ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA

2004, Tome II, Fascicole 2

APPRECIATIONS ON THE SURFACE STATUS OF THE WIRE-GUIDE FRICTION COUPLE

Teodor VASIU

FACULTY OF ENGINEERING OF HUNEDOARA, 331128, HUNEDOARA, str. REVOLUŢIEI, no. 5, ROMANIA; e-mail: dorin.vasiu@fih.utt.ro

Abstract

The wear of the wire laminator parts working in very hard conditions: high temperatures, moist and abrasive environment, high variations of efforts, under complex lubrication conditions, has technical-economical problems of reliability and maintenance in exploitation. Starting from this notice, this work proposes itself the analysis of some of the factors contributing to reducing the duration of continuous exploitation of wire laminators and namely those involved in the friction-wear process at the contact wire-guide.

Key words:

laminators, wear, micro-geometry, microstructure, depreciation

1. INTRODUCTION

The data obtained from the experiments performed by the author [3], combined with the statistic analysis show that the making of a friction couple cannot limit itself to mathematic operations only, but a quite large amount of information element has to be approached, which covers in as wide as possible a range the influence of all parameters for the friction-wear process on the couple under consideration.

But taking into account all the factors of influence proves difficult most of the times, if not impossible. That is why, in some cases, those factors are studied that are considered to have major implications and that can also influence the other ones.

As it follows, we have tried to analyze some principal parameters that come up in the friction-wear process of the wire-guide friction couple.

2. ELEMENTS OF MICRO-GEOMETRY OF THE CONTACT SURFACES OF THE WIRE-GUIDE COUPLE

It is known that, under the aspect of the contact surfaces' micro-geometry, the conditions imposed to a part are determined by the role this one is to fulfill in the ensemble it makes part of. The assimilation of these conditions into some general compulsory prescriptions is difficult to be approached, the individual analysis of each case taken aside being advisable. It is necessary that, function of the different ways of functioning, the optimal micro-geometric parameters of the superficial stratum be established.

The micro-geometric aspect generally characterized by micro-bacteria, waviness and micro-irregularities and localized on the surfaces of the guide and of the laminate, shows some peculiarities compared to the other organs of machines. The micro-geometry of processing of the wire's surface is given by the operation of plastic deformation in laminating cylinders, and that of the guide's surface, by the technology of casting and cleaning the cast surface.

The specific micro-geometry of the laminate suffers modifications of "adaptation" in time, transforming with intermittences in processing micro-geometry, due to repeatedly undergoing successive operations of lamination. The specific micro-geometry of the guide is formed in time, in the friction process.

The determination spots of the specific micro-geometry have been chosen for the wires of ∅6, ∅10 and ∅15.5 mm as final profile, laminated at Hunedoara from S235JR, in compliance with the standard SRN 1025 A_1, because no comparison could be performed with the solicited prescriptions for the respective profiles.

Table 1 shows the value elements of the micro-geometry of the mentioned wire typo-dimensions

Table 1. *Characteristic elements of the micro-geometry of some wires of S235JR*

No.	Sample no.	Vertical amplification	Horizontal amplification	R_a [μm]	R_{max} [μm]	R_p [μm]	R_z [μm]	Obs.
1	1	×500	×20	5.1	40	23.2	16.8	Wire ∅6
2	1′	×500	×20	8.0	51.2	24	27.2	
3	2	×500	×20	4.8	42	16	26	Wire ∅10
4	2′	×500	×20	2.2	28	16	12	
5	3	×500	×20	6.5	48.4	27.2	21.2	Wire ∅15.5
6	3′	×500	×20	6.5	52	23.2	28.8	

The measurements contained more or less oxidized areas, fact explaining the differences in the recorded values. The value of R_a, representing the average departure of rugosity, is under the average value of 10 μm, indicated for the laminated profiles in the Romanian standards. In the guides, micro-geometry can be approached for both manufacturing solutions, the mechanic processing one and the specific, cast, one, since the way it can be seen in Figure 1, the wear is localized in a certain part.

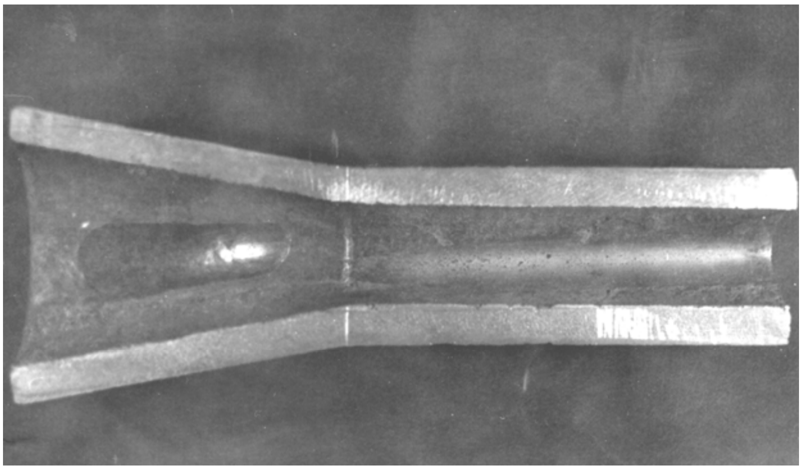

Fig. 1. *Wear of the taper part of a funnel guide*

Table 2 shows the characteristic elements of the guides' micro-geometry.

Table 2. *Characteristic elements of the guides' micro-geometry*

No.	Sample no.	Vertical amplification	Horizontal amplification	R_a [μm]	R_{max} [μm]	R_p [μm]	R_z [μm]	Obs.
1	1	×500	×20	6	60	24	24	No-wear surface
2	2	×500	×20	2	28	8	8	Wear surface
3	2′	×500	×20	2	24.8	9.6	9.6	

The knowledge of the shape and of some of the quantitative parameters of the specific micro-geometry is also useful under the aspect of economy in manufacturing of the friction couples. For the guide, there is noticed that a certain processing micro-geometry made by neat casting and cleaning corresponds to the purpose, especially that specific micro-geometry is localized in random spaces, on small parts of its inner circumference.

From the R_a, R_{max} parameters and the comparative shape of profiles alone, there does not result whether the passage of a processing micro-geometry into a specific one has at its basis a well-established criterion, or it is based on a law. One of the parameters completing the analysis can be the profile's buoyant force after Abbott [1].

If the hypothesis is accepted that the function expressing the variation of the profile's buoyant force with the height of asperities has the properties of a repartition function, then there is the situation when the buoyant force's variation for a given profile has he character of a normal repartition. The character of normality of the repartition function of these two parameters (buoyant force and rugosity) can constitute an criterion at which to report the modification, through a random process, of the surfaces' profiles.

For example, there has been considered the modification by wear of a cast iron guide's micro-geometry, admitting as reference elements: the normal repartition for buoyant force and the number of contacts. The buoyant force's curve (Abbott-Firstone) is obtained by intersecting the rugous profile (obtained by intersecting the friction surface with a normal plane, on a certain direction) with a number of equidistant planes to one of reference (generally the bottom plane of the asperities). For example, the i plane intersects the profile in m zones of length l_{i1}, l_{i2}, …, l_{ij}, …, l_{im}, resulting the total buoyant force length:

$$L_{pi} = \sum_{j=1}^{m} l_{ij} \tag{1}$$

The buoyant force curve can also be determined in non-dimensional coordinates; in the x-coordinate, the buoyant force $F(y) = \frac{L_{pi}}{L}$, and in the y-coordinate, the height y[μm] of the asperities. In this way there is expressed the percentage of the L length of the profile taking the normal charge. In this form of the expression, the buoyant force varies within the limits 0<F(y)<1, the way it is shown in Figure 2.

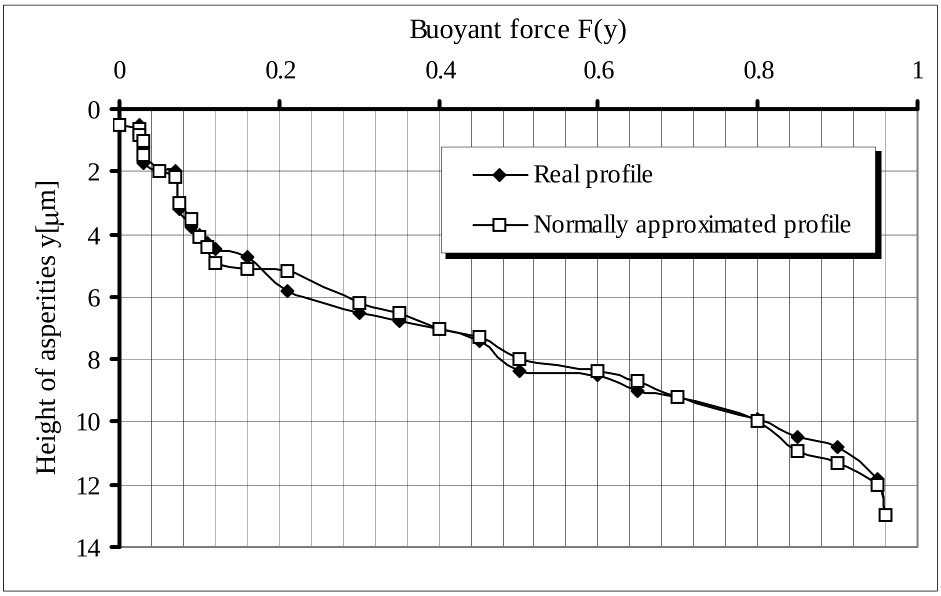

Fig. 2. *Buoyant force after Abbott of the cast iron guide's micro-geometry*

Slight differences are observed between the real profile and that approximated by the normal law, which could be due to the relatively uniform wear of the guides' surfaces, specific to cast irons.

Considering a Gaussian distribution of asperities on the height y and noting with f(y) the density of probability of the normal profile, we obtain the expression:

$$f(y) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(y_i - \bar{y})^2}{2\sigma^2}} \tag{2}$$

Where:

$\sigma = \sqrt{\sum_{i=1}^{n} (y_i - \bar{y})^2 p_i}$ represents the dispersion of values;

y_i-the effective measure of the asperities' height;

$\bar{y} = \sum_{i=1}^{n} y_i p_i$ - the arithmetic mean of the measured values;

$p_i = \frac{n_i}{n}$ - the probability of apparition of the y_i value;

n_i - absolute frequency;

n - the number of values of the asperities' height.

Based on this relation, by means of tables there has been calculated the density of probability f(y), showed in figure 3, for the buoyant force of the real profile.

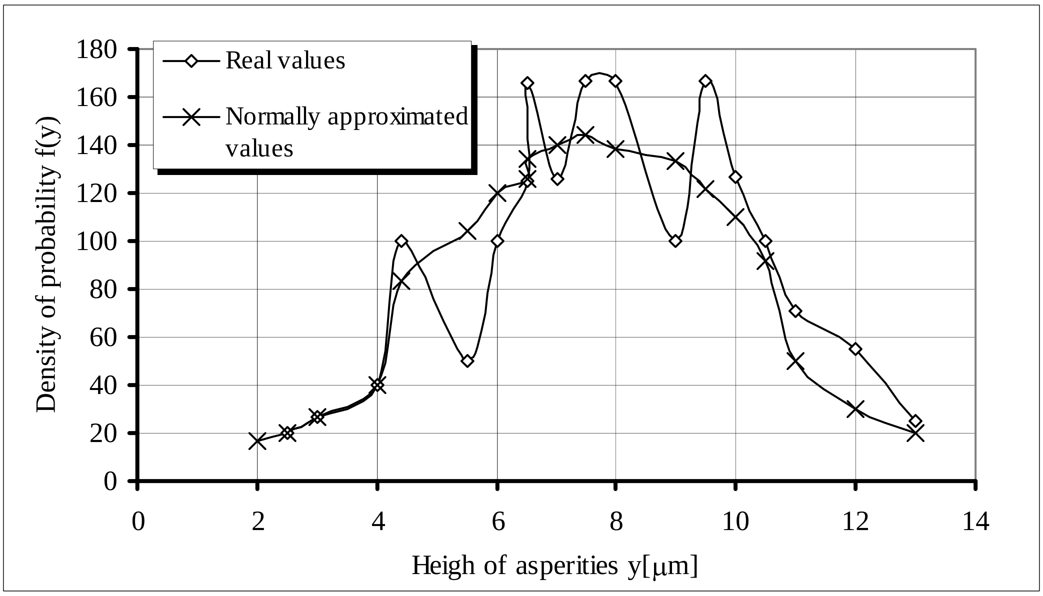

Fig. 3. *Density of probability calculated based on the Gauss' law*

3. SOME METALLURGIC ASPECTS OF THE DRY WIRE-GUIDE FRICTION

The solicitations of mechanic and thermal kind, together with some physical-chemical effects, influence the micro-structure of the surface strata. In fact, at this couple, the friction phenomenon can also be accompanied by possible perturbations in the surface stratum.

In [3] and [4], there have been approached some considerations on the metallographic composition and structure of the S235JR cast iron couple, in the conditions when the moving element was a disc (assimilated with the guide) and the element in relative rest was the test tube (assimilated with the wire).

As it follows, we shall only insist on the significant metallurgic aspects of the wire and funnel guide. The analysis has been performed in a micro-analyzer. From the S235JR wire, a pin was taken, which was attacked with Nital 5%, obtaining the 4-6 images.

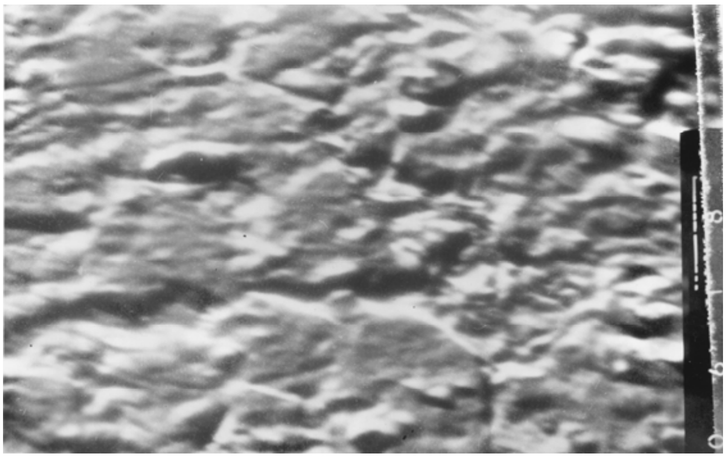

Fig. 4. *Image of composition in longitudinal direction of the S235JR wire* (1500:1)

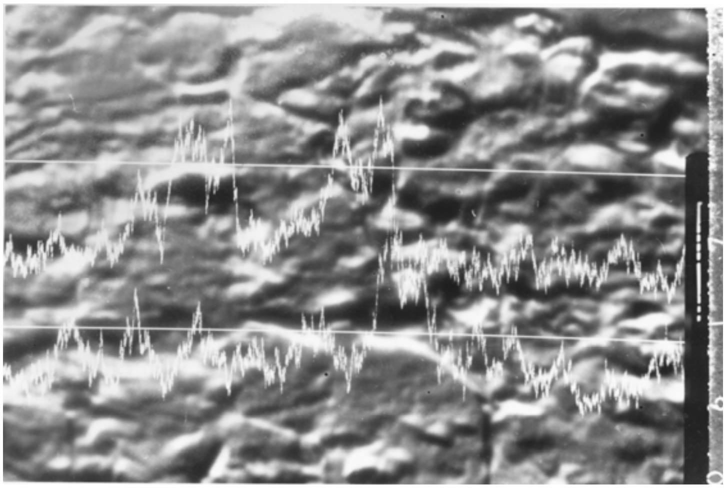

Fig. 5. *Image of composition of Mn on two directions* (1500:1)

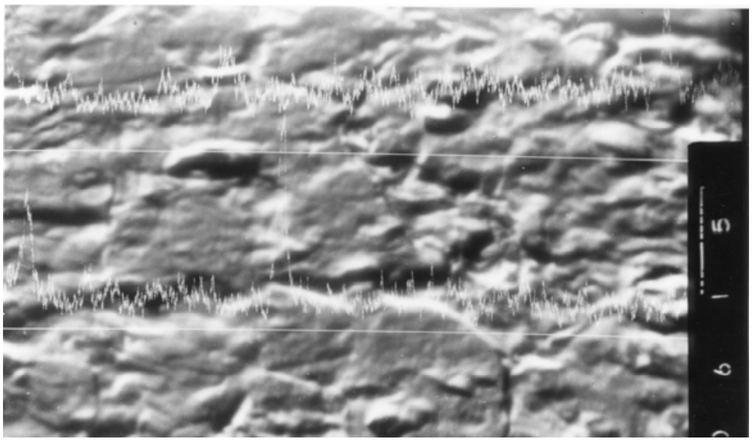

Fig. 6. *Image of composition of carbon on two directions* (1500:1)

From Figure 5 there results a uniform distribution of manganese on the first direction and less uniform on the second (when two maximums appear), fact that could be due to some lacks in the steel elaboration technology at the operation of adding ferro-manganese.

In Figure 6 can be noticed a uniform distribution of carbon on all the studied area, which denotes the observance of some technologic prescriptions.

Under the aspect of S235JR wire's surface, there results that this one does not suffer of alterations of the chemical composition during lamination and guidance. For laminating (the wire), the natural or guided cooling process is important after lamination, which can influence both the metallographic structure and the mechanic properties. But this is a problem of technology.

For the funnel guide, analyses have been performed both in the worn part and for the non-worn part with no attack. For the worn part of the guide, the image in the figure 7 was retained.

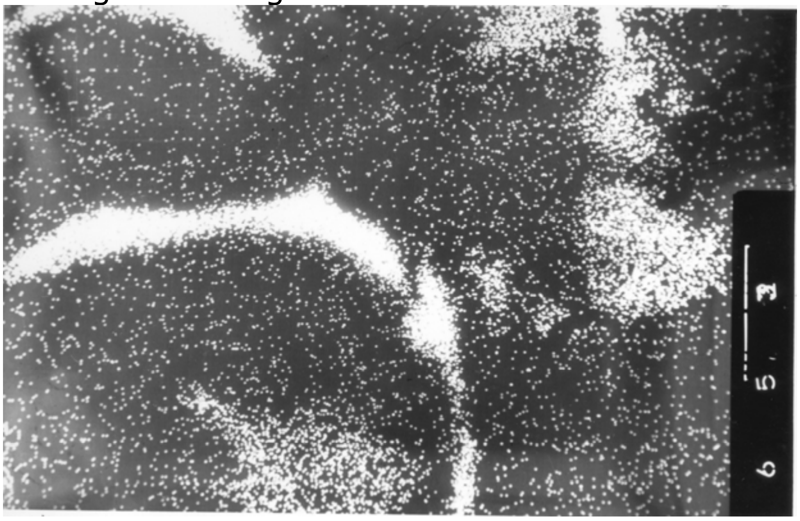

Fig. 7. *Image of repartition of the carbon in the funnel guide* (800:1)

In Figure 7, we can notice the graphite in lamellar form. Analyzing this image, we have noticed that the material of the funnel guide does not suffer alterations under the aspect of the main chemical elements.

The analysis of the metallurgic aspects of the guides has to be extended to other elements, too. Reminding that the introduction and evacuation guides made of cast steel do not have to be heated over 60^0C, unless accidentally and then only up to maximum 200-250^0C, they will be studied more succinctly, not representing particular interest under metallurgic aspect.

The funnel guides made of gray cast iron suffer repeated heating and cooling within the range 25-500^0C, causing them to have their dimensions and volume irreversibly increased. Measuring the increase of dimensions (length and external diameter) after a period of 3 months of continuous functioning, there has been noticed an average increase at these guides, by 8.6 to 14.7 %, function of the brand of the used cast iron.

This increase is due [2] to the oxidation process, to the graphitizing of the cementite from the perlite (accompanied by an increase in volume), to the formations of pores (graphite dissolves into the basic metallic mass), as well as to the formation of the internal tensions (due to the variations of volume caused by transforming the ferrite into austenite).

4. QUANTITATIVE ANALYSIS OF THE PRODUCTS OF WEAR OF THE FRICTION COUPLE WIRE-GUIDE

During the period of study of the friction-wear process of the laminate-guide couple, there was noticed in the area of contact of the two elements of the couple, the formation of a fine metallic powder, which if driven by the moving wire.

For the chemical and granulo-metric analysis of these powders samples were taken that were analyzed on the way described in [3]. The results obtained at the chemical analysis are those indicated in table 3.

Table 3. *Chemical analysis of the iron powders resulted from the process of wear of the laminate-guide couple*

No.	Total Fe [%]	Metallic Fe [%]	FeO [%]			Fe_2O_3 [%]			Fe_3O_4/Fe	Σ [%]
			Total FeO/Fe	Tied FeO/Fe	Free FeO/Fe	Total Fe_2O_3/Fe	Tied Fe_2O_3/Fe	Free Fe_2O_3/Fe		
Thread 1	72.82	1.26	51.99/40.3	20.16/15.63	31.83/24.67	44.8/31.33	44.8/31.33	-	64.96/46.96	98.05
Thread 2	72.32	1.19	50.2/38.91	20.73/16.07	29.49/22.86	46.07/32.82	46.07/32.82	-	66.8/48.29	97.48
Thread 3	72.15	1.29	50.62/39.22	21/16.27	29.62/22.95	46.67/32.64	46.67/32.64	-	67.67/48.92	98.58

Since the sum of oxides is of maximum 98.58%, other chemical components were determined, finding as it follows: 0.2-0.3% SiO_2; 0.55-0.65% Mn; Cr_2O_3-traces; 0.1% CuO; CaO-traces. At the same samples, there was also determined the granulo-metric composition, obtaining the results from the table 4.

Table 4. *Granulo-metric dimensions of oxides*

No.	Granulo-metric composition [mm] in [%]						
	>0.5	0.5÷0.4	0.4÷0.25	0.25÷0.16	0.16÷0.125	0.125÷0.08	<0.08
Thread 1	0.2	0.24	0.2	1.4	3	20.2	74.7
Thread 2	0.3	0.3	0.3	1.3	3	17.88	76.2

We have noticed that the material resulted from the friction-wear process is a fine powder with the dimensions mostly slower than 0.08 mm and constituted in a proportion of 97.5-98.5% of iron oxides. The relatively low content (29.49-31.83%) of wustite is due to the fact that it remains adherent to the metal's surface, and the time from the formation process until the collection allows the drop of temperature below 570^{0}C (below which FeO is no longer stable).

The collected powder contains in a higher proportion the existent oxides on the external side of the oxide pellicle (Fe_3O_4 and Fe_2O_3).

The relatively low percentage of metallic iron can be due to the fact that it derives from the reactions of disproportioning in the non-oxidized steel.

5. CONCLUSIONS

From Figure 3 there results a relatively normal distribution of the density of real probability. This is possible to be due to the multiple tribological and functional factors of the lamination-guidance process.

Analyzing some elements of micro-geometry of the guide-wire surface in the process of dry friction, function of the given parameters, there results as it follows:

- The average discrepancy R_a of irregularities of the wire's surface range in the manufacturing prescriptions for the finite product;
- The specific micro-geometry to the active surface of the guide presents a normal repartition under the aspect of buoyant force profile;
- The contact laminate - guide ensures under the given conditions a corresponding specific micro-geometry.

In the production activity the appreciation is well-established that the micro-geometry of the final surfaces of the laminate is mainly determined by the quality of the laminating cylinder calibers' surface of the finishing stands and, less importantly, by the contact with the guides. In reality, based on the observations made, there results that in the case of a correct mounting of the guides, one can ensure a specific micro-geometry to its surfaces, within corresponding limits, with positive influences on the laminate's surface. In the case of a mounting with abnormal eccentricities, both the micro-geometry and the macro-geometry of the wire's surfaces are influenced.

Measures have been taken of the surfaces' micro-geometry and for the cast introduction and evacuation guides, the conclusions being approximately the same with those derived from the study of the funnel guides' study.

The formation of the structure and composition of the oxides on the couple's surfaces and their removal is the result of a dynamic process of formation, on one side, and of wear, on other side. Unlike oxidation under static conditions, the process of lamination-guidance is influenced by both the existence of high temperature and the activation of the surfaces in relative movement as result of the friction process.

On can consider that at the wear in normal atmosphere and at the technologic temperature of lamination of the wire, the oxide stratum determines a more moderate character of the adhesive friction, over which an also moderate abrasion process overlaps.

From the analysis of the wear products in case of the metallic couples, at dry friction, there results that the main component is constituted by oxides.

It is possible that the mechanism of formation and dislocation of oxides especially from the surfaces of the laminate play an important role in the formation of surfaces' geometry, too.

The study of apparition and dissipation of the products of wear in the environment can also be generally extended over the problematic of friction-wear: microclimate in the work halls, depositions of metallic powders on the driving, measure and control apparatuses, breakthroughs through interstices, etc.

6. REFERENCES

1. PAVELESCU, D. ş.a., 1977 *Tribologie (Tribology),* Ed. Didactică şi Pedagogică, Bucharest, Romania
2. PIWOWARSKI, E., 1967, *Fonte de înaltă calitate (High-Quality Cast Irons)*, Ed. Tehnică, Bucharest, Romania.
3. VASIU, T., VASIU, Gh., 2003, *Aspecte tribologice ale laminatoarelor de sârmă (Tribological Aspects of the Wire Laminators)*, Ed. Mirton, Timişoara, Romania.
4. VASIU, T., 2002, *Triboloski aspekti valjacarmature zicnih valjaonuica*, Journal of Mechanical Engineering, Masinstvo, 4(6), Zenica, p. 207-214, Serbia.
5. VASIU, T., MAKSAY, Şt., 2001, *Estimation of the Wear of Friction Coupling Disc-Cylinder for Constant Contact Forces*, Buletinul Ştiinţific şi Tehnic al Universităţii "Politehnica" din Timişoara, Tome 46(60), fasc. 2, p. 117-120, Romania.