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INFLUENCE OF MACHINING OF EN-GJL-250 AND EN-GJS-400 CAST IRONS ON TRIBOLOGICAL BEHAVIOR

In transport and, particularly in the case of the present study, naval industries, one of the major objectives of research on wear and friction is focused principally on solid lubrication. In the following paper, the tribological behaviors of two well-known, different cast irons, lamellar grey iron (EN-GJL-250) and spheroidal graphite ductile iron (EN-GJS-400), are compared and the results are analyzed. For each material's family, the surfaces' properties are characterized at different stages of the machining process. The particular influence of diverse feed rates in a turning facing is evaluated. Moreover, some tests of the laser cladding process, which contribute to the improvement of superficial properties, are carried out; therefore, the initial morphology before surface treatment is carefully characterized and evaluated in the context of subsequent adhesion qualification.

The final goal of the study is to deliver feasible initial information concerning two similar cast irons that are traditionally used in the naval industry, which would be manufactured and employed in the future as dry lubricated bearings.

Key words: Tribological behavior, grey cast iron, spheroidal graphite cast iron, friction, surface wear.

1. INTRODUCTION

Research on the tribological system has generated wide interest in the mechanical industry and, in particular, the shipping industry. This science provides fundamental knowledge about frictional forces, the morphological and physicochemical properties of two materials in their contact area, and, of course, information about wear and appropriate lubrication to reduce frictional forces and consequently avoid the premature failure of parts.

It is known that surface texturing is an option to achieve an improvement in the coefficient of friction, wear resistance, and especially in a high load capacity [1, 2]. This process is also appropriate for solid and hydrodynamic lubrication.

In the case of hydrodynamic lubrication, it is known that lubrication remains in the contact area until the final nanometers of the lubrication film are exhausted. At this point, the highest peaks of both surfaces are minimally separated. Cameron (1966)[3, 4] proved that for proper hydrodynamic lubrication between two plane surfaces in opposing contact, the fluid layer must reach at least the value of two times the combined roughness for both surfaces. In an effort to improve solid lubrication, the main influence of surface texturing has been studied to find better ways to remove waste abrasive.

Currently, there is an increase in research into solid lubrication [5-7]. Most of the studies go in the direction of getting better wear results by using layer deposition technologies. These deposition methods are critical, because an error during the addition of a lubricant layer could result in a layer detachment and in a subsequent part failure.

Focusing the research on cast iron, a material widely used in the naval industry, many previous studies have analyzed tribological applications, which included differences in oil lubrication and sliding motion [4]. Particularly, in the case of bearings, wear analysis is critical, because these parts function in sparsely lubricated conditions during sliding[8], a process that carries the surfaces into minimal film lubrication [6]; during these events there can be delayed lubrication or lubricant failure, which leads to wear collapse [7].

Available information suggests that the wear response of materials is controlled by a number of material and operating conditions [7], such as the contact areas and the surface settings, the existence of lubricant between surfaces, and knowledge of lubricant properties like morphology and physicochemical composition [8]. These factors increase the difficulty of analysis.

It becomes imperative to analyze the wear characteristics of materials on a case-by-case basis, in order to arrive at a more realistic assessment of wear performance [9]. Accordingly, the present study endeavors to examine the sliding wear behavior of two well-known cast irons (EN-GJS-400 spheroidal and EN-GJL-250 grey), widely used in bearing manufacturing. Both materials are tested under the same conditions, speed, applied load, and distance, but with changes to the initial surface conditions. Testing a variety of initial surfaces textures, using a machining process, should yield information about wear mechanism and the response of materials during load service. This research must be considered as a first step in future work regarding solid bearing lubrication, for the manufacture of parts for ships.

2. MATERIALS AND METHODS

As has been noted previously, in this paper two well-known cast irons are used. The main reason for using a grey and a nodular cast iron comes from the requirements of the naval industry. These two materials are extensively used in the manufacture of ship parts, especially for parts under high-wear demand such as bearings [10, 11].

Table 1.

Composition and mechanical properties for steel [12]

EN GJL 250	EN GJS 400	
2,8-3,3	3,25-3,7	**% C**
1,2-1,7	2,4-3	**%Si**
0,8-1,2	0,1-0,3	**%Mn**
< 0,15	< 0,08	**%P**
< 0,12	< 0,02	**%S**
7,2	7,2	**Density**
> 250MPa	370	**Tensile Strength**
190-240	140-210	**Hardness Range**

These two types of cast iron are supplied as steel rods delivered directly from a foundry with a certified document. After a machining process to clean rod surfaces, steel will be used to get the specimens tested on the tribometer. A CNC turning machine has been utilized to manufacture the samples, in this case only to make facing operations on tested faces and section rods. The machining conditions and geometry were defined as follows:

Table 2.

Machining conditions for specimens initial surface parameter

Material	F (mm/rev)	V_0 (m/min)	S (rpm)
EN GJL 250	0,05	30	300
	0,1	30	300
	0,2	30	300
	0,4	30	300
EN GJS 400	0,05	30	300
	0,1	30	300
	0,2	30	300
	0,4	30	300

The main objective of changing the feed speed on each disc was to create different initial surface conditions, which must be measured in order to be introduced as input variables for tribological tests. In addition, as can be observed in Figure 1, a little slot

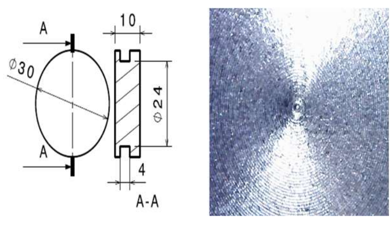

Fig. 1. a.)Disc geometry. b.) Texturized surface (f=0.4mm/rev)

has been made on the discs in order to get a fixation area for the tribometer and establish a wide test area on the facing. In any case, this slot should not affect the tests.

Table 3 indicates the textured surfaces that resulted from the tests.

Table 3.

Results for textured surfaces, acording ISO 4289 [13]

Material	Feed (mm/rev)	Ra (µm)	Rq (µm)	Rsk	Rku	Rt (µm)
EN-GJL-250	0,05	1,05	1,82	-4,427	8,48	19,26
EN-GJL-250	0,1	0,6	0,73	-0,088	1,15	4,14
EN-GJL-250	0,2	1,39	1,73	1,016	1,39	7,88
EN-GJL-250	0,4	3,06	3,56	0,622	0,928	13,94
EN-GJS-400	0,05	0,89	1,19	0,397	1,96	8,17
EN-GJS-400	0,1	1,34	2,07	-1,905	3,1	12,05
EN-GJS-400	0,2	1,65	2,3	-0,988	1,64	11,77
EN-GJS-400	0,4	3,29	3,9	-0,28	0,94	18,51

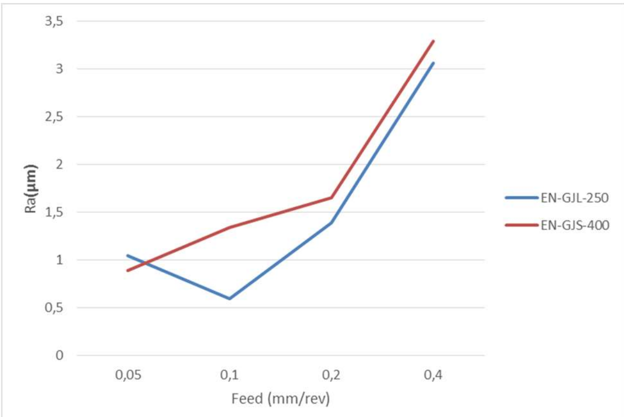

Fig. 2. Connection between feed speed and roughness

The main part of the surfaces is characterized by a negative skewness, and a slightly less high curtosis, as shown in Figure 2.

Paired with the cast iron, 4 mm. diameter steel balls are checked. These balls are a commercial AISI 420 inox alloy. Each par ball-disk was tested on a MI60NI pin on disk tribometer. For all surface conditions, Table 4 indicates the tribometer parameters.

Table 4.

Test conditions for tribometer

Force (Nw)	N (rpm)	Ø (mm)	V (m/s)	Distance (m)
40	200	24	0.04	300

Where force is the value of the perpendicular force applied on the ball, the nominal force is reached by applying standardized loads. N is the spindle speed, Ø is the diameter of the arc described on the disk, which results in the lineal speed for each test. In the test, lineal speed is very slow, because tests were made using no lubrication. Finally, the distance is the maximum value, in meters, reached in the tests. Sometimes this value is not reached, because the wear of pin and disk is excessive, and the spindle stops as a security measure, but in this case the pin has had low wear, and in all cases the experiment has measured distance. The tests have been conducted at room temperature in a controlled metrological laboratory.

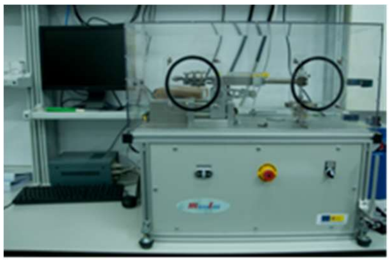

Fig. 2. Tribometer MI60NI

3. RESULTS AND DISCUSSION

Table 5 shows surface results for a groove created on the iron specimens:

Table 5.

Surface results for groove on specimens.

GJL-250	Sa(µm)	SQ(µm)	Sz(µm)	Ssk	Sku
0,05	12,7925	15,295	67,0025	0,715	2,52
0,1	13,5925	16,275	73,1975	0,65	2,5025
0,2	14,66	17,375	77,1625	0,5725	2,3475
0,4	14,5475	17,1525	78,0325	0,5675	2,3325
GJS-400					
0,05	14,2825	17,085	80,4275	0,52	2,435
0,1	13,725	16,4725	77,74	0,55	2,4475
0,2	13,19	15,6425	69,515	0,615	2,355
0,4	13,655	16,05	67,165	0,555	2,235

Ssk shows a high degree of symmetry for surfaces about the mean plane. The measurements are positive, indicating the predominance of peaks in tested specimens [14].

In Sku, the results describe a gradual variation, a groove free of extreme peaks or valley, which indicates either peak or valley defects on the surface.

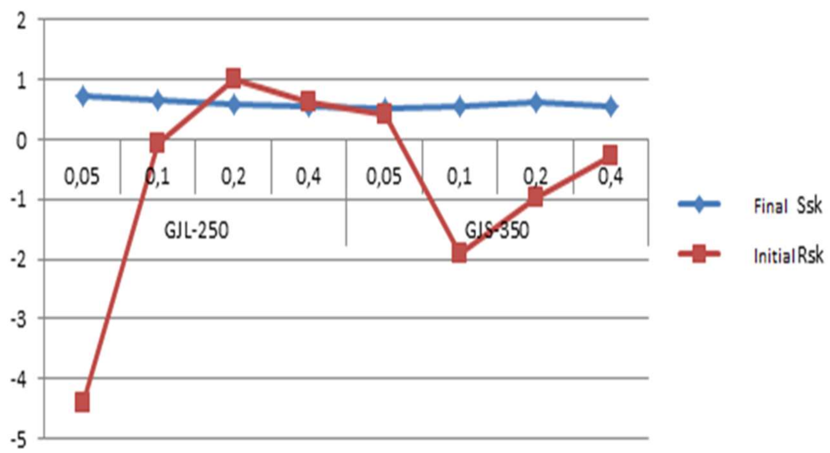

Fig. 4. Groove Ssk compared with initial Rsk values

As can be observed in Figure 5, due to friction, the Ssk value is smoothed.

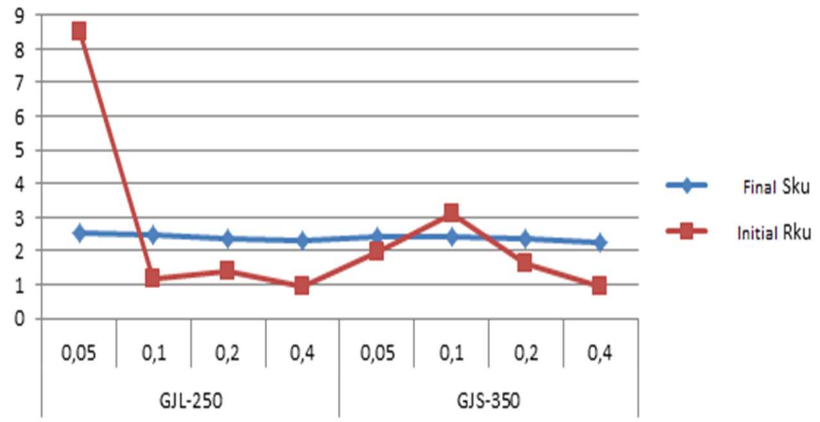

Fig. 5. Groove Sku compared with initial Rku values

According to Sku, tested surfaces are more homogeneous as initial values measured as Rku.

In the following tables, maximum wear is represented. As can be observed, the first material GJL-250, gets a high wear value, representing a more soft iron. This fact could be an inconvenience for a future cladding process, because this cast iron will be covered with a lubricating layer.

Table 6.

Surface results for groove on specimens.

GJL-250	
F(mm/rev)	**Groove depth**
0,05	0,53
0,1	0,77
0,2	0,52
0,4	0,78

GJS-400	
F(mm/rev)	**Groove depth**
0,05	0,66
0,1	0,44
0,2	0,34
0,4	0,46

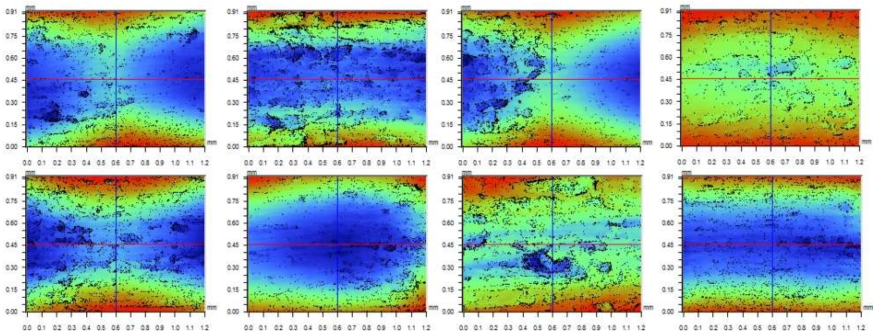

Fig. 6. Visual results on specimens after wear tests.

Table 7 represents the friction coefficient for both cast irons. In this study, the sliding speed is the same in each case, but the objective was to analyze differences between initial surface textures.

Table 7.

Difference of friction, depending on facing feed speed and initial measured Ra values

GJL-250	μ	Ra (μm)
F= 0,05	0,66	1,05
F= 0,1	0,76	0,6
F= 0,2	0,64	1,39
F= 0,4	0,7	3,06

GJS-400	μ	Ra (μm)
F= 0,05	0,68	0,89
F= 0,1	0,62	1,34
F= 0,2	0,68	1,65
F= 0,4	0,76	3,29

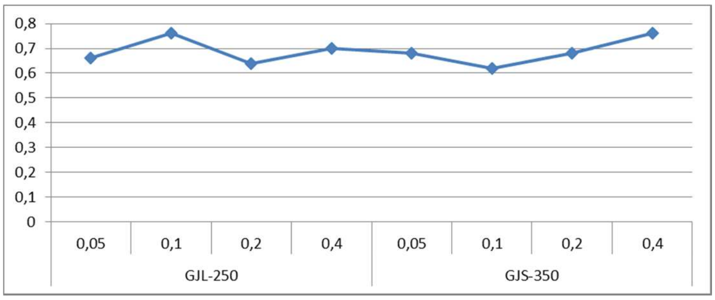

Fig. 7. Friction parameter for cast irons

As can be observed, the coefficient does not have a high increment, depending on surface textures; however, as should be expected, the higher values are reached in the case of 0.4mm/rev values, according to the higher initial Ra values. An unexpected value of μ= 0.76 is reached in the case of F=0.1mm/rev, probably due to porosity on the tested surface, which is related to the manufacturing process of the iron.

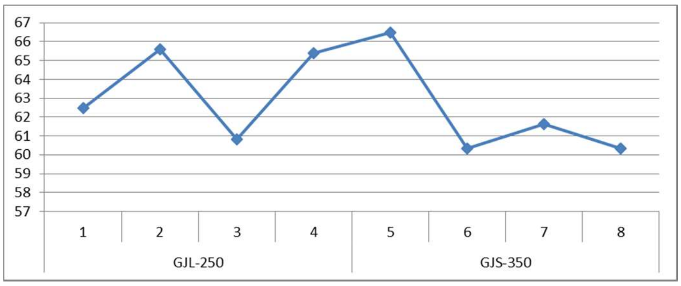

Fig. 8. Max. temperature reached in each test.

Analyzing temperature, the values observed ranged from 60º to 67º. The interval is not very wide and shows a good repeatability, independent on the material and initial Ra; however, as in the case of μ, it is impossible to find a trend, based on initial parameters.

The par in these experiments has only superficial waste, and the round geometry did not vary at all. Moreover, in a few cases, the balls increased their surfaces by iron stitching due to friction.

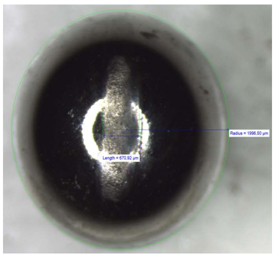

Fig. 3. Wear on par ball

4. CONCLUSIONS

This study provides a basis for the selection of cast iron for wear applications in the naval industry. In future work, the same materials will be tested with a solid lubricating layer, added by laser cladding.

Two different cast irons, with four different surface textures, were tested in a pin on disk machine. The tests have shown that, the higher the machining feed, the higher the initial Ra measurements and the friction coeficient (μ). However, due to the cast process, the presence of dimples sometimes forces μ to reach unexpected values.

By analyzing the grooved surface after the tests, it can be concluded that the par causes a smoothing on iron specimens, as can be observed in Ssk and Sku values.

In images of the ball, the circular geometry barely varies, and there is no observable high wear. Sometimes an increase in the ball radius is shown, but this difference probably comes from stitching on the par surface. The presence of iron on the ball is attributable to friction.

For future work, this study has found that iron GJS400 is harder than GJL250; so for solid lubricating bearings, this material would perform better as a substrate covered with a soft material layer.

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