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RESEARCH ON TRIBOLOGICAL BEHAVIOUR OF MATERIAL NECURON 1050

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Abstract: *This paper presents the experimental research carried out on friction couplings made of Necuron 1050 and GCuSn14 materials. The tribological research carried out aimed at determining the coefficient of friction, determining the temperature variation at the roller-shoe contact and determining the gravimetric wear. The results of the experimental research, for the Necuron 1050 material, led to obtaining the following values: friction coefficient* μ *= (0.325...0.170); gravimetric wear u = max. 0.0270 g, for 30 min operating time; temperature at the roller-shoe contact, t = 60* ^{0}*C for 7 min. Similar results were obtained for the material GCuSn14:* μ *= (0.325...0.175); u = max. 0.5630 g; t = 103* ^{0}*C.*

Keywords: *Necuron 1050, GCuSN 14, coefficient of friction, temperature, gravimetric wear.*

1. GENERAL ASPECTS

Identifying the causes of the destruction of plain bearings is especially important since remediation or replacement with other bearings must be carried out immediately.

Damage to a bearing is the result of several mechanisms of wear of the bearing material or spindle, but also of the lubricant. A bearing can operate in dry, mixed or lubricated mode. The forms of damage depend on the working regime, the materials involved, the environmental conditions and possibly the overloads of the machine.

Plastics are of wide interest for the construction of plain bearings, having besides low cost and advantages of good antifriction properties. This category of materials has known a wide applicability in recent decades due to its special properties: low specific gravity compared to steel and cast iron, high corrosion resistance in various environments, high plasticity, low noise operation, some bearings do not require lubrication, some materials can be environmentally friendly, low friction coefficient, low noise operation, high productivity processing technology with low operations and consumption low energy, [1, 2, 3, 4]. Among the disadvantages can be listed: low reliability, low resistance to high temperatures, low dimensional accuracy, low service life.

A number of technological attempts to make plated antifriction materials were addressed. The paper [5] presents the research carried out bearings made of bronze-plated steel. The lead content in these bearings is usually (20 ... 30) %. Lead decreases the coefficient of friction.

The paper [6] deals with Cu-Pb alloy with lead content of 5, 10, 15, 20, 25, 30 and 40%.

It has been found that the mechanical properties of the alloy (tensile strength, yield strength, hardness, and percentage elongation) decrease with increasing lead content.

Also, wear decreased with increasing amounts of lead in the alloy. After a short run-in period, there is steady-state wear with linear variation. In all cases, regardless of the percentage of lead in the alloy, the wear rate decreases with increasing sliding speed, reaching a minimum value, and then increases with increasing sliding speed.

The paper [7] presents an experimental evaluation of the friction and wear properties of a composite material, which represents a polymer matrix reinforced with particles of cristobalite (αSiO_2) and molybdenum disulfide (MoS_2). This material was tribologically tested under dry friction conditions on a flat ball configuration using the alternative method on a CETR UMT-2 (Bruker Corporation) tribometer.

The wear behaviour of poly (ether-ether-ketone) composite (PEEK) was studied depending on load and test speed [8]. Tribological tests were conducted on the universal UMT-2 tribometer using a pin-on-disk device.

The friction coefficient and wear rate for the studied composites were analysed. The tests carried out allowed to examine the influence of load and speed on the coefficient of friction and wear rate in dry slip mode. Also, structural changes were observed by optical microscopy and SE.

Following experimental tests, it was established that the PEEK carbon fibre/carbon nanotube composite exhibits good wear behaviour under operating conditions.

For the experimental tests of the work, Necuron 1050 material was used. The material is used in the form of several quality classes [9], (NECURON 690, 702, 720, 840, 1001, 1004, 1020, 1050 and 1060) which are used in various industrial applications, such as: models, devices, casting forms, foundry models, casting cores, metal stamping/pressing molds, thermoforming, check rails, etc.

Necuron 690, 702, 720 and 840 [9] represent the range of materials that can be used for different thermoforming or baking processes of composite materials. These quality grades of Necuron material withstand working temperatures of (105 ... 170) ^{0}C.

Necuron 1300 is the class that was used to manufacture stamping/pressing molds.

Necuron 1001, 1004 [9] are the quality classes used in the manufacture of devices, layouts, check rails. These are characterized by dimensional stability.

Necuron 1020, 1050 and 1060 [9] are used to make casting patterns, molds and molding cores. Abrasive strength is the property that characterizes these classes of materials. According to [9] the models made of Necuron 1020 withstood over 10,000 formations (forming pressure of 0.3 MPa), without finding signs of wear. The class with the highest wear resistance (friction) is Necuron 1150.

2. OBJECTIVE OF THE WORK

The objective of the work is to determine the technical characteristics of Necuron 1050 material, in order to use it in the manufacture of plain bearings. GCuSn 14 SR EN 1982:2008 bronze will be used as a comparison material.

The experimental research was carried out on specimens made of 2 categories of materials: Necuron 1050 and GCuSn 14.

The program of experimental determinations covers the following types of tests: mechanical (hardness test, tensile test); tribological (determination of friction coefficient, determination of temperature variation at roll-shoe contact and determination of gravimetric wear).

Tribological tests were carried out on friction couplings made of material: Necuron 1050 and GCuSn 14, which were subjected to tests on the Amsler A135 machine.

3. METHODOLOGY AND TECHNICAL CONDITIONS FOR CARRYING OUT THE TESTS

3.1 Determination of material hardness Necuron 1050

The hardness test was performed by Shore method, according to SR ISO 868-95, measuring scale D. The device used for testing is Durometer Test Stand Model type: SLX-D, tolerance up to ± 2 HD (Fig. 1), which determines the hardness of plastics by penetration.

Fig. 1. Shore D hardness meter Type Test Stand Model: SLX-D.

The experimental determinations were carried out by measurements on specimens taken from the base plate in a longitudinal and transverse direction. Sets of 10 determinations were performed for each of the two investigated directions (Table 1).

Table 1

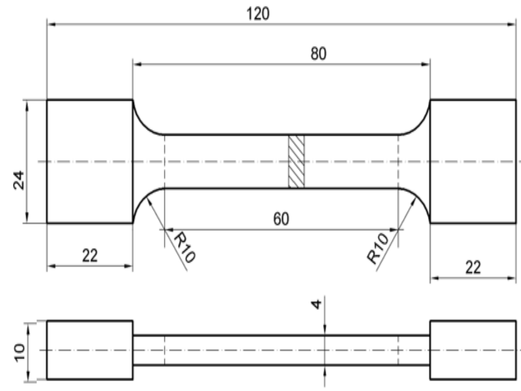
Determination of material hardness Necuron 1050.

No. crt.	Shore D hardness	
	Longitudinal direction	Transverse direction
1	83	82
2	82	80
3	83	81
4	81	80
5	84	85
6	85	88
7	88	90
8	89	87
9	87	86
10	88	85
Average	85	84.4

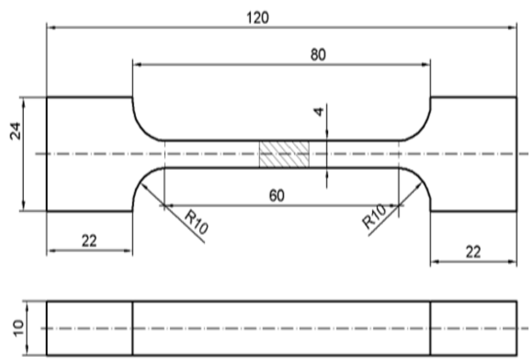
Following the statistical processing of the obtained results regarding the hardness of Necuron 1050 material for the specimens revealed in the transverse direction, an average hardness value of 84.4 Shore D was obtained, and in the longitudinal direction the average hardness value of 85 Shore D was obtained. It is found that the hardness determined on the 2 directions does not vary significantly.

3.2 Tensile test

To determine the mechanical characteristics of the Necuron 1050 material, tensile tests were performed in accordance with the provisions of SR EN ISO 527-2019. As the shapes and dimensions of specimens are not specified in this standard, the shape of flat plate specimens provided for in the tensile test standard for metals SR EN 10002-1:2002 has been adopted. Two types of specimens processed in the transverse direction and processed in the longitudinal direction were made (Fig. 2).



a – specimen machined in the transverse direction



b – specimen processed in longitudinal direction

Fig. 2. Shape and dimensions of specimens intended for tensile testing.

Tensile stress test (Fig. 3) was performed using the LRX Plus type machine for testing plastics, the maximum load of the machine being 2.5 kN, having the precision 95 %.

Figure 4 shows specimens machined in a transverse direction made of Necuron 1050 material before stress and after tensile stress.

After statistical processing of the results, the following characteristic quantities were obtained for specimens processed in the transverse direction: tensile strength R_m = 35.9 MPa and yield strength R_p = 35.4 MPa, respectively for specimens processed in longitudinal direction R_m = 33.7 MPa and yield strength R_p = 33.3 MPa.

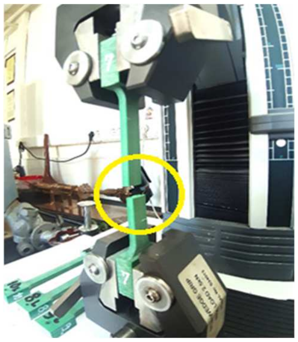
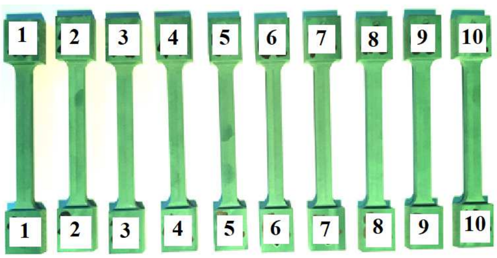
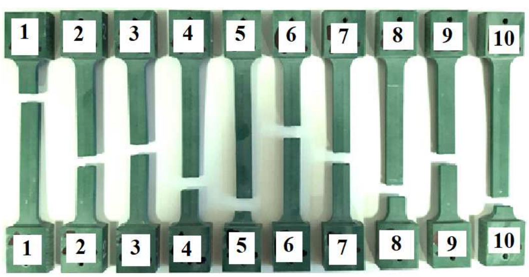


Fig. 3. LRX Plus type machine for plastics testing.



a – specimens before tensile stress



b – specimens required for traction

Fig. 4. Transversely machined specimens before and after tensile stress.

From the interpretation of the data, it is found that the values obtained for the 2 categories of specimens (transverse and longitudinally processed) are very close, the difference being 1.1%.

3.3 Tribological tests

The tribological tests were carried out on the Amsler A 135 test machine and were aimed at: determining the coefficient of friction at roll-shoe contact, determining the temperature variation at roll-shoe contact, and determining gravimetric wear.

3.3.1 Determination of friction coefficient

The tests were carried out under pure slip conditions. The Amsler friction coupling with contact on the cylindrical surface was used. The set of specimens consists of a movable cylindrical roller and a fixed shoe (Fig. 5). 5 determinations were performed for each set.

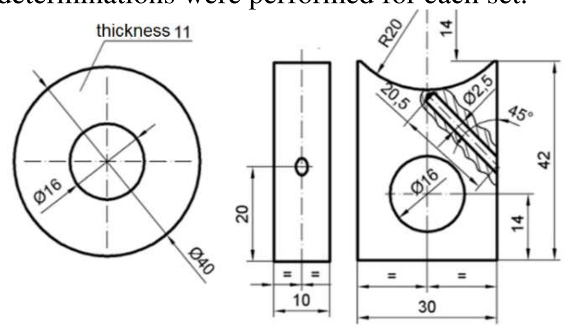


Fig. 5. Amsler specimens with a diameter of 40 mm.

The roller specimens were made of hard chrome plated AISI 4130 steel, and the sabot specimens were made of Necuron 1050 and bronze (GCuSn 14) SR EN 1982:2008 respectively (Fig. 6).

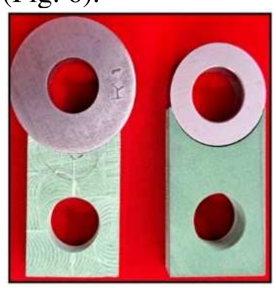


Fig. 6. Set of specimens (roll-shoe).

The maximum load applied to the shoe is 1471 N. The rotational speed of the roller is 200 rpm, which corresponds to a sliding speed of 0.42 m/s for the 40 mm diameter roller and 0.31 m/s for the 30 mm diameter roller.

The program of the experimental trials is presented in Table 2.

From the point of view of the test methodology, proceed as follows: load the installation with the load (N) and record the friction moment (M_f). Based on the measured value of the friction moment, determine the value of the friction coefficient with the relationship [4]:

$$\mu = (2 \cdot M_f) / (d \cdot N) \quad (1)$$

where: d is the diameter of the roller.

Table 2

Program of experimental tests for the determination of the coefficient of friction.

Type of test	Apparatus used and working environment	Type of specimen		Load
		Shoe	Roll	
Determination of friction coefficient	Amsler type A 135, air working environment	Necuron 1050	AISI 4130 hard chrome plated steel φ 30 mm	Different load values will apply: (196, 245, 490, 735, 980) N
		Necuron 1050	AISI 4130 hard chrome plated steel φ 40 mm	
		GCuSn 14	AISI 4130 hard chrome plated steel φ 40 mm	

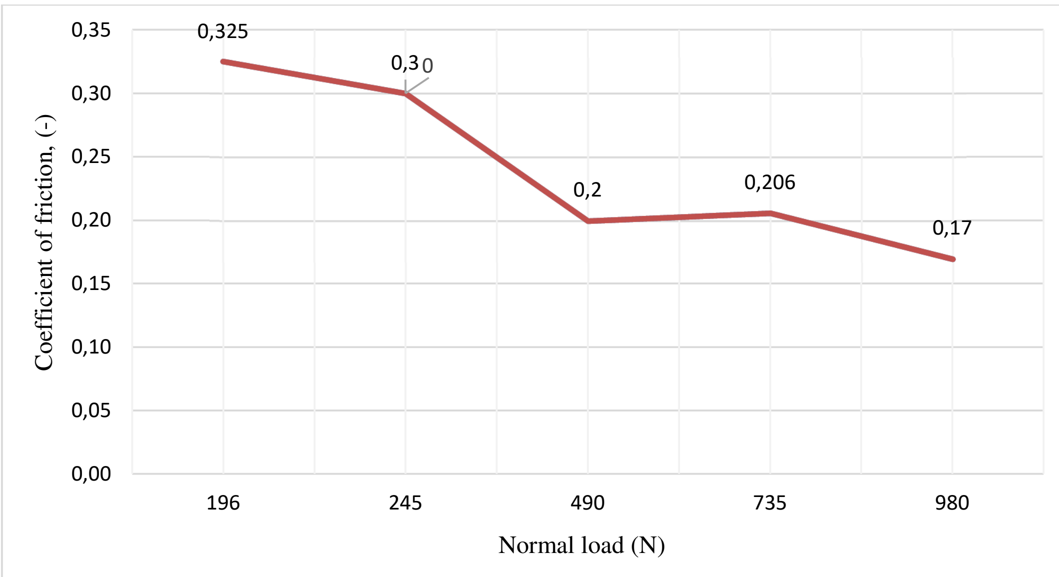


Fig. 7. Friction coefficient variation as a function of load for shoe made of Necuron 1050 and roll φ 40 mm made of hard chrome plated 4130 steel.

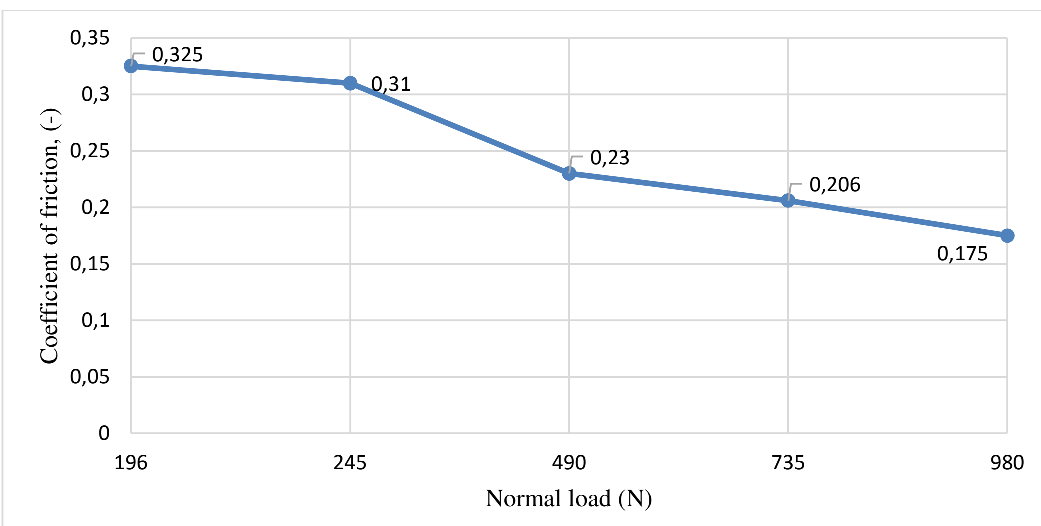


Fig. 8. Variation of friction coefficient depending on load for shoe of GCuSn 14 and roll φ 40 mm of hard chrome plated AISI 4130 steel.

Figure 7 shows the variation of the friction coefficients determined when testing the shoe made of Necuron 1050 and the roll φ 40 mm of hard chrome plated AISI 4130 steel for different loading loads: 196 N, 245 N, 490 N, 735 N, 980 N.

Figure 8 shows the variation of the friction coefficients determined when testing the shoe made of GCuSn 14 and the roll φ 40 mm made of hard chrome plated AISI 4130 steel for different loading loads: 196 N, 245 N, 490 N, 735 N, 980 N.

3.3.2 Determination of temperature variation at roller-shoe contact

By appropriate shoe construction (drilling, as shown in Figure 5) the temperature in the central shoe-roller contact area can be measured. For this purpose, a Cromel-Alumel thermocouple with a mantle diameter of 1.5 mm is used, having an accuracy of ± 1 ^{0}C (Fig. 9). The response time of the transducer is less than 15 seconds.

Fig. 9. Temperature measurement at roller-shoe contact.

The program of experimental determinations for establishing the temperature variation over time, at the roller-shoe contact includes tests performed on the Amsler type A 135 machine, the working environment being air. The shoe type specimen is made of Necuron 1050, respectively GCuSn 14 bronze, and the roll of hard chrome chrome AISI 4130 steel. For the roller specimen, 2 working diameters were used: φ 40 mm and φ 30 mm. The load applied was: (196; 245; 490; 735; 980) N.

Figure 10 shows the temperature variation over time for testing the material coupler, a shoe made of Necuron 1050 with φ 40 mm roller, made of hard chrome plated AISI 4130 steel, at a loading load of 735 N.

Figure 11 shows the temperature variation over time for testing the coupling of materials, a shoe made of bronze (GCuSn 14) with roll φ 40 mm, made of hard chrome plated steel AISI 4130, at a load of 735 N.

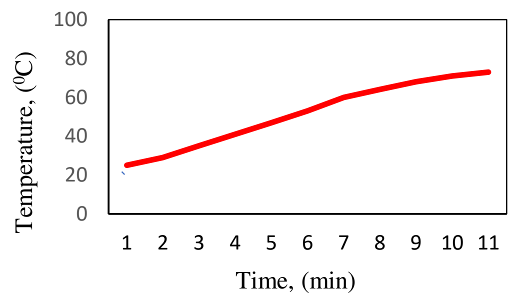


Fig. 10. Temperature variation over time for shoe in Necuron 1050 and roll φ 40 mm in hard chrome plated steel 4130, load 735 N.

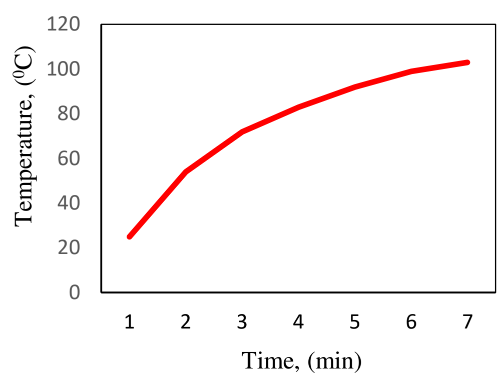


Fig. 11. Temperature variation over time for the shoe of GCuSn 14 and roll φ 40 mm, 4130 hard chrome plated steel, load 735 N.

3.3.3 Determination of gravimetric wear

The wear of the shoe samples was determined gravimetrically by weighing them at various time intervals using a Mettler H35 analytical balance, having an accuracy of 0.0001.

Before each weighing, the surfaces of the clogs were cleaned with methylethylketone, and then dried in warm air. Gravimetric wear was determined using the relationship:

$$u_i = m_0 - m_i \quad (2)$$

where: u_i is the gravimetric wear at time τ_i; m_0 – initial mass of the shoe; m_i – mass of the shoe at time τ_i.

Figure 12 shows the wear curve obtained when testing the sabot-type specimen made of Necuron 1050 with the 30 mm φ roller specimen made of hard chrome plated AISI 4130 steel at a loading load of 735 N. The initial mass of the shoe specimen (before testing) was $m_0 = 13.2098$ g, and after 30 minutes of wear stress, the shoe was weighed with mass m_{30} = 13.2027 g, indicating wear $u_{30} = 0.0071$ g.

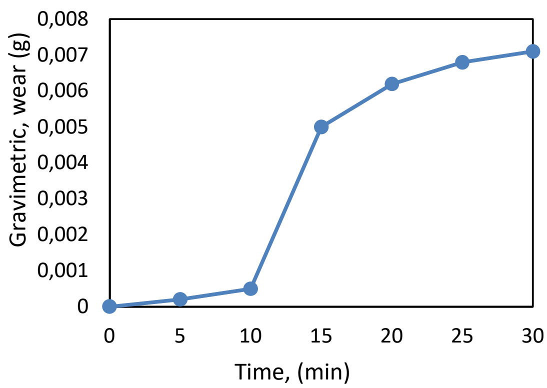


Fig. 12. Wear curve of Necuron 1050 by φ 30 mm at load of 735 N.

Figure 13 shows the wear curve of Necuron 1050 when tested with roll diameters ϕ30 mm and φ 40 mm, made of hard chrome plated steel AISI 4130 at different loads (490 N, 735 N and 1471 N).

Figure 14 shows the variation in wear over time of GCuSn 14. The roller-shoe coupling with diameters of φ 30 mm and φ 40 mm respectively was tested at different loads (490 N and 735 N).

After the wear determination tests, the microstructure examination of the roller-shoe test couplings was performed. The examination of the microstructure of the Necuron 1050 material was carried out by electron microscopy with the OLIMPUS V-CAMD-2 microscope.

The structure of the Necuron 1050 material consists of chemical compounds based on aluminium, phosphorus, silicon and iron oxides, with a dispersion of the chemical composition, placed in a phosphorus matrix, with the presence of zonally agglomerated pores.

Images of the microstructure of the Necuron 1050 material were taken with the magnification power (200x), to highlight the pores and chemical compounds in different areas of the investigated specimen (Fig. 15).

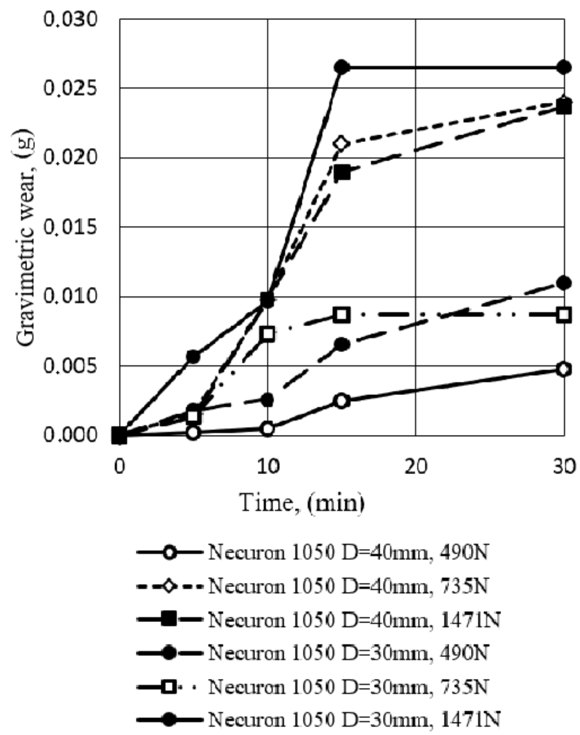


Fig. 13. Material wear curve Necuron 1050.

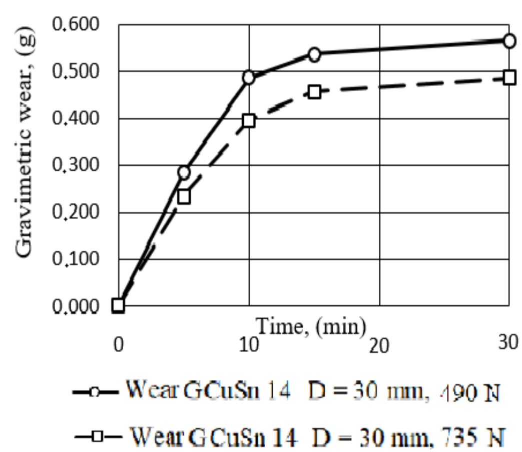
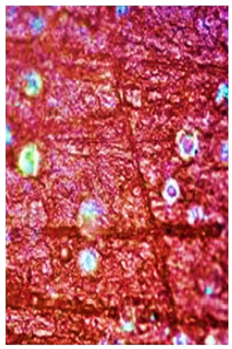


Fig. 14. Material wear curve GCuSn 14.

Images were taken before the wear test and after the wear test. From the analysis of the microstructure of the Necuron 1030 material (Fig. 15), after the wear test there were degradations of the roller-shoe contact surface, visualized by lines, which attests to the fact that the wear is of an abrasive type, which was produced by chipping the plastic material Necuron 1050 in contact with AISI 4130 hard chrome steel roller.

a – before the test



b – after the test

Fig. 15. Microstructure of Necuron 1050 material

From the analysis of the microstructure of AISI 4130 hard chromed steel, it was found that it shows no degradation due to wear tests, being homogeneous, with a fine structure (Fig. 16).

Fig. 16. Microstructure of AISI 4310 material

3.4 Interpretation of results

The objective of the work is to determine the mechanical and tribological characteristics of the materials Necuron 1050 and GCuSn14 for the purpose of their use in the manufacture of sliding bearings.

According to the plan of experimental determinations, two categories of tests were carried out: experimental tests regarding the determination of the resistance characteristics of the studied materials (Necuron 1050, GCuSn14) and tribological tests aimed at determining the coefficient of friction, the temperature at the roller-shoe contact and the determination of gravimetric wear by tests on the Amsler A135 machine.

The hardness test of the Necuron 1050 material was carried out on samples taken from the base plate in the transverse and longitudinal direction, obtaining average values of 84.4 Shore D (for the samples raised in the transverse direction), respectively of 85 Shore D (for the samples raised along the longitudinal direction). It is found that the hardness determined in the two directions does not vary significantly, the values obtained showing insignificant variations, which do not exceed 1.1 %.

The results of the experimental research, for the Necuron 1050 material, regarding the values obtained for the coefficient of friction, led to obtaining the following values: $\mu = (0.325...0.170)$. It is found that the values of the friction coefficient decrease with the increase of the loading force, the value $\mu = 0.170$ being obtained for the loading load $F = 980$ N. This fact is explained by the smoothing of the surface micro asperities under the action of the loading load and the self-lubricating properties of the material plastic. Similar results were obtained for the case of using the GCuSn14 material, where the friction coefficient values are between $\mu = (0.325...0.175)$.

From the point of view of temperature variation at the roller-shoe contact, through a suitable construction of the shoe, the temperature in the central contact area was measured. The variation of temperature with time for the Necuron 1050 shoe and the ϕ 40 mm hard chrome steel 4130 roller with the loading load $F = 735$ N resulted in a temperature $t = 60\ ^0$C recorded for the 7 min run time. In similar testing conditions of the GCuSn14 material, a temperature value of $t = 103\ ^0$C was recorded. This finding indicates that Necuron 1050 plastic exhibits a higher heat dissipation capacity during operation than GCuSn14 bronze.

Shoe wear was determined gravimetrically by weighing them at various time intervals using a type of Mettler H35 analytical balance. The results obtained because of the tests carried out are presented in figures 13 and 14. From the analysis of the obtained results, it is found that for the test of the material Necuron 1050 with ϕ 30 mm, at the loading load F = 735 N, for 30 minutes, the value of the recorded wear of was u = 0.0071 g.

Similarly for the material GCuSn14 with ϕ 30 mm, at the loading load F = 735 N, for 30 minutes, the wear value recorded was u = 0.4850 g, which means an increase of 68.3 times compared to the Necuron 1050 material. This finding indicates that the Necuron 1050 material exhibits better wear behavior under service conditions.

Therefore, comparing the behavior of the 2 studied materials in the typological tests, it can be concluded that the Necuron 1050 material has good sliding properties, smooth operation without seizing, low friction coefficient and low wear.

4. CONCLUSIONS

The results obtained because of the tests carried out allowed the following conclusions to be drawn:

- curves of variation of friction coefficients depending on the load determined when testing the constructed shoe of Necuron 1050 and of GCuSn 14 indicate insignificant variations, not exceeding 1.1%;
- the wear curves, when testing the shoe made of Necuron 1050 and GCuSn 14, show significant variations and indicate that the Necuron 1050 material performs much better at wear;
- temperature variation over time at roll-shoe contact, when testing the shoe made of Necuron 1050 and GCuSn 14 indicates higher values obtained for GCuSn 14 material (103 ^{0}C) compared to Necuron 1050 (60 ^{0}C), which indicates that Necuron 1050 material behaves better at temperature.

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CERCETĂRI PRIVIND COMPORTAREA TRIBOLOGICĂ A MATERIALUL NECURON 1050

În această lucrare se prezintă cercetările experimentale efectuate pe cuplele de frecare confecționate din materialele Necuron 1050 și GCuSn14. Cercetările tribologice efectuate au vizat determinarea coeficientului de frecare, determinarea variației temperaturii la contactul rolă-sabot și determinarea uzurii gravimetrice. Rezultatele cercetărilor experimentale, pentru materialul Necuron 1050, au condus la obținerea următoarelor valori: coeficientul de frecare μ = (0.325…0.170); uzura gravimetrică u = max. 0,0270 g, pentru durata de funcționare 30 min; temperatura la contactul rolă-sabot t = 60 ^{0}C pentru durata 7 min. Rezultate similare au fost obținute și pentru materialul GCuSn14: μ = (0.325…0.175); u = max. 0,5630 g; t = 103 ^{0}C.

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