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# MEASUREMENT METHODOLOGY OF CHARACTERISTICS AND ELECTION OF MATERIALS OF ELEMENTS OF TRIBOMECHANICAL SYSTEMS

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Achieving the equality between the time of functional aging of mechanical systems and the time of allowed wear of the system elements is the main task of tribology. This can be reached by choosing the optimal material of elements of tribo-mehanical systems. The paper gives the results of experimental research of tribological and mechanical characteristics several pairs of material. Investigations were performed on the device with a rotating disc and static pin.

*Key words:* measurement, materials, tribo-mechanical systems, wear

**Metodologija mjerenja karakteristika i izbor materijala elemenata tribomehaničkih sustava.** Dostizanje jednakosti vjeka funkcionalnog starenja strojnih sustava i vjeka dopuštenog habanja elemenata sustava, je osnovni zadatak tribologije, koji je moguće izvesti izborom optimalnog materijala elemenata tribomehaničkog sustava. U radu se daju rezultati eksperimentalnih istraživanja triboloških i mehaničkih karakteristika više parova materijala. Istraživanja su izvedena na uređaju sa rotirajućim diskom i mirujućim pinom.

*Ključne riječi:* mjerenje, materijali, tribomehanički sustavi, habanje

## INTRODUCTION

A product represents the most characteristic parameter of a country's technological development. The performance of each product is assessed on the market and as the customer becomes more demanding, the expectations of the product increase and individual desires become much more apparent. As a result, the level of product quality is continuously improved, delivery time is constantly reduced and the price falls. It is impossible to objectively evaluate the importance of certain materials in the development of human progress. Therefore, for each material, it is necessary to become acquainted with its basic properties, manner of use, transportation, maintenance etc. Product features and feedback from the environment and the surroundings have become the basis and starting set of parameters for the design of products [1].

## TRIBOLOGICAL CHARACTERISTICS OF MATERIALS AND CORRECT DESIGN TRIBOLOGICALLY

The usage of new materials for making solid elements of tribo-mechanical systems of all types is still not wide-spread. Mechanical properties, machinability and the ability to change the properties of surface layers by physical-chemical and other procedures are the reason why metal materials are most commonly used for making the solid elements of a tribo-mechanical system [2]. Tribological properties of materials are the basis for the creation of numerous databases in the Tribological Information System which is being developed in a number of developed countries. It is commonly accepted that the safety of industrial, transportation and agricultural systems and their productivity are determined by acquaintance with these characteristics. Tribological characteristics are relative and depend on the location within the elements of a tribo-mechanical system where contact is realized [3,4]. Identification and measurment of tribological characteristics of the elements of a tribo-mechanical system is reduced to the identification of friction processing in the contact zone and wear process of each element separately [5,6].

Tribologically proper design is a new aspect in a systematic approach and methodological elaboration of the construction process [7]. This is the concept behind improving the methodology of construction and computer aided design. By analyzing the process of construction as an information process, a general scheme of a construction process can be represented as interaction of two main modules: informational control and operational modules (Figure 1).

From the standpoint of tribologically proper design, the segments of the knowledge base related to problems of friction and wear and the mutual relations of two bodies in contact during their relative motion are of particular importance. This is a view of tribological information as organized groups of processed tribological data

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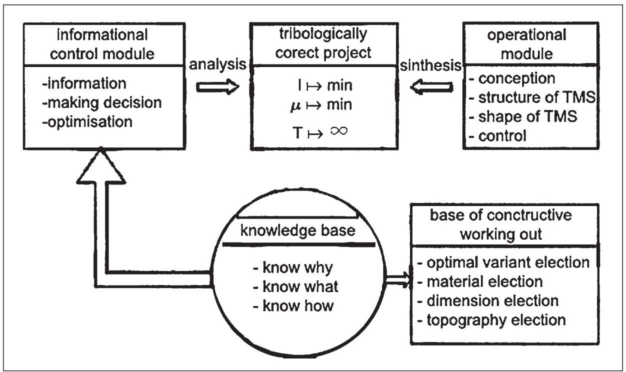


**Figure 1** The general scheme of tribologically proper design

and facts. It is indisputable that tribological processes are very complex processes that depend on many factors. At this time, the scientific world has insufficient tribological information, especially concerning the amount of systematized information which is applicable in practical construction. Furthermore, the efforts of developed countries, in order to reduce the consumption of energy and materials as well as to reduce environmental problems, cannot lead to more significant results without additional research in all fields of tribology [7].

The field of Tribomaterials is a specific area of tribology which refers to the determination of tribological characteristics of existing materials and the development of new materials from which elements of a tribo-mechanical system are made. The tribological characteristics of a material after the duration of a period of contact are relative and are dependent on the methods by which they are determined and the conditions under which the contact among the elements of tribo-mechanical system is realized. Modern equipment and devices embedded in a tribometer with accompanying instrumentation enable an accurate and reliable measurement of normal force or frictional force or the coefficient of friction. In order to determine the measurement of pin or disc disintigration after a particular duration of contact, many methods are used which are based on the measurement of their dimensions or the traces of which the process of wear makes in the tactile surfaces of elements.

## CONDITIONS OF EXPERIMENTAL RESEARCH

Experimental research was performed on the tribometer "pin on disc" which achieved linear contact between the front surface of the pin and the rim of the disc surface. Characteristics of nodular casts are given in [2]. Figure 2 (left) shows the EN-GJS-400-15 structure, charge 5815-13 increased 500 times, corrosive, ferrite pearlite basis and in Figure 2 (right) the structure of EN-GJS-600-3, charge 5766-13, increased 500 times, corrosive, mostly pearlite basis is given.

Isothermal improvement of nodular casts was carried out so that the element was rapidly cooled from the temperature of austenitization to the temperature of isotherm which is higher than the temperature at which the creation of martensite begins. A temperature of $T_i$=390 °C is maintained until the desired transformation is reached and then it is cooled to room temperature. The purpose of this is to avoid the transformation of austenite into martensite, which would cause the appearance of stress and cracks. By maintaining a temperature of $T_i$=390 °C, an intermediate structure called benit is obtained, which provides very positive mechanical properties to the processed element [2].

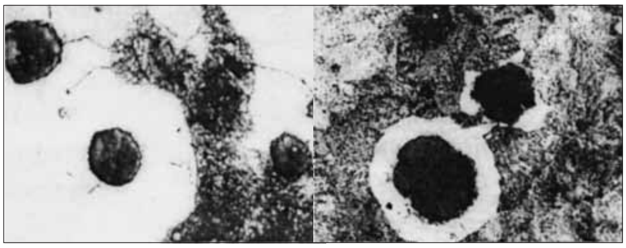

**Figure 2** Structure of EN-GJS-400-15, charge 5815-13 (left); Structure of EN-GJS-600-3, charge 5766-13, (right)

Table 1 **Conditions of testing of elements of tribo-mechanical system**

| | |
|---|---|
| Normal load / N | 200 |
| Temperature | Air temperature |
| Sliding speed / | 2 |
| Type of lubrication | Boundary lubrication |
| Duration of contact / min | 60 |

A testing program was creating which used two discs made of gray cast EN-GJL-250 and steel C45E. During the tests, three pins were applied which were composed of EN-GJS-400-15 (PIN B), EN-GJS-600-3 (PIN C) and 90MNCRV8 (PIN A). Ten experimental tests were carried out over a period of 60 minutes of effective contact with the boundary lubrication. The testing conditions are illustrated in Table 1, while Table 2 depicts the elements of the tribo-mechanical system.

Table 2 **Elements of tribo-mechanical system**

| Contact geometry | | Line | | |
|---|---|---|---|---|
| Pin | | PIN A | PIN B | PIN C |
| Pin surface | $R_a$ / μm | 0,22 | 0,23 | 0,25 |
| | $R_{max}$/ μm | 1,8 | 1,7 | 2,6 |
| Disk material | C45E | | EN-GJL-250 | |
| Disk surface | $R_a$ / μm | 0,60 | 0,50 | |
| | $R_{max}$/ μm | 6,2 | 4,2 | |
| Lubricant | HVL-22 Modriča | | | |

## RESEARCH RESULTS

One of the values which can be used when evaluating the improvement of tribological features of a tribo-mechanical system is friction force, which is generated by applying procedures to improve the contact area. This is significant because power consumption depends on it. The tribological characteristics of the tribo-mechanical system depend on the intensity of the development of wear processes in the contact zones of its elements. The continuous operation of productive means depends on the duration of the critical elements of the critical tribo-mechanical system contained within it. Once the critical element of the critical tribo-mechanical system reaches the maximum allowable disintigration productive means is stopped and individual elements or the entire system is replaced.

Table 3 **Test results**

| Pin material | | EN-GJS-400-15 | EN-GJS-600-3 |
|---|---|---|---|
| Frictional force /N | | 20,8 | 20,8 |
| Coefficient of friction | | 0,104 | 0,096 |
| $rb_{pin(av)}$ /mm | | 0,840 | 0,625 |
| $\delta_{pin(av)}$ /mm | | 0,00130 | 0,00072 |
| Disk material | | C45E | EN-GJL-250 |
| Disk surface | $R_a$ / $\mu$m | 0,54 | 0,43 |
| | $R_{max}$ / $\mu$m | 6,0 | 3,8 |

The second value which can be used for evaluating the degree of improvement of tribological characteristics in a tribo-mechanical system is the amount of time a tribo-mechanical system is able to operate before a critical disintigration of one of its elements occurs. The results of these tests are given in Table 3.

Geometry of contact and the pin worn surface is given in Figure 3.

The form of the signal of friction coefficient at the beginning and the end of the achievement of contact between the pin of EN-GJS-400-15 and disc of C45E is given in Figure 4.

The parameter which was most often used was the wear change of the dimensions of one element in contact. In this research, the parameters of the pin and disc topography before and after the achievement of contact trace of wear on the pin are significant. The parameters of the surface topography of the pin and the disc before and after the beginning of wear on pin of EN-GJS-400-15 and disc of C45E are presented in Figure 5.

The basic characteristics of the diagrams shown in Figure 4 and 5 are:

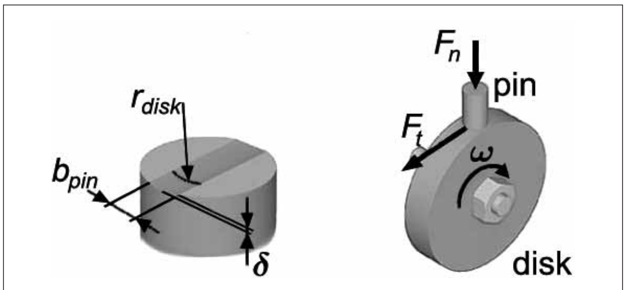


**Figure 3** Geometry of contact and pin worn surfaces

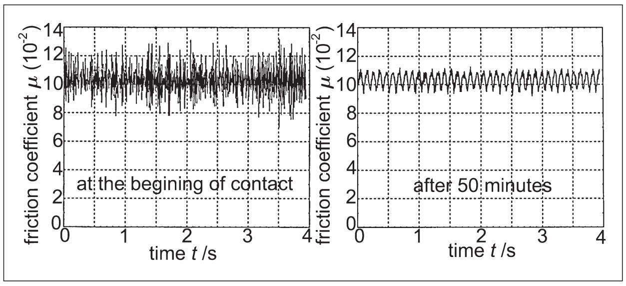


**Figure 4** Form of the signal of friction coefficient at the beginning and the end of the achievement of contact between the pin of EN-GJS-400-15 and disc of C45E.

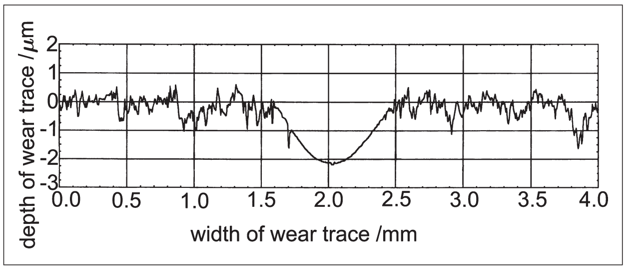


**Figure 5** Parameters of topography of the pin and the disc surface before and after the beginning of wear on pin of EN-GJS-400-15 and disc of C45E.

– Each point shown in the diagrams of friction coefficient measured represents the average of 750 points measured during a period of 5 seconds.
– During a 60 minute test of continuous contact there was no appearance of destruction of the oil film.
– The above values of width and depth of trace wear at the pin are the result of microscopic measurements and calculations by the expression given in [4]. The parameters of the surface topography of the pin and the disc before and after the wear on the pin of EN-GJS-600-3 and disc of C45E are shown in Figure 6.

The coefficient of friction depends on many factors. In this research the influence of material elements of tribo-mechanical system and sliding speed were examined (Figure 7).

The width of wear trace in dependence on the material of elements in the pair at the sliding speed at the lubrication process with lubricant HVL-22 measured after thirty minutes of realization of contact is shown in Figure 8.

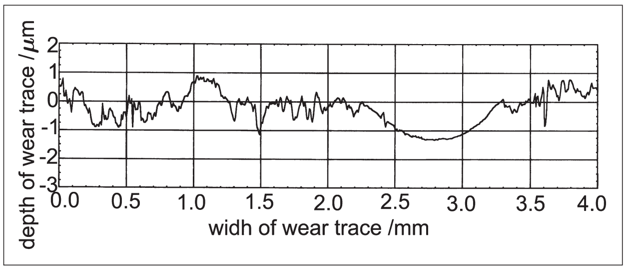


**Figure 6** Surface topography parameters of the pin and the disc before and after the beginning of wear on the pin of EN-GJS-600-3 and disc C45E.

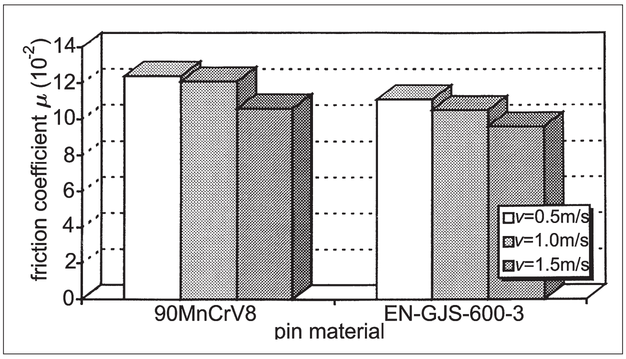


**Figure 7** Coefficient of friction in dependence on pin material and sliding speed at lubrication with the lubricant HVL-22, for disc material EN-GJL-250.

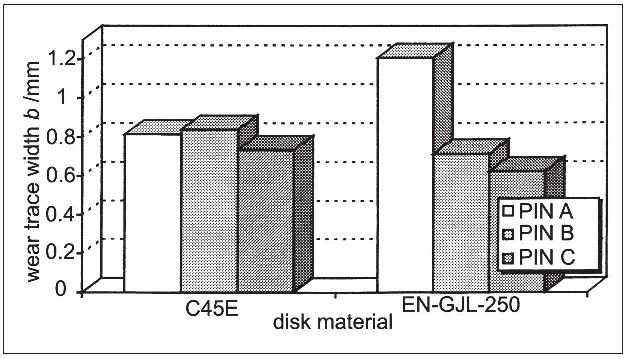


**Figure 8** The width of wear trace in dependence on the material of elements in the pair

## ANALYSIS OF RESEARCH RESULTS

The test results include data on the friction coefficients in dependence on the material of elements and the sliding speed and the topography of the surface of elements of tribo-mechanical systems and width of wear trace in dependence on the material of elements in the pair. Based on the analysis of research results can be noted that:

- Frictional force and friction coefficients are smaller when the realization of contact between the pin of nodular casts and disk of steel and gray cast than frictional force and coefficient of friction that arises when the realization of contact between the pin of steel and the disc of steel and gray cast (Table 1, Figure 7).
- Smaller frictional force and friction coefficient were obtained using the EN-GJS-600-3 pin (Table 3, Figure 7).
- The smallest trace of wear was obtained for the investigation using disc material EN-GJL-250 on pins made of nodular casts EN-GJS-400-15 and EN-GJS-600-3 (Figure 8).
- Elements made of nodular casts have a significant advantage in terms of their properties of wear in comparison to the steel elements which were tested.
- Elements made of nodular casts have a small but important advantage in comparison with elements made of steel in terms of their anti-frictional properties.

Tribological losses of energy and materials in the production and exploitation of products have been occurred in numerous tribo-mechanical systems. Identifying which material or condition of the process will give the best tribological characteristics to certain elements of a tribo-mechanical system can only be achieved by implementing a specific three stage procedure. In the first stage, the geometry of the contact and the conditions under which the contact between the elements of tribo-mechanical system is achieved are identified. In the second stage, a search is performed to find information about the tribological characteristics of all three elements in the tribo-mechanical system and the possible conditions. In the third stage, an approach determination of tribological characteristics of the elements of a tribo-mechanical system is fulfilled. When selecting materials for creating solid elements of a tribo-mechanical system, it is necessary to be familiar with their tribological properties; in particular, their resistance to wear in possible conditions of achieving the contact. In order to reduce tribological losses in terms of materials, it is evident that the lower or higher performance of products or production, in terms of tribology, will be pre-determined by the choice of materials. All subsequent events will merely be the consequences of the decision taken on the selection of materials for the elements of a tribo-mechanical system. A choice of material suggests that optimal materials should be selected, thereby solving the optimization process in an appropriate manner. In this process of materials selection, besides the dominant requirements of the relevant material characteristics all other relevant values such as mechanical resistance, technological properties, procurement, price, etc must also be taken into consideration when choosing the optimal material.

## CONCLUSION

Knowledge of tribological coupled pairs of materials is required for evaluation in order to evaluate the exploitative properties of tribo-mechanical systems. Based on this successfully completed experimental research model, it can be said that elements made of nodular casts have better tribological properties in terms of their energy and economic aspects than the steel elements that were investigated. However, when a specific application is in question, it is necessary to examine the elements made of pairs of materials under concrete conditions of exploitation. In addition, it is also necessary to be well-acquainted with the tribo-mechanical system, its complexity and the importance and responsibility of each element in under all possible circumstances and under any strain to which it is exposed.

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**List of symbols and acronyms**

| | |
|---|---|
| TMS | Tribo mehanical systems |
| $\mu$ | Friction coeficient |
| I | Wear intensity |
| T | Part life |
| $T_i$ | Temperature of isothermal improvement |
| $F_n$ | Normal load |
| $F_t$ | Tangent load |
| $\omega$ | Angular velocity |
| $r_{disk}$ | Radius of disc |
| $b_{pin(av)}$ | Wear trace width (average) |
| $\delta_{pin(av)}$ | Wear trace depth (average) |
| $R_a$ | Average profile deviation |
| $R_{max}$ | Maximum profile deviation |

**Note:** The responsible translator for English language Elisabeth Salmore, professional lecturer, Faculty of philosophy, Novi Sad, Serbia