3.	Wheat	32405	0.420123943	0.579876057	0.243619816	FALSE	FALSE
4.	Leguminous plants	1019	0.013211119	0.986788881	0.013036585	FALSE	TRUE
5.	Corn, from which:	23112	0.299642172	0.700357828	0.209856741	FALSE	TRUE
6.	Corn for seeds	10876	0.14100503	0.85899497	0.121122612	FALSE	TRUE
7.	Sunflower, from which:	6208	0.080485402	0.919514598	0.074007502	FALSE	TRUE
8.	Sunflower for seeds	82	0.001063113	0.998936887	0.001061982	FALSE	FALSE
9.	Colza	967	0.01253695	0.98746305	0.012379775	FALSE	FALSE
10.	Field vegetables	4969	0.06442203	0.93557797	0.060271832	FALSE	TRUE
11.	Total fruit and berries, including:	8452	0.109578385	0.890421615	0.097570963	FALSE	TRUE
12.	Seed-bearing fruits	2381	0.030869159	0.969130841	0.029916254	FALSE	FALSE
13.	Stone fruits	6071	0.078709226	0.921290774	0.072514084	FALSE	TRUE
14.	**Total vegetation products**	**77132**	1	0	0	TRUE	TRUE

The source: *the authors' calculations based on the data from a special form on the activity of the agricultural enterprise "Nistru-Olanesti" JSC, 2012*

The trend to diversify economic activities in various countries is different. Highly developed industrial countries (the USA, Germany, Japan) prefer the strategy of economic activities that are specialized in various ways. Their products do not have equivalents in most cases in the world, they are unique and cannot be interchanged, they are necessary and, therefore, cannot cause instability in the country. The complementary diversification of core activities is specific to all the countries.

The diversification of activities means additional forms of work organization; additional investment, technological knowledge in each activity; systematic study of the market, homologous technologies in the country and from abroad; potential success of the scientific and technological progress and innovators in the domain of corresponding economic activities; economic mechanisms of labour motivation; economic contribution of every final product in the financial system of the company or enterprise. [2, p. 227].

Diversification can generate financial stability and reduce economic efficiency; it correlates with the number of risks in the marketing of final products. Mono-product activities in the short run are superior to multi -product activities. In the long run mono businesses are at risk of bankruptcy, operating under the impact of the economic crises, scientific and technical progress, geostrategic policies, etc. Metaphorically speaking, the area of economic support in mono businesses is small, such enterprises usually decay [2, p. 227].

Mono-activities are usually carried out by highly developed industrial countries in the countries where labour is cheap. Technological changes may exclude certain segments from the production "chain", including mono-activities in the countries with cheap labour force. Agricultural activities, their final products, the level of agricultural raw materials processing, final product diversification generates a variety of problems.

3. CHARACTERISTICS OF THE DIVERSIFICATION LEVEL WITHIN AGRICULTURAL ENTERPRISES FROM THE REPUBLIC OF MOLDOVA

Reduced costs of energy resources can generate the following: the diversification of agricultural raw materials and final products; changes at the level of pay-offs, creating conditions for productive accumulations, development of agricultural processing technologies, changing workforce needs; demand for the skilled labour force, improving unproductive consumption in rural areas and, thus, increasing the demand for agricultural products, creating favourable conditions for the development of agriculture and production industries. The current structure of the Moldavian economy cannot be considered as a modern, industry-oriented, with a high economic potential, strong technological capabilities and intense participation in the world economic circuit, the current structure of the Republic of Moldova is an agricultural disjointed structure with an underutilized economic potential, with little participation in the international economic circuit. The economical, social and cultural life in rural areas of the Republic of Moldova increasingly degrades in the last 20 years.

The diversification of agricultural products turns into a demand-multiplier mechanism, reducing Moldova’s dependence on some countries that export energy and import agricultural products from the Republic of Moldova. The diversification of the Republic of Moldova is a process that develops in time, latently and can only be achieved by a sustained program that is coordinated and guided by the country's authorities. Unregulated market economy will certainly further contribute to the abandonment of the countryside, inefficiency of agriculture and export of agricultural raw materials, to the increased unemployment, reduced GDP, increased import and state debts. In other words, to the country's transformation into a poorer country.

In the last 20 years agriculture of the Republic of Moldova has been passing through organizational and institutional transformations, of relations to property, significant changes in the productive specialization and cooperation, of the change of production and trade partners. The instability of productive relationships, inflation processes, monopolists’ impact on farmers, higher prices for bank loans, low prices for agricultural products and agricultural raw materials, reduction of state subsidies, uncertainty and risks in the processes of final products sale, labour flow from rural areas, imperfect new forms of organization, " invasion" of the agricultural products import, etc. have created problems that require urgent, complex, scientifically and practically rationalized solutions. Moreover, records on productive expenditures in agriculture do not reflect the real cost of final products, prices of agricultural products do not cover all manufacturer’s expenses. Financial stability, covering of all production costs, making a profit, the farmer in the Republic of Moldova can only achieve through the diversification of activities, final products, by improving the record of expenditures. The diversification of activities is not primary for a farmer, it is the "power" of markets that matters; prices, their structure, dictates the diversification structure. The market power in its turn may set prices above or below the producer’s marginal price (cost) of food products. This can happen under the impact of foreign trade. Exports of agricultural products can generate increased domestic prices, imports can restore the price below the minimum level for the country’s producer. The market is of great interest to the farmer for two reasons:

1. at what price , how much, when and how one can market agricultural products;
2. what is the evolution of the price structure.

The first aspect contributes to the solution of the existing problem, the second one – to the solution of future problems.

The diversification of the final product structure is one of the country’s strategic issues for the Republic of Moldova with trading partners who have various economic policies. The Republic of Moldova can ensure its financial stability only by means of diversification, standing economic "attacks" from some external business partners and exploiting the productive potential of rural areas. The diversification involves achieving the economic stability principle, ensuring rural population with jobs, systematic development of conditions to restructure the current diversification, starting from the evolution of prices on both domestic and foreign markets, motivating labour forces in the domain of new technologies development, new final product; the study of the consumption structure at foreign markets, creating a structure to coordinate diversification processes in space and time in the country, using the potential of mathematical programming methods to select variants of economic activities and final products.

Diversification is performed taking into account the maximum profit, financial stability and creation of new jobs.

Therefore, it is necessary to create an information system by means of which a farmer can learn the following:

1. the analysis of the current structure of final products;
2. prospects for restructuring the current structure;
3. the evolution of the price for final products at both domestic and foreign markets;
4. possibilities of innovation implementation in order to improve production technologies, development of new final products;
5. possibilities to drive foreign investment in diversification processes of economic activities in rural areas.

CONCLUSIONS

The Republic of Moldova's economic progress is subject to a current economic structure change into another structure that corresponds to the demand, country's potential opportunities related to the development and adaptation of agriculture to international requirements. Thus, the diversification of production takes place when we produce new products, improve existing ones, create new production branches and sub-branches, determined by free market requirements in terms of the technological and scientific progress.

Diversification as a side of the production intensification is one of the ways to increase the profitability of agricultural products. The intensification promotion and diversification of agricultural products can be achieved by improving the level of farmers' training as well as by consistent measures on trade actions or public interventions to stimulate the expansion of these goals (stipulations of the sector strategy), which will pay more attention to the economic multi-functionality of rural areas and preservation and enhancement of their core business activity.

The economical, social and cultural life in rural areas of the Republic of Moldova increasingly degrades in the last 20 years. In this context the diversification of agricultural products as well as the diversification of economic partners that export oil, energy resources, etc. becomes a serious problem in the Republic of Moldova.

The strategy of the competitive economic development based on the diversification of agricultural products is the main vector for the Republic of Moldova to achieve sustainable economic development and to transform the Republic of Moldova from a poor country into a prosperous country.

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SOME ELASTOPLASTICALLY DEFORMATION AND FAILURE COMPOSITE IRON - NICKEL COATINGS

PhD, professor V. Javgureanu, PhD, associate professor P. Gordelenco
Technical University of Moldova, Chisinau

1. INTRODUCTION

1.1. Research and testing of physical and mechanical properties of materials

Electrolytic wear-resistant coatings are widely used for hardening and restoration parts in the industry in order to increase their longevity.

Electro deposition conditions have a significant impact on the physical and mechanical properties of wear-resistant galvanized coating. Knowledge of physical and mechanical characteristics of wear-resistant plating needed to make informed choices technological conditions of deposition, depending on the operating conditions of the recovered parts of machines, as well as for important structural calculations [1-3].

1.2. Overview

Actual problems of study of physical and mechanical properties of materials in the surface and the surface layers due to the fact that the deformations associated with contact with modern methods of treatment and hardened metal compounds.

Test kinetic hardness and micro hardness opens up new possibilities for the determination of physical and mechanical properties and fracture toughness of electrolytic plating coating [1-3].

In the robot are some features elastoplastic deformation and brittle fracture iron-nickel composite coatings obtained from electrolyte 4 [2, p.59]. The samples used rollers with diameter 30mm, thickness of the coating 0.5 mm and a length of 100mm, which were processed under optimal grinding.

The importance of identifying the characteristics of elastic-plastic (he, hp, h) required for robot deformation (Ae, Ap, A), not restored and dynamic hardness (Hh, Hd) modulus (E), the critical load indentation diamond spherical indenter with a start brittle fracture (Pcr), the ratio of non-reduced and dynamic hardness to elastic modulus (Hh/E, Hd/E), yield strength (σ_T), the true tensile strength (SB), tensile strength (σ_b), yield strength ($\sigma_{0,2}$) toughness (e_H), the degree of deformation of the material in the contact zone (ψ) is invaluable.

Physic mechanical characteristics were determined at the facility for the study of the hardness of materials in macro volume equipped with an inductive sensor and a differential amplifier allows you to record chart indentation diamond spherical indenter and indentation recovery after removal of the load [2].

Table 1. Physical and mechanical properties of Fe-Ni composite coatings.

Electrolysis conditions		**Work expended on the deformation of coatings**			***Hh, H/mm²* *h=2 μm***	***Hd, H/mm²***	***P, H***	***Pcr, H***	***E ×10⁻⁴, H/mm²***	***Hh/E***	***Hd/E***
Dk, ×10⁻⁴ кA/m²	***T, ⁰C***	***Ay, H× mm***	***An, H× mm***	***A, H× mm***							
5	40	0.0172	0.0132	0.0304	3630	2422	45.6	350	21.0	0.0173	0.0115
10	40	0.0177	0.0135	0.0312	3670	2449	46.1	335	20.5	0.0179	0.0119
20	40	0.0186	0.0132	0.0318	3800	2534	47.7	320	19.8	0.0192	0.0128
30	40	0.0202	0.0132	0.0334	3980	2686	50.0	300	19.5	0.0204	0.0136
40	40	0.0214	0.0132	0.0346	4120	2746	51.7	275	19.3	0.0213	0.0142
50	40	0.0235	0.0138	0.0373	4470	2980	56.1	260	18.8	0.0238	0.0159
60	40	0.0202	0.0121	0.0323	4020	2683	50.5	245	18.0	0.0223	0.0149
80	40	0.0188	0.009	0.0278	3320	2215	41.7	215	17.5	0.0190	0.0127

Table 2. Work expended on the deformation of coatings.

Electrolysis conditions		Work expended on the deformation of coatings			*Hh H/mm² h=2μm*	*Hd H/mm²*	*P, H*	*Pcr, H*	*E×10⁴ H/mm²*	*Hh/E*	*Hd/E*
Dk, ×10⁻⁴ кA/m²	*T, ⁰C*	*Ae, H mm*	*Ap H mm*	*A H mm*							
50	20	0,0211	0,0067	0,0278	3320	2215	41,7	205	17,1	0,0194	0,013
50	40	0,0235	0,0148	0,0383	4470	2980	56,1	260	18,8	0,0238	0,0159
50	60	0,0156	0,0138	0,0294	3630	2422	45,6	315	20,5	0,0177	0,0118

Dynamic Hardness (Hd) as the ratio of the total determined robots elastoplastic deformation expended in (A) to the volume of deformable material (**V**) under load, in all investigated iron -nickel composite coating.

2. DISCUSSION OF EXPERIMENTAL STUDIES

An important parameter in the study of physical and mechanical characteristics of wear-resistant plating is their fragility. This property plating is undesirable since the craze fragility affects such important characteristic as wear resistance [2].

With increasing current density (Dk) of 5 x 10^{-4} to $80x10^{-4}$ kA/m^2 electrolysis at a constant temperature (40°C), the critical load (Pcr) and the iron-nickel coatings modulus (E) is reduced accordingly from 350 to 215 (H) and from $21x10^{-4}$ to 17.5×10^{-4} (N/mm^2). Work expended in elastic (Ae), plastic (Ap), unrestored hardness (Hd), dynamic hardness (Ha), the indentation load on the diamond spherical indenter (P) ratio Hh/E and Hd/E have extreme values with the change of the current density (Dk) from $5x10^{-4}$ to $80x10^{-4}$ kA/m^2 to electrolysis at a constant temperature (40°C). Physical and mechanical properties of iron-nickel coatings (Table 1 and 2) determined for one indentation depth (h=2 μm) by a known method [2].

Studies have shown that with increasing current density of $5x10^{-4}$ to $50x10^{-4}$ kA/m^2 electrolyte at a constant temperature (40°C) the work expended in elastic deformation coverage increased from 17.2×10^{-3} to 23.5×10^{-3} (N•mm), the work expended in plastic deformation, coatings increased from 13.2×10^{3} to 13.8×10^{3} (N•mm), the total work spent on elastoplastic deformation of the coating increased from 30.4×10^{-3} to 37.3×10^{-3} (N•mm). With further increase of the current density of 50×10^{-4} to 80×10^{-4} kA/m^2, electrolysis at a constant temperature (40°C) work spent on elastic deformation of coatings decreased from 23.5×10^{-3} to 18.8×10^{-3} (N•mm) total work spent on plastic deformation decreased from 13.8×10^{-3} to 9.0×10^{-3} (N•mm), the total work spent on elastoplastic deformation of coatings decreased from 37.3×10^{-3} to 27.8×10^{-3} (N•mm). From the results of research can be seen that the work expended in elastic (Ae), plastic (Ap) and elastic-plastic (A) deformation of iron-nickel coatings at a constant temperature electrolysis are extreme.

Character changes unreduced hardness (Hh), dynamic hardness (Hd) and extrusion load the diamond spherical indenter at a depth of 2 mm with increasing current density from 5x to 80x (kA/m2), at a constant temperature electrolysis (-40°C) has an extreme character.

With increasing current density of 5x 10^{-4} to $50x10^{-4}$ (kA/m^2) unrestored coating hardness (Hh) increased from 3630 to 4470 (N/mm^2), dynamic coating hardness Hd, increased from 2422 to 2980 (N/mm^2) and the load on the diamond indentation spherical indenter (P) increased from 45.6 to 56,1 (H). With further increase in current density (D_K) from $50x10^{-4}$ to $80x10^{-4}$ (kA/m^2) at constant temperature electrolysis (40°C) hardness unrestored (Hh) decreased from 4470 to 3320 (N/mm^2) dynamic coating hardness decreased from 2980 to 2215 (H/mm^2) and the indentation load on the diamond spherical indenter decreased from 56.1 to 41.7 (H) (table 1).

With increasing temperature electrolysis (T, Table 2) at a constant current density ($D_K = 50x10^{-4}$ kA/m^2 from 20 to 60^{o}C), the critical load indentation on diamond spherical indenter characterizes the beginning of brittle fracture of iron-nickel coatings, and elastic modulus of the coating increases, respectively, from 205 to 315 (H) and from 17.1 x 10^4 to 20,5 x10^4 (H/mm^2).

After electrolysis conditions laid out in the deformation coatings Nature of the change work expended in elastic (Ae), plastic (Ap) and elastic-plastic deformation of iron-nickel coatings with temperature electrolysis from 20 to 60°C at a constant current density ($D_K = 50x10^{-4}$ kA/m^2) also has an extreme character. With increasing temperature, the cell from 20 to 40°C at a constant current density ($D_K = 50x10^{-4}$ kA/m^2), the work expended in elastic (Ae), plastic (Ap) and elastic-plastic deformed (A) increased respectively from $21.1x10^{-3}$ to 23.5×10^{-3} (N•mm) from 6.7 x10 3 to 14.8 $x10^3$ (N•mm), and from 27.8×10^{-3} to 38.3 $x10^{-3}$ (N•mm). With further increase of the temperature (T) of the cell from 40 to 60°C at a constant current density (D_K = $50x10^{-4}$ kA/m^2) work spent on elastic (Ae), plastic (Ap) and elastic plastic deformation (A) iron-nickel coatings decreased correspondingly from 23.5×10^{-3} to 15.6 $x10^{-3}$ (N•mm) of 14.8×10^{-3} to 13.8 $x10^{-3}$ (N•mm), and from 38.3×10^{-3} to 29.4 $x10^{-3}$ (N•mm).

Character of change of hardness unreduced (Hh), a dynamic hardness (Hd), and the load - spherical indentation diamond indenter at a depth of 2 microns from the electrolysis temperature increases from 20 to 60°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) have also extreme. With increasing temperature electrolysis (T) from 20°C to 40°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) unrestored hardness (Hh) has increased from 3320 to 4470 (N/mm^2), dynamic hardness (Hd) increased from 2215 to 2980 (N/mm^2), and the load - indentation diamond spherical indenter (P) increased from 41.7 to 56.1 (H). With further increase of the temperature of the cell from 40°C to 60°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) unreduced hardness (Hh) decreased from 4470 to 2422 (N/mm^2), dynamic hardness (Hd) decreased from 2980 to 2422 (N/mm^2), and the load - indentation diamond spherical indenter (P) decreased from 56.1 to 46.5 (H).

Much attention in the study of physical and mechanical properties of wear-resistant plating on defining their tendency to brittle fracture. The fragility of the coating is significantly affected by the conditions of their electro deposition [2].

C increase in current density (D_K) and the electrolysis temperature (T) coatings tendency to brittle fracture increases. Composition of the electrolyte, which is obtained from wear-resistant coatings, can have a different impact on the considered properties of the coatings [2].

It was proved that the method of measuring the hardness of the coatings at different loads (up to Pct) unrestored hardness (Hh) is constant.

With further increase in load (>Pcr) is the value rises sharply, indicating a deviation from the mechanical similarity.

On the regularities of a significant influence of electrolysis conditions coatings [2].

With increasing current density and decreasing temperature electrolysis violation original pattern passes with less pressure on the diamond spherical indenter [2-8].

In studying the characteristics of elastic and plastic deformation of iron-nickel coatings obtained after processing the indentation diagrams showed that responsible for the results is the change in the character of elastic deformation depending on the loading condition.

Regardless of the subject to the iron-nickel coatings with increasing load on the diamond - spherical indenter elastic deformation component coatings first increase dramatically (up to Pcr) and then rises slightly (after Pcr).

This proves that the main reason causing the violation of the law of the mechanical similarity due to the onset of brittle fracture of iron-nickel coatings [1]. Comparing the value of critical load indentation (Pcr) for spherical diamond indenter with their values determined by observation of the formation of ring cracks around the indentation, it can be argued that the beginning of the destruction of the coatings can be determined much more accurately by measuring the indentation depth (h) and diamond spherical indenter critical load (Pcr), as to the formation of an annular crack growth is possible source and the formation of new cracks are difficult to watch for. Critical stress (Hhcr) can be taken as a criterion for evaluating the tendency to brittle fracture coatings.

Studying the effect of current density (Dk) and the electrolysis temperature (T) on the tendency of iron nickel coatings to brittle fracture showed that with increasing current density of $5x10^{-4}$ to $80x10^{-4}$ (kA/m^2) at a constant temperature electrolysis (40°C) critical load indentation on diamond spherical indenter is reduced from 350 to 215 (H), indicating an increase in the propensity of iron-nickel coating to brittle fracture. With increasing temperature, the cell from 20 to 60°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2), the critical load indentation on diamond spherical indenter is increased from 205 to 315 (H), indicating a decline in the propensity to brittle iron-nickel coatings destruction.

One of the problems of engineering is predicting wear resistance of materials. In that sense, the hardness test method applies to micromechanical testing, allowing the most reasonable approach to these material characteristics. We obtained dimensional parameters Hh, Hd, P, P_{CR}, and the dimensionless Hh/E and Hd/E have a good correlation with the wear rate wear resistance of iron-nickel composite coatings. Ratio Hh/E and Hd/E into account the elastoplastic properties of iron-nickel coatings accurately describe the process of wear.

Thus parameters Hh, Hd, Hh/E and Hd/E can be used to further clarify the description of the wear rate on these parameters and is based on the concept of additive contributions of these structural indicators (1,3-8).

The results showed that the ratio Hh/E and Hd/E elastoplastic characteristics into account, iron-nickel coatings have extreme value, as previously discussed parameters (Ae, An is, A, Hh, Hd, P) with a change in the electrolysis conditions (Dk, T) for obtaining optimal properties of iron-nickel coatings in terms of their durability.

With increasing current density (Dk) of 5 x 10^{-4} to $50x10^{-4}$ (kA/m^2) at a constant temperature of electrolysis (40°C) the ratio Hh/E and Hd/E (Table 1), respectively, increases from 17.3×10^{-3} to 23.8×10^{-3} and 11.5×10^{-3} to $15.9x10^{-3}$. With a further increase in current density (Dk) from $50x10^{-4}$ to $80x10^{-4}$ (kA/m^2) at a constant temperature of electrolysis (40°C), the ratio Hh/E and Hd/E accordingly reduced from 23.8×10^{-3} to 3 and $19x10^{-3}$ from 15.9×10^{-3} to $12.7\ x10^{-3}$.

With increasing temperature electrolysis (T) from 20 to 40°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) ratio Hh/E and Hd/E increases conform to 19.4×10^{-3} to 23.8×10^{-3} and from $13x10^{-3}$ to $15.9x10^{-3}$. With further increase of the electrolysis temperature of 40 to 60°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) ratio Hh/E and Hd/E accordingly reduced from 23.8×10^{-3} to 17.7×10^{-3} and 15, $9x10^{-3}$ to 11.8×10^{-3}.

3. CONCLUSION

It was established experimentally that the unreduced hardness (Hh), dynamic hardness (Hd) work spent on elastic (Ae), plastic (Ap) elastic-plastic (A) deformation, the load on a spherical diamond indenter (P for h = 2 ***μm***) ratio Hh/E and Hd/E has experimental conditions change electrolysis (Dk, T) for the study of iron-nickel coatings.

Experimental value unreduced hardness (Hh) dynamic hardness (Hd), the work expended in elastic (Ae), plastic (Ap) elastic-plastic deformation (A) load on a spherical diamond indenter (P) ratio Hh/E and Hd/E coincides with those obtained robot us recommendations for iron-nickel coatings in terms of ensuring their optimum durability.

Experimentally established the beginning of brittle fracture of iron-nickel coatings (Pcr, Hhcr) with modified conditions of electrolysis (Dk, T), the critical load (Pcr) indentation on diamond spherical indenter and the critical stress (Hhcr), which can be taken as a criterion for assessing the propensity coatings for brittle fracture.

The method of measuring the hardness in macro volume allows most reasonably and accurately determine the physical and mechanical characteristics (Hh; Hd; Ae; Ap; A; P; Hhcr; Pcr; Hh/E, Hd/E) iron-nickel coatings.

Physical and mechanical characteristics (Hh; Hd; Ae; Ap; A; P; Hh/E, Hd/E) iron-nickel coatings have good correlation with the intensity of wear of these coatings.

Physical and mechanical characteristics (Hh; Hd; Ae; Ap; A; P; Hh/E, Hd/E) can be used to refine the description of the wear rate of iron-nickel coatings.

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OPTIMIZATION AS A MEANS OF DEVELOPING ENTERPRISE IN THE NEW ECONOMIC CONDITIONS

M.I.Vlas, PhD, Mammadov E. I., Munjiu C.E.
JSC "Moldovahydromash"

The economic crisis has created new economic conditions, in which each enterprise in the real economy has difficult tasks - to survive and develop.

In such circumstances, it would seem necessary to follow the option for reducing costs related to personnel, development programs and non-production costs in the system of multidirectional vectors.

The option is attractive at first sight and may allow overcoming the crisis in the short term, but the historical experience of past crises shows that reducing these costs will reduce production to the impossibility of further recovery in general.

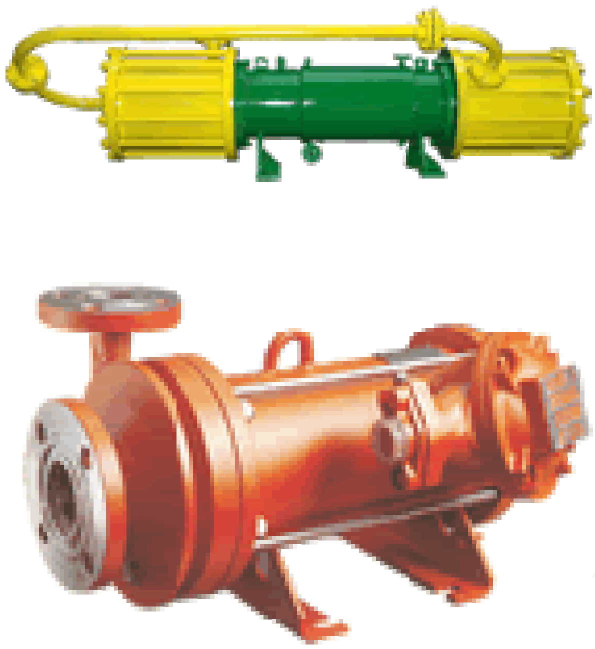

Figure 1.

Drawing. Objects of certification in JSC "*Moldovahydromash*".

On the other hand, aiming at development in challenging economic conditions, the enterprise needs to achieve no lower costs, but decrease in losses, increase in productivity and labor efficiency, creating the products requested by the modern market, cots thereof being minimal. Productiveness of any process depends on degree of their optimality and value of potential efficiency of personnel involved in, with which processes can be optimized and efficiency of personnel can be increased. Rational realization of the potential of personnel is hidden in such concepts as standardization and standard.

A standard implies a document, which, for the purpose of system and repeated application, establishes rules, guidelines, and features for objects of technical regulation (requirements to the algorithms of design processes, sample manufacturing, batch production, assembly, checkout, tests, storage, transport, use and disposal, execution of other works provided by other regulations).

According to this definition, standards are regulations, which prescribe certain right actions to obtain the final competitive outcome.

Creating an algorithm of the ideal process, description and execution hereof in the form of a document - standard is not a guarantee that this ideal process will work as a real process can have many losses unforeseen in an ideally modeled description.

Such an understanding of the standard leads to standardization in enterprises conducted formally, as the management considers it sufficient merely to describe and document activity of the enterprise. Many enterprises, as the present time dictates, perform certification under ISO 9001 now. They create databases describing the processes of the enterprise, but often it does not only increase efficiency, but prejudices the enterprise, as developed new standards are not enforced, and the current ones are ignored, because the distortion of toolkit, i.e. impact on the real processes, occurs. At the same time, the workload of personnel increases significantly, as they have to fill in various documents during the shift, instead of spending this time to solve problems and enhance their efficiency. Such an approach to standardization will not lead to the expected improvements of labor quality. Therefore, the documentation and description of the processes is not a standardization by itself, it is the minimum necessary condition, but not sufficient for its implementation.

The reasons for such inefficiency are due to the standardization is carried out without preparation, without establishing goal and objective specific to the personnel, and that relates to the limitation of the conventional definition of a standard.

Another nuance resulting in non-operability of the standard is the so-called voluntariness of the standard application, which is contrary to common sense [2], for any standard is similar to the law binding for all participants of the production process.

Thus, the traditional approach to standardization will not lead to the expected improvements of the activity, if one acts according to generally accepted definitions. And therefore, to determine the inward nature of the concepts of standard and standardization without restrictions affecting the activity of enterprises, key features of the standard are as follows:

- any standard of the organization is similar to the law binding for all participants in the production process;
- the best methods of achieving results tested by personnel itself should be standardized;
- the rules are the standard, when executed by all participants in the same operating process;
- the standard should be the measure of performance evaluation, quality indicator, which will allow hoping that the work is completed and paid accordingly;
- the standard performance should be systematic, regular, and stable;
- the standard should improve continually in conjunction with improving the quality of personnel labor.

Otherwise, the standard of the organization represents stable, sustained, reference and mandatory actions of employees, leading to the same result of quality labor.

This statement agrees with the words of Edward Deming: "*Words mean nothing if they cannot be transformed into actions everyone agrees with*" [2]. Consequently, the most important feature of the standard is transformation of rules into actions of quality labor.

Criterion for the standard existence is simple: "*If the rules are followed, there is a standard, if not followed, there is no standard!*"

Modern understanding of standard changes profoundly the approach to standardization, when creating standards, the correct actions of employees are to be achieved in the first place, then interpreted, described and affixed in standards of organization. Otherwise, standardization will be expressed in increased volume of waste paper of enterprise quite inapplicable in practice. Thus, standardization, the activity aimed at achieving the optimum degree of adjustment of requirements for products, services, and processes by establishing provisions for general, system, and voluntary use concerning factual and potential problems, will be regular for formation of sustainable and stable actions of employees leading to the desired production results. Moreover, the best modes of operation are to be described and employees are to be trained for their use, necessary skills are to be formed; the fulfillment of standards is to be motivated materially to this end.

The essence of standard and standardization is defined. However, for true success of standardization, it is necessary to overcome persistent stereotypes of actions of employees inconsistent with provisions adopted by the organization. It is important to train managers at all levels to manage subordinates to increase the reliability of employees after each administrative impact through its actualization.

The standard will not work, if the employees have no sustainable skills for its application. However, with the help of standardization toolkit, one can optimize processes systematically and technologically and maximize the value of the enterprise employees' potential, increasing ultimately the economic efficiency of the enterprise as a whole, and that allows it to develop even in conditions of economic crisis.

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THE APROXIMATE METOD OF REPRESENTATION OF REAL MATERIAL IN THE STRUCTURAL MODEL

Dr.fiz.mat. N. Sveatenco
Universitatea Tehnică a Moldovei

INTRODUCTION

The study [8] was devoted to solution of the problem of representation of a real material in the structural model of micro-heterogeneous medium [1-5]. The experiments were established on the basis of which the rheological functions of subelements can be identified unequivocally.

However, the need to test the thin-walled tubes subjecting to the action of the internal pressure P_i and the axial force F at different constant rates of the gripping device movement and different temperatures narrows the possibilities of use of the published experimental data, which mainly represent results of the thin-walled tubes tests by axial tension at constant rates of the gripping device movement $\dot{d}_{zz} = const$ or by torque at constant rates of change of the torsion angle $\dot{d}_{\varphi z} = const$ (z, r, φ is the cylindrical coordinate system).

We will demonstrate how to with sufficient degree of precision the problem of representation of a real material in the structural model can be solved on the basis of data obtained for the thin-walled tubes by putting to the uniaxial tensile test.

1. THE STATE PARAMETERES

The macroscopic element, being at the initial time in natural state, is subjected to mechanical and thermal action. Material behavior during deformation is supposed to depends significantly on the rate of loading and heating. To describe the micro-heterogeneous medium behavior the macro-scopically homogeneous volume element V_0 of the polycrystalline body is considered to be composed of an infinite number of kinematically connected subelements with different thermorheological features. Subelement as the elementary structure identifies the set of all material particles in the interior domain V_0 that have the same irreversible strain tensors.

Within the limits of the examined model let us assume that all types of interactions between subelements in the conglomerate are formed only under the influence of average connections, i.e. material particles in the conglomerate do not deform independently, but only in a coordinated manner. The interaction between two subelements is realized by means of the interactions between material particles which are appertained to the different subelements. This fact is reflected by replacement of the local state parameters in physical equation for subelement on the average values of the whole set.

The thermoviscoplastic properties of subele-ments within the limits of the structural model [2,5,8] may be determined on the basis of diagrams of the proportional loading $e = e(p, \gamma, \upsilon)$ at different constant values of the state parameters γ and υ.

The state parameter υ describes rheological effects of the subelement, and is expressed by the ratio of the volume variation and its limit possible value, being the same for all subelements

$$\upsilon = \frac{1}{\varepsilon_{0k}} \int_0^1 (\bar{\varepsilon}_0 - \beta \bar{e}_0) d\psi . \qquad (1)$$

or

$$\upsilon = \frac{\varepsilon_0 - \beta e_0}{\varepsilon_{0k}}, \quad \varepsilon_0 = \int_0^1 \bar{\varepsilon}_0 d\psi , \quad e_0 = \int_0^1 \bar{e}_0 d\psi . \qquad (2)$$

Differentiating with respect to time we find the loading conditions at $\upsilon = const$:

$$\dot{\varepsilon}_0 = \beta \dot{e}_0 = \beta \frac{\dot{\sigma}_0}{K} . \qquad (3)$$

Assuming that at the low level of irreversible deformations the elastic volume variation exceeds considerably the irreversible

$$\dot{\varepsilon}_0 \approx \dot{e}_0 + \alpha_T \dot{T} , \qquad (4)$$

we obtain that the rate of temperature's change is proportional to the rate of average stress's change

$$\dot{T} = -\frac{1-\beta}{\alpha_T K} \dot{\sigma}_0 . \qquad (5)$$

Thus, the deformation at $\upsilon = const$ corresponds to isothermal loading if $\beta = 1$.

Rate of irreversible deformation trajectory length's change is the state parameter that reflects the sensitivity of subelement to rate of external action's change:

$$\dot{\bar{\lambda}} = \sqrt{\dot{\bar{p}}_{ij}\dot{\bar{p}}_{ij}}. \qquad (6)$$

Average rate of irreversible deformation's change in subset of subelements, being under loading above the elastic limit, is another state parameter

$$\gamma = \frac{1}{\psi_\lambda}\int_0^1 \dot{\bar{\lambda}}(\psi')d\psi', \qquad 0 \le \psi_\lambda \le 1, \qquad (7)$$

where ψ is the distinctive parameter of subelement and coincides, during the initial loading, with the weight of irreversibly deformed subelements when given subelement exceeded the elastic limit; ψ_λ – summary weights of subelements for which the parameter $\dot{\bar{\lambda}}$ is nonzero.

In monotonous processes throughout the subset of irreversibly deformed subelements an active process of loading occurs, that corresponds to the monotony of the evolution of weight of irreversibly deformed subelements in this process. This means that towards ψ only one separation boundary forms between reversibly $\psi' < \psi \le 1$ and irreversibly $0 \le \psi \le \psi'$ deformed subelements.

Taking into account the law of the admissible trajectories [1,5,7] and the fact that in the monotonous processes the variations $d\bar{p}$ in all subelements have one and the same sign, we can write

$$d\lambda = \int_0^{\psi'} d\bar{\lambda}\, d\psi, \qquad d\bar{p}\big|_{\psi>\psi'} = 0, \qquad \gamma = \frac{\dot{\lambda}}{\psi'}. \qquad (8)$$

In the monotonous process of deformation along a rectilinear trajectory

$$\gamma = \frac{1}{\psi'}\int_0^{\psi'} \dot{\bar{p}}\, d\psi = \frac{\dot{p}}{\psi'}, \qquad \dot{\bar{p}}\big|_{\psi>\psi'} = 0. \qquad (9)$$

2. UNIAXIAL TENSILE TESTS AT DIFFERENT RATES OF THE GRIPPING DEVICE MOVEMENT

In the study [8] to calculate the parameter γ on the basis of tests of the thin-walled tubes being under the influence of the internal pressure P_i and the axial force F the following formula was obtained

$$\gamma = \left[\frac{(1-m+a)(2-\zeta)}{6G(a_0+m)} - \frac{\beta(m-a)(1+\zeta)}{3K(a_0+m)}\right]\frac{\dot{t}_{zz}}{a_{zz}} + \frac{m-a}{a_0+m}\frac{\dot{d}_{zz}}{a_{zz}}. \qquad (10)$$

The orientation of the loading trajectory in the space of axial t_{zz} and circumferential $t_{\varphi\varphi}$ stresses we will define by the parameter ζ

$$\zeta = \frac{t_{\varphi\varphi}}{t_{zz}}, \qquad a_{zz} = \frac{2-\zeta}{\sqrt{6\left(1-\zeta+\zeta^2\right)}}, \qquad (11)$$

$$t_{zz} = \frac{F}{2\pi Rh} + \frac{P_i R}{2h}, \qquad t_{\varphi\varphi} = \frac{P_i R}{h}, \qquad (12)$$

where h is the tube wall's thickness and R is the average radius of the tube.

In the study [8] it was demonstrated that in the case of the axial tension is impossible to carry out experiment under a constant state parameter γ. Therefore, the solution of the problem of the representation of the real material in the structural model on the basis of experiments conducted by stretching can be achieved only in an approximate way.

In the case of axial tension the circumferential stresses are equal to zero

$$t_{zz} = \frac{F}{2\pi Rh}, \qquad t_{\varphi\varphi} = 0, \qquad (13)$$

$$\zeta = 0, \qquad a_{zz} = \sqrt{2/3}, \qquad (14)$$

for isothermal loading $\beta = 1$, then from (10) we obtain

$$\gamma = \sqrt{\frac{3}{2}}\left[\frac{K-(m-a)(K+G)}{3GK(a+m)}\dot{t}_{zz} + \frac{m-a}{a+m}\dot{d}_{zz}\right]. \qquad (15)$$

Taking into consideration that at $\varepsilon = \varepsilon_{el}$ rate of the axial normal stress change is directly proportional to rate of the axial strain change

$$\dot{t}_{zz} = K(1-2\nu)\dot{d}_{zz}, \qquad (16)$$

we can write the expression for determining the parameter γ in this way

$$\gamma_1 = \sqrt{\frac{2}{3}}\frac{1+\nu}{a_0+m}\dot{d}_{zz}, \qquad (17)$$

where in accordance with the results obtained at [5,6,7] m is the interior parameter of the scheme of kinematic interaction between subelements and depends on the linear hardening coefficient a_0:

$$m = -a_0 + \sqrt{a_0 + a_0^2} . \quad (18)$$

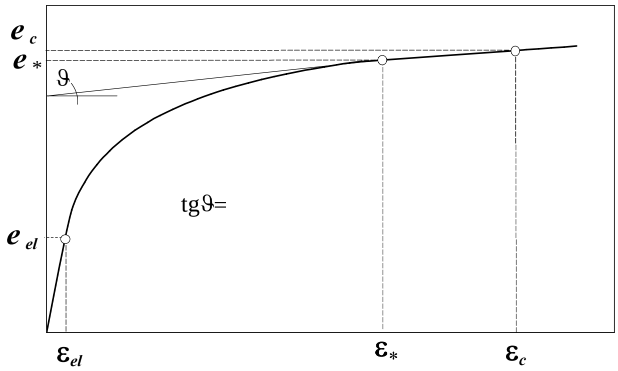

Figure 1. Diagram of the proportional loading of the thin-walled tubes by axial force at constant temperature $T = const$ and constant rate of longitudinal strain change $\dot{d}_{zz} = const$

Let us rebuild the diagram $t_{zz} \sim d_{zz}$ in the space of modules of strain deviators $e \sim \varepsilon$ (figure 1)

$$\sigma = \sqrt{\frac{2}{3}} t_{zz} , \quad e = \sqrt{\frac{2}{3}} \frac{t_{zz}}{2G}, \quad \varepsilon = \sqrt{\frac{3}{2}} \left(d_{zz} - \varepsilon_0 \right). \quad (19)$$

Assuming that the volume varies elastically, we find

$$\varepsilon = \sqrt{\frac{3}{2}} \left(d_{zz} - \frac{t_{zz}}{3K} \right). \quad (20)$$

A number of authors [9] found that in the strain diagram $e \sim \varepsilon$ is observed a linear hardening sector, the slope of which does not depend on the temperature and rate of loading.

Linear hardening coefficient $æ$ according to the diagram $e \sim \varepsilon$:

$$æ = \frac{\Delta e}{\Delta \varepsilon} = \frac{\Delta \sigma}{2G \Delta \varepsilon} , \quad (21)$$

or taking into account the relations (19) and (20)

$$æ = \frac{2(1+\nu)æ_{zz}}{3-(1-2\nu)æ_{zz}} , \quad æ_{zz} = \frac{\Delta t_{zz}}{E \Delta d_{zz}} . \quad (22)$$

Knowing the hardening coefficient $æ$ in the diagram $e \sim \varepsilon$, we determine the hardening coefficient in the diagram $e \sim p$ $(p = \varepsilon - e)$ within sector $p_* \le p \le p_c$ (where p_* corresponds to the time when all the subelements exceeded the elastic limit $\psi' = 1$, p_c is a measure, starting from which the linear isotropic hardening is broken)

$$a + a_0 = \frac{\Delta e}{\Delta p} = \frac{\Delta e / \Delta \varepsilon}{1 - \Delta e / \Delta \varepsilon} = \frac{æ}{1 - æ} , \quad (23)$$

Within the sector $p_* \le p \le p_c$ of the linear hardening of body's element expression (9) acquires the forme

$$\gamma = \dot{p} , \quad (24)$$

or using the relation (21) we obtain

$$\gamma = \dot{\varepsilon} - \dot{e} = (1 - æ) \dot{\varepsilon} . \quad (25)$$

Differentiating (19)-(20) with respect to time and inserting them into (25) we can express the parameter γ as the function of rate of the gripping device movement $\dot{d}_{zz}$

$$\gamma = \sqrt{\frac{3}{2}} \left(1 - \frac{\Delta t_{zz}}{E \Delta d_{zz}} \right) \dot{d}_{zz} , \quad (26)$$

or introducing (22) the state parameter can be represented in this way

$$\gamma_2 = \sqrt{\frac{3}{2}} (1 - æ_{zz}) \dot{d}_{zz} . \quad (27)$$

From (27) follows that within the sector of linear hardening the experiment under condition $\dot{d}_{zz} = const$ corresponds to loading at $\gamma = const$. This conclusion with a high degree of precision remains valid beyond the sector of linear hardening.

Indeed, for any $\varepsilon > \varepsilon_c$ in (25) can be accepted that $\dot{e} = æ(\varepsilon) \dot{\varepsilon}$, where $æ$ is expressed as a function of ε. Then

$$\gamma = \left[1 - æ(\varepsilon) \right] \dot{\varepsilon} . \quad (28)$$

Further outside of linear hardening section the processes of softening in a material evolve [2], so $æ(\varepsilon)$ is a decreasing function. For most materials within the linear hardening section $æ \approx 10^{-2}$. Therefore, the quantity $æ(\varepsilon)$ compared with unity can be neglected and in this case we may take $\gamma = \dot{\varepsilon}$. Substituting (20) and (22) into (28)

$$\gamma = \sqrt{\frac{2}{3}} (1 + \nu) æ_{zz} \dot{d}_{zz} . \quad (29)$$

Consequently, within and outside the linear hardening section the state parameter γ with precision of the second order is constant.

Within the sector $\varepsilon_{el} < \varepsilon < \varepsilon_*$ of the diagram $e \sim \varepsilon$ the parameter γ in tensile tests at a constant rate of the gripping device movement $\dot{d}_{zz} = const$ undergoes considerable changes. Let us examine how the parameter γ varies from point $\varepsilon = \varepsilon_{el}$, corresponding to the value γ_1 (17) at point $\varepsilon = \varepsilon_*$, corresponding to the value γ_2 (27).

For this purpose the state parameter γ will be expressed by the Poisson's ratio and linear hardening coefficient a, using the relations (18), (22) and (23). In this paper we restrict to examine the case when the coefficients of linear isotropic and kinematic hardening are equal $a = a_0$

$$\gamma_1 = \sqrt{\frac{2}{3}} \frac{1+\nu}{\sqrt{a+a^2}} \dot{d}_{zz}, \qquad (30)$$

$$\gamma_2 = \sqrt{\frac{3}{2}} \frac{1+\nu}{1+\nu+3a} \dot{d}_{zz}. \qquad (31)$$

Thus, in tensile tests at a constant rate of the gripping device movement $\dot{d}_{zz} = const$ within the sector $\varepsilon_{el} < \varepsilon < \varepsilon_*$ of the diagram $e \sim \varepsilon$ the parameter γ has decreased γ_1/γ_2 times (figure 2)

$$\frac{\gamma_1}{\gamma_2} = \frac{2}{3} \frac{1+\nu+3a}{\sqrt{a+a^2}}. \qquad (32)$$

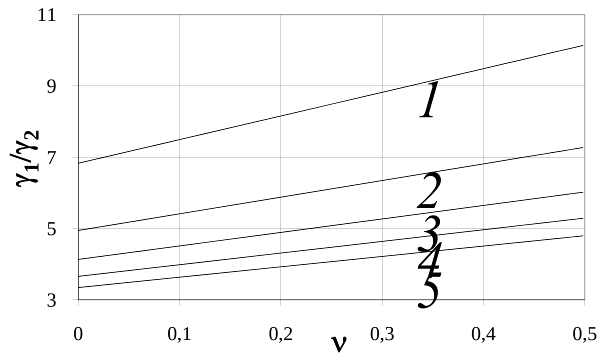

Figure 2. Parameter variation γ within the section $\varepsilon_{el} < \varepsilon < \varepsilon_*$ for the real values of the parameter *a*: ***1*** *– a=0,01;* ***2*** *– a=0,02;* ***3*** *– a=0,03;* ***4*** *– a=0,04;* ***5*** *– a=0,05*

According to the figure 2 the state parameter γ within the range $\varepsilon_{el} < \varepsilon < \varepsilon_*$ is decreased 4-9 times for values of the Poisson's ratio $\nu = 0{,}2 - 0{,}3$. Therefore, the variation cannot be neglected.

Let us study the process of determining of the function $e = e(p, \gamma, \upsilon)$ on the basis of simple tensile tests under different temperatures and different rates of the gripping device movement.

The characteristic values $e_{el} = \varepsilon_{el}$, e_*, ε_* are determined for the each curve $e = e(\varepsilon)$ obtained under conditions $\dot{d}_{zz} = const$ and $T = const$. As a consequence we have the following functions

$$e_{el} = e_{el}(\dot{d}_{zz}, T), \quad e_* = e_*(\dot{d}_{zz}, T), \quad \varepsilon_* = \varepsilon_*(\dot{d}_{zz}, T). \qquad (33)$$

To pass from the rate of the gripping device movement $\dot{d}_{zz}$ to another argument – the state parameter γ, we must solve at constant temperature the equation $\gamma_1 = \gamma_2$, which according to (30) and (31) can be written as

$$\frac{\dot{d}_{11}^{(1)}}{\dot{d}_{11}^{(2)}} = \frac{3}{2} \frac{1+\nu_2}{1+\nu_1} \frac{\sqrt{a+a^2}}{1+\nu_2+3a}, \qquad (34)$$

where ν depends on the loading conditions

$$\nu_1 = \nu\left(\dot{d}_{zz}^{(2)}\right), \quad \nu_1 = \nu\left(\dot{d}_{zz}^{(2)}\right). \qquad (35)$$

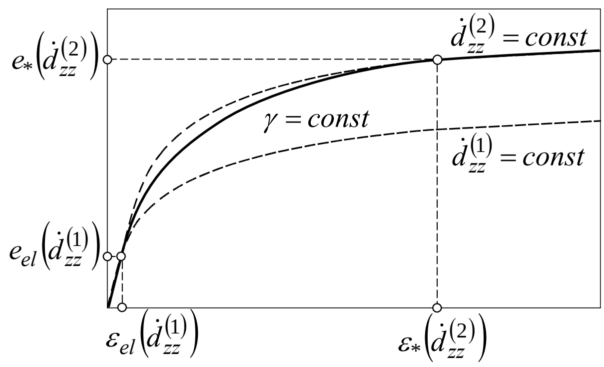

Figure 3. Determining of the characteristic values e_{el}, e_*, ε_* at constant magnitude of the state parameter γ.

The results of solving this equation give us the possibility to find out $e_{el}\left(\dot{d}_{zz}^{(1)}\right)$, $e_*\left(\dot{d}_{zz}^{(2)}\right)$, $\varepsilon_*\left(\dot{d}_{zz}^{(2)}\right)$ for the same value of the parameter γ ($\gamma_1 = \gamma_2$) and $T = const$ (Figure 3).

Taking into account that isothermal loading corresponds to deformation with $\upsilon = const$, functions (33) are written as

$$e_{el} = e_{el}(\gamma, \upsilon), \quad e_* = e_*(\gamma, \upsilon), \quad \varepsilon_* = \varepsilon_*(\gamma, \upsilon). \qquad (36)$$

We will approximate the nonlinear section of curve $e \sim p$ within the limits $0 \le p \le p_*$ (other way $\varepsilon_{el} - e_{el} \le p \le \varepsilon_* - e_*$) using the following function

$$e(p,\gamma,\upsilon) = e_{el}(\gamma,\upsilon) + D(\gamma,\upsilon)p^{n(\gamma,\upsilon)}, \quad (37)$$

where e_{el}, D, n at fixed values of the state parameters γ and υ are constant size.

The coefficients of the approximation can be established by studying the conditions at the beginning of the linear hardening sector

$$e\Big|_{p=p_*} = e_{el}(\gamma,\upsilon) + D(\gamma,\upsilon)p_*^{n(\gamma,\upsilon)} = e_*(\gamma,\upsilon), \quad (38)$$

$$\frac{\partial e}{\partial p}\Big|_{p=p_*} = D(\gamma,\upsilon)n(\gamma,\upsilon)p_*^{n(\gamma,\upsilon)-1} = \frac{æ}{1-æ}. \quad (39)$$

Solving the system (38)-(39) we express the coefficients of approximation $n(\gamma,\upsilon)$ and $D(\gamma,\upsilon)$ in the characteristic values of diagram obtained on the basis of simple tensile tests

$$n(\gamma,\upsilon) = \frac{æ}{1-æ}\frac{\varepsilon_*(\gamma,\upsilon) - e_*(\gamma,\upsilon)}{e_*(\gamma,\upsilon) - e_{el}(\gamma,\upsilon)}, \quad (40)$$

$$D(\gamma,\upsilon) = \frac{e_*(\gamma,\upsilon) - e_{el}(\gamma,\upsilon)}{\left[\varepsilon_*(\gamma,\upsilon) - e_*(\gamma,\upsilon)\right]^{n(\gamma,\upsilon)}}. \quad (41)$$

The accuracy of setting of the characteristic curves $e = e(p,\gamma,\upsilon)$ will depend on the structure of the approximating function (37) and the accuracy of choice the characteristic points of the strain diagram e_{el}, e_*, ε_*.

CONCLUSIONS

In the study [8] it was demonstrated that in the case of the uniaxial tension is impossible to carry out experiment under a constant state parameter γ.

Therefore, elaboration of approximate method for determining the thermorheological properties of subelements on the basis of uniaxial tensile diagrams made for thin-walled tubes under different constant rates of the gripping device movement and temperature levels significantly expands the usability of published experimental data.

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THE PSYCHOLOGY OF CREATIVITY

"I live on the fringe of society, and the rules of normal society have no currency for those on the fringe"
Tamara de Lempicka

In the twentieth century it was the Gestalt psychologists who developed the classic and highly influential four-stage theory of human creativity according to which human creativity involves the successive stages of preparation, incubation, illumination, and verification. Preparation is immersion in study and problem solving activities, addressing some fundamental and recalcitrant puzzle for which there is no apparent solution; incubation is leaving the problem alone at a conscious level (as some would argue, letting the unconscious do its work); illumination is the sudden flash of insight where the solution emerges all at once – the parts of the puzzle, the important bits of relevant information come together, in fact, re-configure into a novel "*Gestalt*" or whole; and finally, verification where the presumed solution is critically examined and tested in order to see if it really works (Koffka, 1935; Kohler, 1947).

It is important to note that within this model, creativity involves an initial intense study of the domain, requiring great expenditure of time and energy (and often struggle and frustration) and the trying out of different unsuccessful ways of thinking about the problem—creativity isn't easy and it doesn't come to the naive or unschooled in a domain. Second, the creative insight is a holistic emergence: When it comes it isn't piecemeal; there is rather a dramatic re-organization of consciousness. (This point parallels the ideas of punctuated equilibria and self-organization within the natural science of evolution.) Next, even if the creative flash is intuitive (a holistic realization) the preliminary study and the final stage of verification both involve linear and logical thought processes. The problem must be thought out and the solution must be thought through, using the analytical and rational modes of thinking. Finally, creative acts are often connected with problems, puzzles, challenges, and conundrums. One could say that they are adaptive efforts to deal with the difficulties of life. Creation is a stress-induced problem-solving activity.

Representing opposite poles of psychological theory, Carl Rogers, the humanistic psychotherapist and B.F. Skinner, the behaviorist and experimentalist, once debated in print the pros and cons of their seemingly contradictory positions concerning how best to understand human psychology (Rogers and Skinner, 1956). Of special note was the question of what would be the ideal environment to support the fully functional, psychologically healthy, and productive human being and, further, what would be the best environment for stimulating human creativity. Though they differed in their responses – Skinner arguing for a highly structured and consistent environment and Rogers emphasizing the importance of positive affect and unconditional positive regard being given to people – it is fascinating that ultimately both of them agreed that it is love and affection (or for Skinner positive social reinforcement) that engenders creativity within people.

Hence motivation and even emotional affect seem to play a significant role in human creativity, above and beyond simply cognitive processes and capacities. Further, creativity is not something that simply goes on "*in the head*" – at the very least, it appears to be nourished and provoked by certain environmental conditions.

In the late 1950s, Skinner's operant conditioning explanation of human behavior became the object of a highly critical assault that bears on the creativity issue. The linguist, Noam Chomsky, argued that human language is a highly creative act structured by abstract syntactical generative rules; it is not something that can be explained as a set of learned habits (Chomsky, 1959, 1966). Almost all human linguistic utterances are creative in the sense that they are not replications of expressions heard before; rather they are invariably novel. Knowing a language is to know a set of generative rules that allows one to create a potentially infinite number of grammatically correct unique sentences. From Chomsky's perspective, at least regarding language, all humans are creative; it is not something reserved for a select few.

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Column written by professor Valeriu Dulgheru, Ph.D. Dr. Sc. from Technical University of Moldova

In Memoriam

Eugeniu GREBENIKOV: 20.01.1932 – 29.12.2013

December 29, 2013, marked the departure of one of us of Professor Eugeniu Grebenikov, a noted expert in applied mathematics, celestial mechanics, the theory of nonlinear oscillations, and mathematical simulation. It is amazing how a single person has managed to obtain fundamental results in all these areas and to contribute to many others associated with science management and training activities at various higher educational institutions. Despite his age, Grebenikov leads an active life. He frequently takes part in national and international scientific conferences and seminars, where he gives talks.

His contributions are devoted to pure mathematical issues in the stability theory of solutions to differential equations and to applications in celestial mechanics, computer simulation, computer programming, etc. Due to Grebenikov's achievements in these areas, he is a renowned expert in each of them. For example, specialists in celestial mechanics, where he began his scientific career, have named asteroid No. 4268 after Grebenikov (with 11 other Romanian personalities: *Mihai Eminescu (asteroid No. 9.495; George Enescu (asteroid No. 9. 493; Constantin Brîncuşi (asteroid No.6.429; Elena Văcărescu (formation from Venus planet; Nicolae Donici (asteroid No. 9.494;Victor Daimaca (comet Van Gent-Peltie-Daimaca; Herman Oberth (asteroid No. 9.253; Nicolae Sănduleac (asteroid No. 9.403; Jan Drăgescu (asteroid No. 12.498; Spiru Haret (crater from invisible face of the Moon; Constantin Dârvulescu (asteroid No. 2.331).* In recent years, he has made important contributions to the restricted many-body theory. They were obtained via computer simulation and computer algebra languages and could not be derived by analytical methods.

Grebenikov was born on January 20, 1932, in the village of Sloboziya Mare (Romania, now the Republic of Moldova) into the family of an orthodox priest and an elementary school teacher. In 1949, he graduated with honors from the Romanian Lyceum at Kahul (Moldova) and entered the Department of Astronomy at the Faculty of Mechanics and Mathematics of Moscow State University (MSU). In 1954, he graduated with honors from the university. While a student, Grebenikov did research in celestial mechanics under notable MSU Professors N.D. Moiseev and G.N. Duboshin. After graduation, he continued his studies as a graduate student at MSU under the supervision of Moiseev, who had great influence on Grebenikov's early scientific career. In 1957, Grebenikov completed his graduate studies and defended at MSU his candidate's dissertation in astronomy entitled "*Analytical Theory of the Motion of Saturn's Eighth Moon Iapetus".* In 1967, Grebenikov defended his doctoral dissertation "*Qualitative Studies of Differential Equations in Celestial Mechanics*", in which he was the first to substantiate the well-known Krylov–Bogolyubov method as applied to resonance multifrequency systems of differential equations with slow and fast phase variables. For such systems, he developed a general analytical perturbation theory (up to an arbitrary order with respect to a small parameter) and devised an analytical integration method for infinite systems of partial differential equations as applied to the determination of the Krylov–Bogolyubov transformation functions. For multifrequency systems, he designed an optimal choice algorithm for determining unknown functions appearing in high-order averaged systems. These methods were designed for resonance systems of differential equations, which involve small denominators—the most substantial obstacle to the application of the Krylov–Bogolyubov method.

In various years, Grebenikov held various high positions associated with his science management activities. In 1969–1978, he headed the Department of Mathematics at the Institute of Theoretical and Experimental Physics of the USSR State Committee on Atomic Energy. In 1978–1988, he was director of the MSU Research Computer Center. In 1988–1997, he was a department head at the Institute of Problems of Cybernetics of the Russian Academy of Sciences and worked as deputy director at the Institute for High-Performance Computer Systems of the Russian Academy of Sciences. After this institute was disbanded, Grebenikov, together with his team, was transferred to the Computing Center of the Russian

Academy of Sciences, where he headed the Department of Nonlinear Analysis Methods in 1997.

Simultaneously with his intensive scientific activities, Grebenikov participates in training young scientists at different levels. In his student and postgraduate years, he taught mathematics at evening schools in the Krasnopresnenskij District of Moscow. Starting in 1957, after completing his graduate studies, he taught at the Faculty of Mechanics and Mathematics and at the Faculty of Physics of MSU. Later, he headed the Department of Mathematical Analysis at the Peoples' Friendship University of Russia, worked as a professor of the Department of Cybernetics at the Moscow State Institute of Electronics and Mathematics (Technical University), headed the Department of Algebra and Analysis at the Moscow State Aviation Institute (Technical University), served as a professor of the Department of Higher Mathematics at the Engineering University of the Republic of Moldova, and headed the Department of Mathematical Analysis at the University of Podlasie (Siedlce, Poland) (1996-2003). Over 50 years of his activities in science and science management, Grebenikov has trained numerous highly skilled professionals. Over the last five years, he supervised four candidate's and two doctoral dissertations. His students do research and teach in Armenia, Byelorussia, Israel, Kazakhstan, Mexico, the Republic of Moldova, Poland, Romania, and the USA.

For his great achievements, Grebenikov won the State Prize of the USSR in 1971. He was also awarded the Prize of the USSR Council of Ministers in 1983 and the Academician Krylov Prize of the Ukrainian Academy of Sciences in 1999. Professor Grebenikov was a full member of the Academy of Nonlinear Sciences, an honorary member of the Academy of Sciences of the Republic of Moldova, and an Doctor Honoris Causa of several foreign universities: Doctor Honoris Causa al Universităţii „*Babeş - Bolyai*" from Cluj-Napoca, Romania (1993); Doctor Honoris Causa of State University from Atârau, Kazahstan (2001); Doctor Honoris Causa of Technical University of Moldova, Chishinau, Republic of Moldova (2003); Doctor Honoris Causa of Technical University „*Gh. Asachi*", Iassy, Romania; Doctor Honoris Causa of University „*V. Alecsandri*", Bacau, Romania; Doctor Honoris Causa of University „*B.P.Hasdeu"*", Cahul, Republic of Moldova.

Due to his active participation in MSU seminars on celestial mechanics and the theory of ordinary differential equations, Grebenikov's major research interests in those years were focused on the analytical and qualitative theory of ordinary differential equations and their applications to nonlinear mechanics, in particular, to celestial space dynamics and the theory of nonlinear oscillations. In his first publications, Grebenikov demonstrated the effectiveness of Hill's analytical method as applied to the dynamics of natural and artificial satellites orbiting with large inclinations relative to the ecliptic plane and the planets' equator plane.

Grebenikov proposed and justified the new idea of developing asymptotic methods that minimize the deviations of solutions to averaged equations from those to the original equations. For this purpose, he used the stepwise correction of initial conditions combined with the principle of nonlinear multifrequency systems given on multidimensional tori. Following this approach, Grebenikov and his students examined new dynamic aspects of well-known problems, such as the restricted three(and more)-body problem with various resonances; resonance Hamiltonian systems; the motion of a geostationary satellite; problems in highenergy physics (the dynamics of charged beams in accelerators); and mathematical modelling in biology, geology, and other disciplines.

During the last decade, Grebenikov and his followers have been successfully developing a mathematical area that can be called Lagrange–Wintner homographic dynamics. Due to new information technologies, in particular, new computer algebra systems (such as Mathematica, Maple, etc.), they found new multiparameter classes of exact solutions to the Newtonian many-body problem such as exact Lagrangian and Euler solutions to the differential equations in the Newtonian three-body problem. The objects of study are new gravitation models in celestial mechanics and space dynamics with complete and incomplete geometric and dynamic symmetries.

Continuing Lagrange and Wintner's studies in the theory of homographic three-body solutions, Grebenikov formulated necessary and sufficient conditions for the existence of homographic solutions to the Newtonian many-body problem with an arbitrary finite number of bodies. Due to these results, he concluded that the Trapezium cluster in the Orion Nebula is not a homographic solution to the Newtonian four-body problem; hence, its trapezoidal shape cannot be conserved. Grebenikov proposed a new dynamic model of the restricted many-body problem ($n > 3$) that studies the motion of a passive mass in the gravitational field generated by a large number of bodies whose trajectories are homographic curves. For the restricted many-body problem, he proved a theorem on the existence of a first integral similar to the Jacobi first integral in the restricted three-body problem. Together with his students, Grebenikov developed effective computer methods for linearizing Hamiltonian systems in the neighbourhood of any stationary solution. Mathematica-based software packages were developed for the symbol (not numerical) normalization of Hamiltonians in the neighborhood of any stationary solution. In other words, effective software tools were designed for one of the most complicated problems in qualitative celestial mechanics and space dynamics – the Lyapunov stability of stationary solutions to the restricted manybody problem. These studies were based on results obtained in KAM theory (the theory of the existence of conventional periodic solutions to multidimensional Hamiltonian systems on multidimensional tori named after Kolmogorov, Arnold, and Moser).

He has participated in many scientific national and international conferences. He was a member of the Program Committee of the annual International Workshop on Computer Algebra in Scientific Computing (CASC), which is held in different countries.

Together with his students and colleagues, Grebenikov has published **28** monographs and more than **200** scientific papers. The bibliography of scientific works by Grebenikov given below is reduced. Therefore, I had to pick from them a small number that are especially known.

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Valeriu Dulgheru
PhD, Dr.Sc. professor
Technical University of Moldova

PERSONALITIES FROM THE MERIDIANS OF THE ENGINEERING UNIVERSE

Silviu Puşcaşu was born in Craiova on the 10th of May 1927, which was the National day of Romania at that time, exactly during the military parade. He was the only child of a family made up of two primary school teachers. His father, Marin Puşcaşu, was a primary school teacher at "*Ion Eliade Rădulescu*" School from Craiova. Perfect educator, proving a total moral integrity, he became the director of this school. His mother, the primary school teacher Eliza Puşcaşu, born Schindler, was passionate of painting and piano. He even played at the organ of the Catholic Church from Craiova.

Between 1934 and 1938 he attended the primary school at "*Ion Eliade Rădulescu*" school, under his parents' careful supervision, and then, after a difficult entrance examination, he was admitted in the secondary school at "*Frati Buzesti*" High school from Craiova, which he graduated in 1946. In the same year he passed the entrance examination at the Faculty of Electromechanics of Timisoara. There were 400 candidates and he managed to pass the entrance examination in the second position, distinguishing himself from the very beginning. The energy sector of economy was growing very fast, so, realizing the role that Oltenia would play in the energetic sector, he chose "*The Transport and the Distribution of Electric Energy*" specialization.

First Steps in Academic System. In 1950 he got his engineer diploma and he was sent to comply with his time of probation at the Regional Company for Electricity of Stalin Town which used to be the former name of Brasov. He worked for a short period of time for the Regional Company for Electricity from Sibiu, and in December 1950 we was employed as an assistant to the Faculty of Mechanization of Agriculture which was part of The Agronomic Institute of Craiova, founded only three years before according to the *Law no. 138 regarding the setting up and organizing the University of Craiova*, voted by the Depute Assembly on the 5th of April 1947 and signed by King Michael I on the 21st of April 1947.

Starting with May 1951 he became a lecturer. During those years, the economic priority was the electrification. The electrification of industry, the electrification of agriculture, the electrification of transportation means. Taking these conditions into account, in 1951 it was set up at Craiova The Institute of Electrical Machines and Equipment which included the Faculty of Electrotechniques, and, then, from 1953 also the Faculty of Electrification of Industry, Agriculture and Transports. In these conditions, the professional evolution of Silviu Puşcaşu met the requirements of engineering educational system of Craiova. As a result, from September 1952 until 1958 he worked as a lecturer within this institute.

Radio Amateur and Excursionist. During the '50s the wireless activity and electronics developed in Romania. Silviu Puşcaşu, fan of electronics, became also a wireless fan, so, in 1958 he got a transmitter diploma, 3rd category. As a radio amateur, he had the YO7 – 136 indicative. His passion for electronics and radio led his professional career towards the Radio Studio of Craiova where he was engineer-in-chief for a while and where he was a collaborator for a long period of time. In September 1958, The Institute of Electrical Equipment ceased its activity, and professor Silviu Puşcaşu was transferred with his academic activity to the Polytechniques Institute of Timişoara, but his family remained in Craiova, so, for two years, until 1960, he commuted weekly between Craiova and Timişoara. During these two years, he hade a lot of friends at Timişoara. One of them was Professor Eugen Seracin, a passionate alpinist, with whom he traveled through all the Romanian mountains, and then his son, Dan Puşcaşu. I remember that, many years later, in 82-83 I went with him to the Teaching Station from Rânca. He was normally a communicative man, but that time he was really exuberant. The memories might have made him to be so.

Professor at the Pedagogical Institute. In 1960 the Pedagogical Institute was set up at Craiova, so he came back in this town. The experience he accumulated over these years, but also his qualities asserted him through his colleagues from Craiova, As a result, for five years, between 1963 and 1968 he was the head of the Department of Electrotechniques and Industrial Knowledge within the Pedagogical Institute. In parallel he also held the position of Dean of The Faculty of Physics and Chemistry (March 1963-March 1964) and pro-rector of The Pedagogical Institute (March 1964 - September 1966).

University of Craiova Stage. Meanwhile the University of Craiova was set up, and Silviu Puşcaşu becomes an assistant professor in 1966. He was one of the first pro-rectors for two years, from September 1966 to March 1968. Then, for 12 years, from September 1968 to September 1980, he was the head of the Department of Electrotechniques Basics, transformed in the Department of Electromechanics by unifying the Department of Machines, Equipment and Electrical Drives. This became a huge department and I belonged to this department starting with 1980. I remember the scientific debates, but also Silviu Puşcaşu's tactful method to direct us to a creative goal. He was studying cryogens or, better said, of electrotechniques at very low temperatures. Even now, at Craiova, his disciples continue this activity. During that time, he was also involved in promoting industrial property, namely inventions and not only.

In 1970 he defended his Ph.D. thesis at the Polytechnics Institute of Timişoara. The subject was "Contributions to the behaviour of fluorescent tubes supplied with variable frequency". He got his Ph.D. Diploma in Engineering on the 30^{th} of March 1971. Ten years later, in March 1981, Professor Silviu Puşcaşu participated to the defence of my Ph.D. thesis as a member of the Commission of Analysis. I can still remember the elegance of his paper and his rhetoric manner of speaking. My mother who assisted to my Ph.D. defence didn't have the necessary knowledge for understanding the subject of my thesis. She judged only the formal parts of the ceremony and at the end she told me "*My son, anyone can see that he is a great professor!" referring to Silviu Puşcaşu!*"

Rector of University of Craiova. From May 1981 until October 1984 he was Rector of University of Craiova. During that period he did a lot of things. I have to say that he supported me to bring in 1982 a M18 computer manufactured in Bucharest. This computer was necessary for the course "*The Use of Computers in Electrical Drives*". During that time there was only one computer in faculty, at the Computer Department. Many people were involved in this purchase, but as a Rector, he approved to set up a lab for Electrical Drives in two very modern rooms. These rooms still exist and they are used for students to learn about computers. With this computer some of my colleagues finished their Ph.D. thesis, others learnt the first things. As a Rector, he also supported the practical stages for the students of University of Craiova. I remember the interest he had in studying the students' practical achievements, looking for innovative products for the Production Workshop of the Faculty of Electrotechnics. After 1984 he came back to the Faculty of Electrotechniques as a head of the Department of Electrotechnics and Eletromechanics until 1990. During that year many radical changes occurred, but he remained the same.He wrote two reference books: "Modern Springs of Light", published at the Scientific Publishing House in 1968 and "*Sizes and Non-Sinusoidal Electrical Regimes*", Scrisul Romanesc Publishing House in 1974. He also wrote over 120 scientific papers published in Romania and abroad and he was member of numerous scientific research contracts.

Canada – a one way direction. He totally gave up his teaching career in 2000. I wonder if he withdrew because the changes after 1990 were difficult or because he wanted to move to Canada in order to be with his son Dan and his grandchildren, Vlad and Anca Maria. It was surely difficult for him to be apart from Craiova and Romania. He left Craiova once, in 1958, but he came back.

This time he didn't. On the 4^{th} of September 2007, 22,30 local time, his soul flew through air, probably to Craiova, over the Romanian mountains, maybe accompanied by YO7 – 136 indicative.

Column written by professor eng .Gheorghe Manolea, University of Craiova, Doctor Honoris Causa of Technical University of Moldova from Chişinău