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INVESTIGATION OF STRUCTURAL CHARACTERISTICS ON FERRITIC NODULAR CAST IRON

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Abstract: The linear form of graphite in gray cast iron is not favorable due to the weakening of the metal base and strong sources of stress concentration at the ends of the lamellae. Converting the lamellar form of graphite into nodular form is done by adding modifiers and pre-secreting smaller amounts of magnesium or cerium. In this way, the stress concentration due to graphite inclusions in nodular cast iron is significantly lower than in gray cast iron. “Nodular cast iron is a foundry pseudobinary alloy of iron and carbon, which was mostly excreted in the form of spherical graphite”. Depending on the structure of the metal base, the properties of strength and plasticity also depend, but certainly the shape, size and arrangement of graphite nodules has a significant influence. For these reasons, the size of graphite nodules is also determined, the highest values of the average nodule being from 50 to 10 µm. In this paper, a researched nodular cast iron with a ferrite structural base is given. The mentioned nodular casting was isothermally improved and tribologically tested, on a “pin and disc” tribometer. The obtained results are presented tabularly and diagrammatically.

Key words: Nodular casting, nodular graphite, tribology, coefficient of friction.

1. INTRODUCTION

The increasing need for higher quality products sets increasingly specific production requirements, for these reasons nodular cast iron is a material of abundant and diverse constructive value due to its outstanding technological and use properties. Extensive and diverse production and application is made possible by choosing the appropriate chemical composition of unalloyed or alloyed composition and structure with special properties. The possibility of efficient processing by various procedures, primarily thermal processing, contributes to the detailed improvement of the properties of ductile iron as well as to the expansion of the area of its application. Ferrite nodular cast iron is produced by the process of osmosis - trigger. For the production of melt in cupola furnaces in cold air for nodulation, it is very necessary to have a high-quality and well-sorted metal cartridge and a good quality of foundry coke.

The composition of the metal insert for EN quality 10027-1 (NL420):

– Steel waste 40%; low-manganese gray pig iron “sorrel” 40%; circular material NL 420 20%; ferrosilicon (F_eS_i) and briquettes 4 kg.

– Batch 5815-13 and other necessary accessories.

The values of properties of ductile iron (NL) lie between the properties of steel and those of gray iron, with the fact that ductile iron can be partially even hot and cold formed (rolled and forged, etc.). The advantage is that graphite is spherical in shape, and a sphere has the smallest volume at constant volume. In addition, the graphite spheres are not in contact with each other, so graphite can be considered compact, similar to vermicular cast iron. During the production of perlite nodular cast iron, the standard EN 10027-1 (NL420-12) was adhered to, its characteristics: tensile strength, plasticity limits and Poisson values. In addition to the above, we state that we adhered to the standard for the basic cast sample (SRPS EN 1563:2005).

The selected V4-mark cast sample refers to the tensile strength test specimen in accordance with the standard. Tribological tests were carried out on a tribometer with a measuring chain. The measuring chain of tribological tests contains the measuring equipment as well as the most important shown contact between the pin and the disk. The contact between the pin and the disk is shown in detail in the pictures. The results of the research are presented in tables and figures.

2. PROGRAM AND CONDITIONS OF EXPERIMENTAL RESEARCH

Isothermal improvement of nodular cast iron is a relatively new procedure that has been implemented recently. A more than two-fold increase in hardness compared to standard nodular cast iron is achieved without changing the values of toughness and ductility.

2.1. Chemical composition of nodular cast iron

Table 1. *Chemical composition*

Label	C	Si	Mn	Mg	S	P
Percentage share [%]	3,36	2,95	0,08	0,036	0,005	0,002

2.2. Mechanical properties

Tensile strength R_m=436,0 N/mm^2
Yield strength $Rp_{0,2}$=318,6 N/mm^2
Elongation after tearing A_5=19,8 %
Constriction after tearing Z=18,6 %
Average hardness HB=178
Impact fracture action K=15,8 J

2.3. Structural properties of nodular cast iron EN-GJS-420-12

Good mechanical properties of nodular cast iron are achieved by adjusted chemical composition, careful control of the production process and well-chosen and controlled heat treatment.

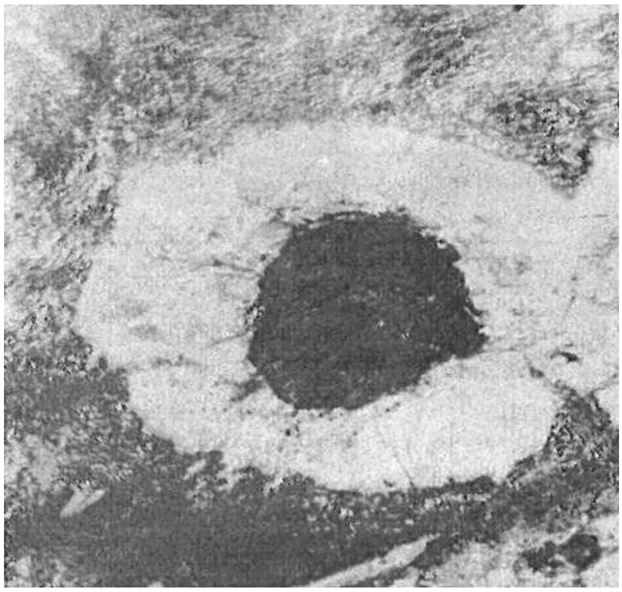

Figure 1. *Spherical graphite in a ferrite matrix of nodular cast iron En-GJS-420-12, magnification 250 times (Charge 5815-13), unetched*

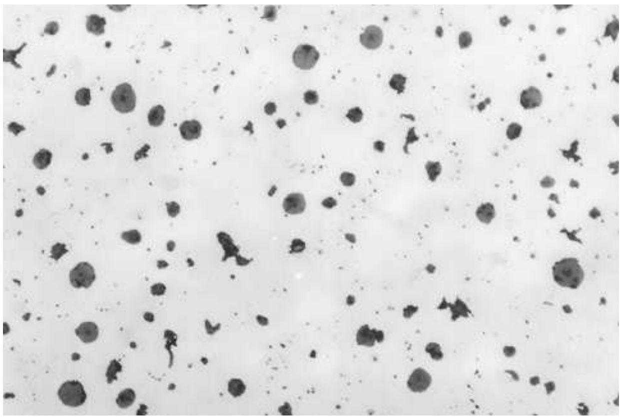

Figure 2. *Spherical graphite in a ferrite matrix of nodular cast iron En-GJS-420-12, magnification 100 times (Charge 5815-13), etched*

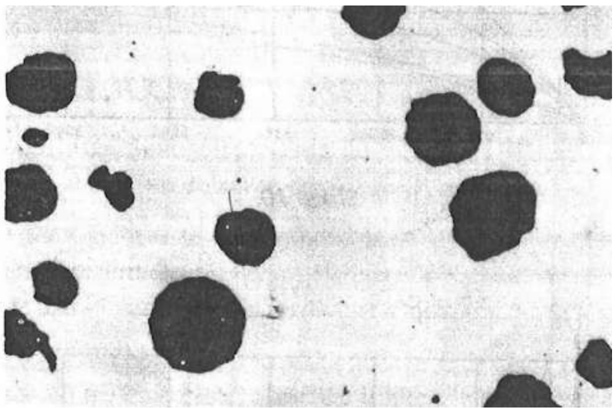

Figure 3. *Structural properties of ductile iron after isothermal improvement En-GJS-420-12*

2.4. Isothermal improvement of ferritic ductile iron En-GJS-420-12

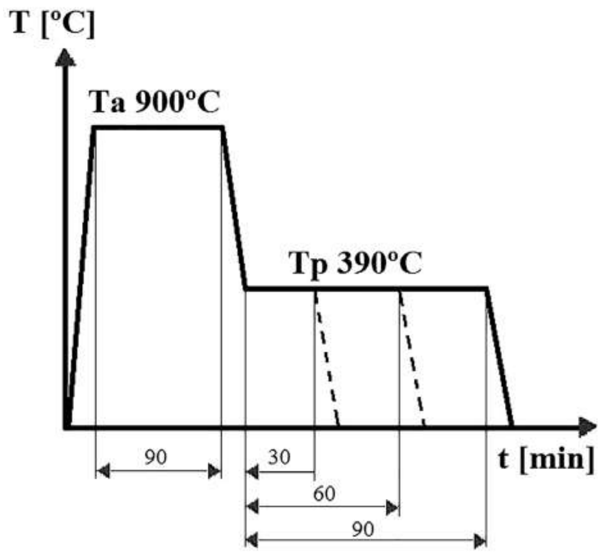

Figure 4. Diagram of isothermal improvement of ferritic ductile iron En-GJS-420-12

Isothermal improvement of nodular cast iron was carried out according to Figure 4, and consists of austenization to a temperature of 900˚C and a time of 90 min, sudden cooling to the isothermal transformation temperature of 390˚C, holding at that temperature (30 min, 60 min and 90 min) and then cooling to room temperature. Figure 5 shows the pin and disc used to conduct the experiment.

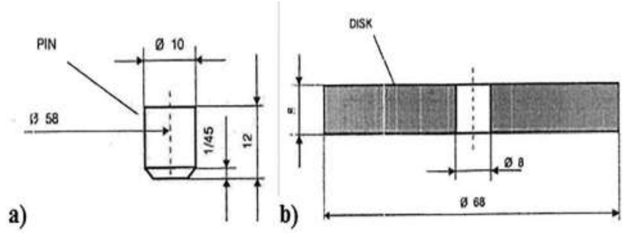

Figure 5. a) Pin tube and b) disc tube used in the experimental procedure

The test tubes in Figure 5a and 5b are made in accordance with the SRPS EN 1563:2005 (EN 10027-1) standard. The disc is made of nodular cast iron with a ferrite structural base with an average hardness of HB=368, while the pin is made of carbon steel with a guaranteed chemical composition of an average hardness of HB=468. This hardness of the steel pin is achieved by the tempering process.

Lubricating oil was used during the experiment. Lubrication in all conducted experiments and operations was carried out by passing the lower part of the disc through the lower bath, which contained the same amount of POLAR INA 55-k oil.

Figure 6 shows a tribometer with a measuring chain (tribometry parameters measurement). The material, shape and dimensions of the contact elements are chosen in accordance with the requirements of the research program. Figure 6 defines the geometric configuration that was used in the research, the results of which are given in the paper.

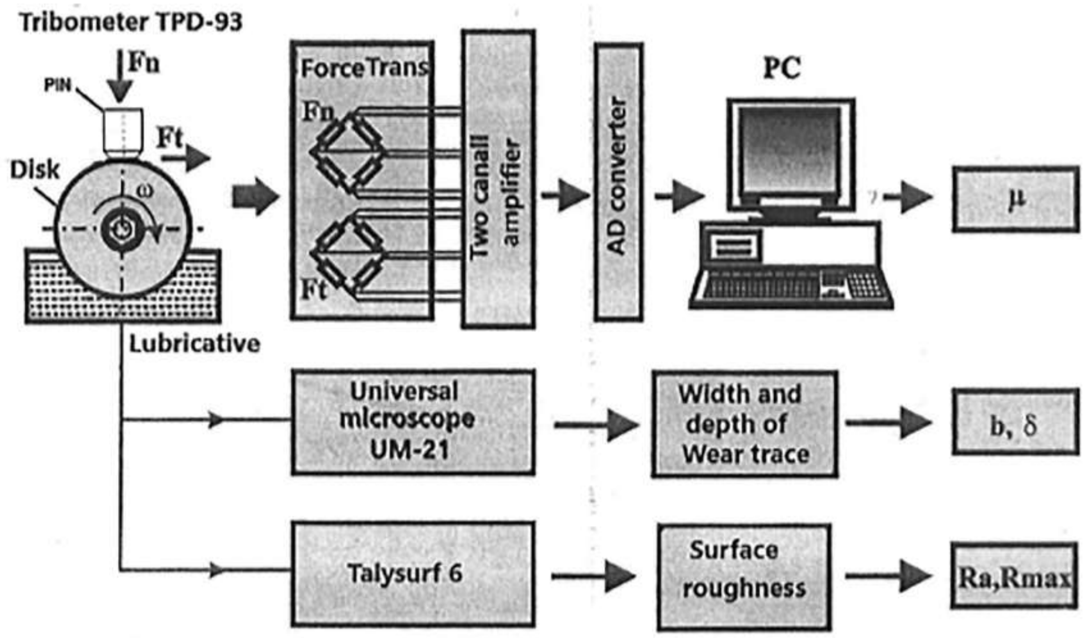

Figure 6. Tribometer with measuring chain (own production Ješić D. Tribometry parameters measurement)

From the sketch of the tribometer, the achieved contact between the pin and the disk is visible, and it is also visible from the picture that it is a linear contact with the presence of a third body, the polar INA 55K lubricating oil, and the amount of lubricating oil of Q =25, ml.

3. DISPLAY OF RESEARCH RESULTS

A modern approach to solving tribological problems in order to achieve optimal lubrication results, taking into account all the characteristics of the tribosystem. With such an approach between operations and the main aspect of tribology: economic, scientific-professional, interdisciplinary.

To solve the problem, it is important to know the structural characteristics of the tribological system.

The structure of the examined tribological system of the tribometer contains elemental contact:

- rotating disc made of material of isothermally improved nodular cast iron, hardness HB=368,
- fixed pin made of steel EN 10027-1 (Ck45, Č1531) with a ferritic pearlite structural base. The steel is hardened to a hardness of HB=468. The stated hardness is the average determined after 5 measurements.

With the possibility of bringing the lubricant to the contact zone under ambient conditions. Figure 5 defines the geometric configuration. Thanks to the modular construction of the tribometer, by changing the position of the drive disc (which represents the complete unit in relation to the contact load module), it is possible to realize the horizontal and vertical position of the disc, for the needs of certain modifications of the tribometer elements. In this way, in choosing the shape of the pin, the tribometer can be used in testing tribological phenomena with different elementary geometric schemes of testing the tribological system, in which normal contact is achieved:

- by surface,
- by line and
- on point.

This paper presents part of the research results, mainly on the dependence of the coefficient of friction and types of thermal processing of isothermally improved nodular cast iron with a ferritic structural base.

Figures 7 to 10 show the contact between the steel pin and the disc with different normal loads and different sliding speeds.

Figure 7 shows the loading materials as well as the time of isothermal improvement. Figures 7 and 8 show the softening temperature of 390°C and different softening times (30 min, 60 min and 90 min). Different normal load forces are visible. In Figure 7, F_n=7 daN and in Figure 8, F_n=24 daN. The sliding speeds V=1.9 m/s and V=1.4 m/s are visible.

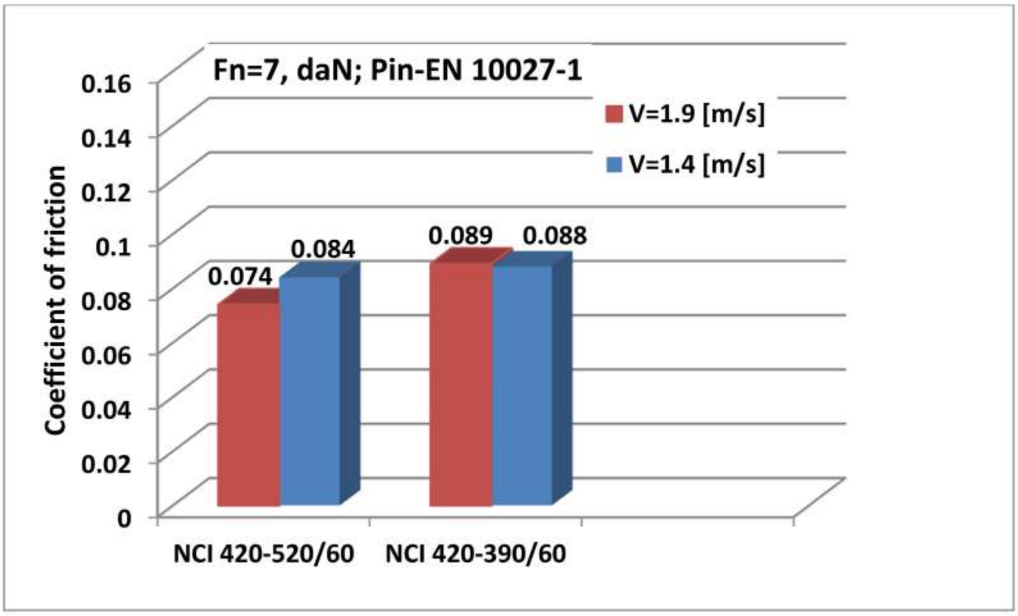

Figure 7. *The dependence of the friction coefficient with different types of isothermal improvement is shown*

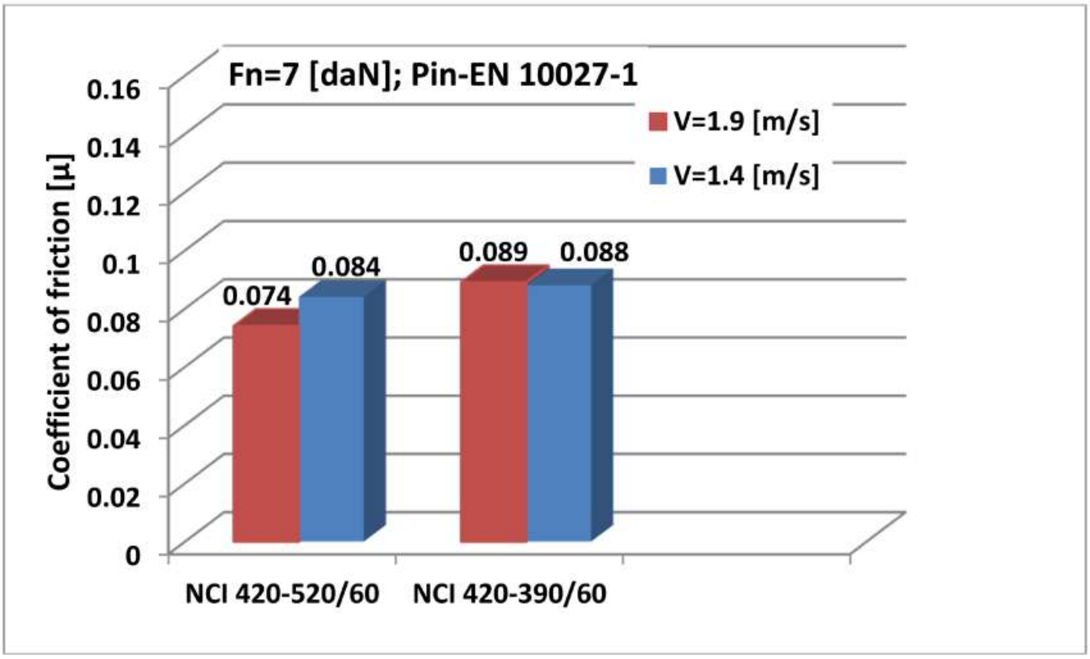

Figure 8. *The dependence of the friction coefficient with different types of isothermal improvement is shown*

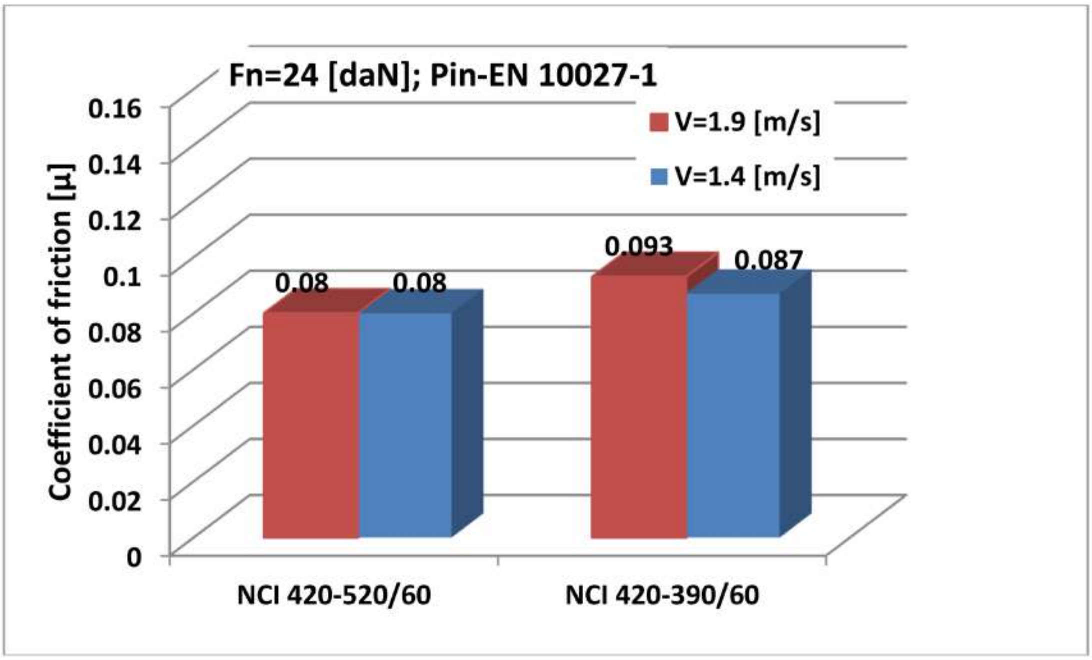

Figure 9. *The dependence of the friction coefficient with different types of isothermal improvement is shown*

Figure 9 and 10 show two materials obtained by classical improvement at a temperature of 520 °C and a softening time of 60 min. Yielding and isothermally yielded material 390/60. It is important to note the comparison between classical and isothermal nodular casting.

Figure 10 also compares classical and isothermal improvement of nodular cast iron. The loads are also different, for Figure 9 F_n=24 daN, while for Figure 10 F_n=7 daN, the sliding speeds are the same, and this can all be seen in the diagrams shown.

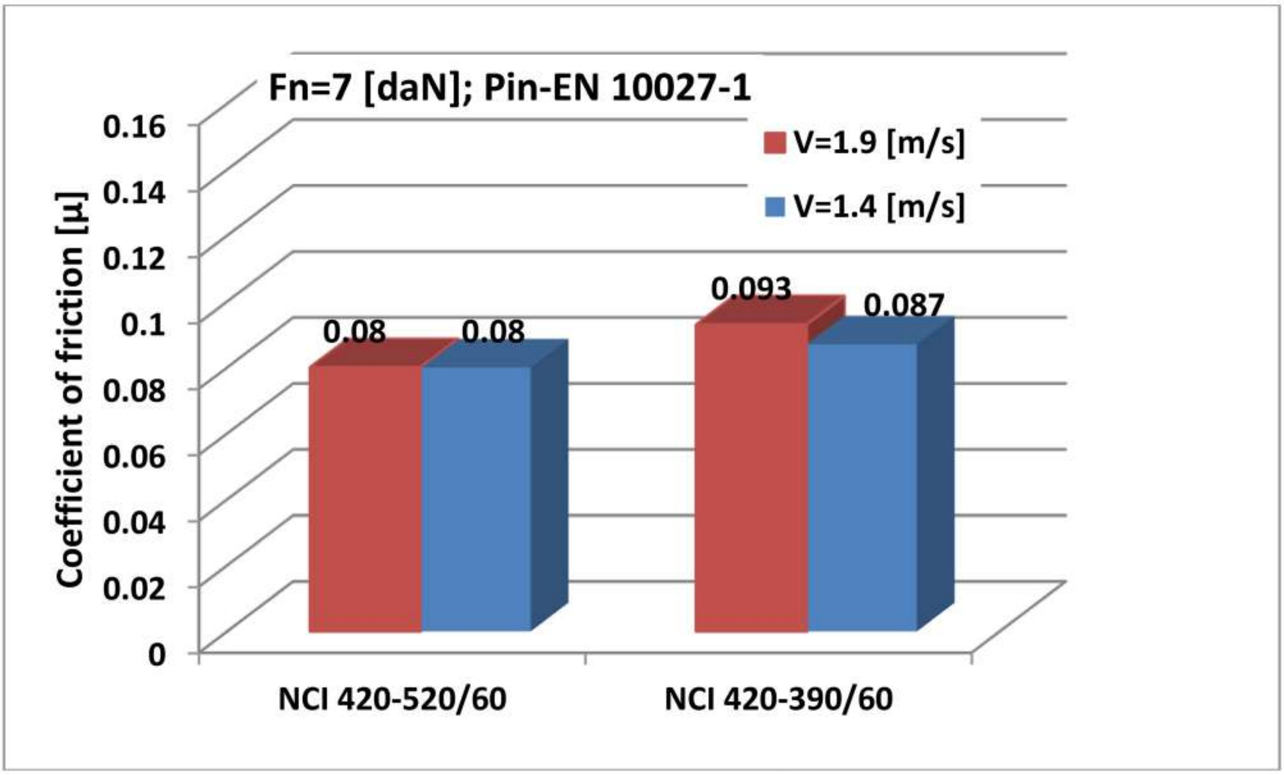

Figure 10. *The dependence of the friction coefficient with different types of isothermal improvement is shown*

4. CONCLUSION

In ferritic nodular casting, the success of nodulation is important, it is tested for each pot of nodular melt. In case of poorly successful nodulation, the castings are scrapped from that pot.

If it is a very valuable casting, the test is repeated on a double number of test thumbs made from a technological casting on that sample. If repeated tests give good results, the castings are accepted as satisfactory.

Isothermally improved nodular cast iron is a material whose properties can be varied in a wide range by choosing appropriate parameters such as temperature, time, chemical composition, cross-section, etc.

The test results show that with isothermally improved nodular cast iron, a structure of bainite and austenite can be created, which has significantly increased mechanical properties with increased resistance to wear, especially athesia compared to thermally untreated nodular cast iron. Figures 7 and 8 show the obtained friction coefficients, which are smaller at sliding speed V=1.9 m/s at low load. Selected loads variable at sliding speed allow a better choice of materials.

It can be seen in Figures 9 and 10 that in Figure 9 at higher load and higher sliding speed the improved nodular cast has better characteristics. The pictures show the characteristics of nodular cast iron and the very important structural composition of ferritic nodular cast iron and the number of inclusions, as well as proper nodulation, and especially the uniform diameter of the nodules.

It can be concluded that isothermal nodular cast iron NL 420 has increased wear resistance as well as the most favorable coefficient of friction at the isothermal transformation temperature of 390°C, with a softening time of 60 min.

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ИСТРАЖИВАЊЕ СТРУКТУРНИХ КАРАКТЕРИСТИКА НА ФЕРИТНОМ НОДУЛАРНОМ ЛИВУ

Сажетак: Линеарни облик графита у сивом ливу није повољан услед слабљења металне основе и јаких извора концентрације напона на крајевима ламела. Превођењем ламеларног облика графита у нодуларни облик врши се додавањем модификатора предизлучивањем мањих количина магнезијума или цера. На тај начин концентрација напона услед укључака графита код нодуларног лива је знатно мања у односу на сиви лив. „Нодуларни лив је ливачка псеудобинарна легура жељеза и угљеника који са претежним делом излучио у облику кугластог графита“. Зависно од структуре металне основе зависе и својства чврстоће и пластичности али свакако да је облик, величина и распоред нодула графита има значајан утицај. Из тих разлога се утврђује и величина нодула графита чије највеће вредности просечног нодула износе од 50 до 10 μм. У овом раду се даје истражен нодуларни лив са феритном структурном основом. Поменути нодуларни лив је изотермички побољшан и триболошки испитиван, на трибометру „пин и диск“. Добијени резултати се приказују табеларно и дијаграмски.

Кључне речи: Нодуларни лив, кугласти графит, трибологија, коефицијент трења.

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