Serbian Tribology Society

SERBIATRIB '15

14th International Conference on Tribology

University of Belgrade, Faculty of Mechanical Engineering

Belgrade, Serbia, 13 – 15 May 2015

THE INVESTIGATION OF FRICTION AND WEAR CHARACTERISTIC OF CAST IRON AGAINST MANGANESE PHOSPHATE COATED AND AUSTEMPERED COMPRESSOR CRANKSHAFT

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Abstract: *Refrigerator is one of the important technological household appliances, and as a result of increased energy cost, efficiency has become a subject of great importance in refrigerator industry. Compressor is the most important cooling device in refrigerator which effects cooling performance. Reduction of frictional losses in the compressor where the relatively moving elements exist is of great importance in this respect. In the present study, austempered and MnP coated ductile cast iron's friction coefficient and wear loses when works conjugate with gray cast iron crankshaft bearing has been investigated experimentally for both dry and boundary lubrication condition with different speed and load conditions.*

Keywords: *austempered cast iron, crankshaft, compressor, MnP coated cast iron.*

1. INTRODUCTION

Technological advances have led to a change in the home life largely as it affects every aspect of human life. When the technological household appliances have changed in many ways with the liveable life into our lives and has become easier. Refrigerator is the one of the wide spread technological household appliances which has important role for healthy and longer storage of food. Nowadays, as a result of increased energy cost, efficiency has become a subject of great importance in refrigerator industry. Compressor is the most important cooling device in refrigerator which effects cooling performance. Reduction of frictional losses in the compressor between relatively moving surfaces is of great importance in this respect.

Cast irons are used many industrial applications for many years because of the thermal conductivity, good machinability, vibration damping ability, good strength properties and wear resistance. Moreover, cast irons are used in automotive industry as piston, cylinder liner, clutch and brake system because of these properties, and their tribological behaviour are analyzed for this applications [1,2].

Gray cast iron and ductile cast iron are widely preferred for compressor crankshafts because of easy manufacturing, cost and high wear resistance properties. Also in order to improve some properties of iron, some elements adapted to material as Ni, Cu, Cr and Mo and some other process can be applied as austempering, quenching and coating. Aluminium, bronze, copper-lead alloys and bronze-phosphate alloys are used as crankshaft bearing material.

At the literature research, studies of friction and wear behaviour of different cast iron's in comparison [3-6], and investigations of heat treatment affects on tribological behaviours of cast iron’s [7,8] have found. These studies carried out in dry friction conditions. In work carried out by Yavuz and others the boundary friction case has also taken into consideration [9].

In our study, materials were coated and heat treated to reduce friction coefficient and wear loses on compressor crankshaft and these values were studied on pin-on disk test apparatus.

In the present study, austempered and MnP coated ductile cast iron’s friction coefficient and wear rates when works conjugate with gray cast iron crankshaft bearing has been investigated experimentally for both dry and boundary lubrication condition.

2. TEST APPARATUS AND MATERIALS

2.1 Test apparatus

A commercially available block-on-ring apparatus was used to determine the friction and wear properties of test specimens. The representation of the experimental setup is given schematically in Figure 1. As shown in Figure 1 normal load acting on the stationary test specimen is applied through the load holder by using dead-weights. Pin mounted to the specimen holder so that the cylindrical outside surface of specimen will be in line contact with the disk as seen from Figure 2. The frictional force formed between the test specimen and the disk during sliding motion was measured by a force transducer placed on the pin holder. The force transducer has a load range ± 200 N with a sensitivity of ± 2 mV, which is equivalent to a maximum ± 0.1 N error in the measurements. The counterface was driven by a D.C. motor in 30-800 rpm (0.1-2.5 m/s) variable speed range. The wear experiments were carried out on the basis of loss of mass measured with a scale 0.0001 g in accuracy.

2.2 Materials

Two different disks were prepared with two different methods for experiments; first one is GGG40 ductile cast iron which was austempered, and the second one is the GGG40 ductile cast iron which was MnP coated. SEM images of these disks showing their internal structure is given in the Figure 3. The counterface was manufactured a cylindrical shape with a width of 15 mm and a diameter of 60 mm. Surface roughness values of these disks are given in Table 1. The pin were made of GG25 gray cast iron having 12 mm diameter and 10 mm in length.

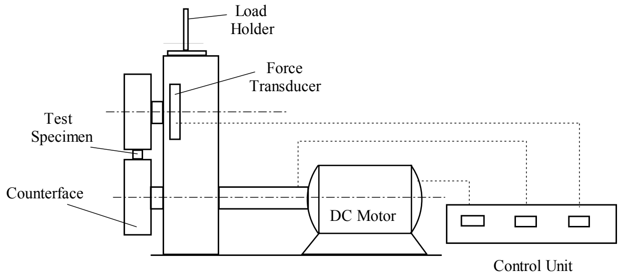

Figure 1. Principle diagram of the test system

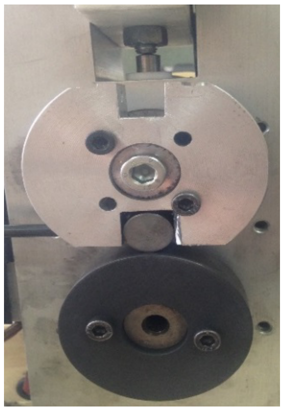

Figure 2. General view of pin and disk

Table 1. Surface roughness of materials

Material	Surface roughness, *Ra* [µm]
MnP coated disk	1.05
Austempered disk	0.36

Additionally, hardness values of materials used for pin and disk materials were also determined since the hardness of metallic materials may have a critical influence on the tribological characteristics of these relatively moving surfaces. Results of hardness tests are given in Figure 4 in HV scale.

2.3 Experimental procedure

The experiments were carried out in the 18 – 20 °C environmental temperature and

50...60 % relative humidity. Before the experiments, both counterface and pin surfaces were cleaned with carbon tetrachloride. The force transducer was adjusted to initial value at the beginning of each experiment. To investigate the effect of sliding speed and normal load on friction coefficient, 10 different sliding speed (0.2 – 2 m/s), and three different normal load (10, 20 and 40 N) values were studied. The variations of friction coefficient with respect to sliding speed were recorded at dry and boundary lubricated conditions. The properties of compressor oil which was used on boundary layer condition are shown in Table 2.

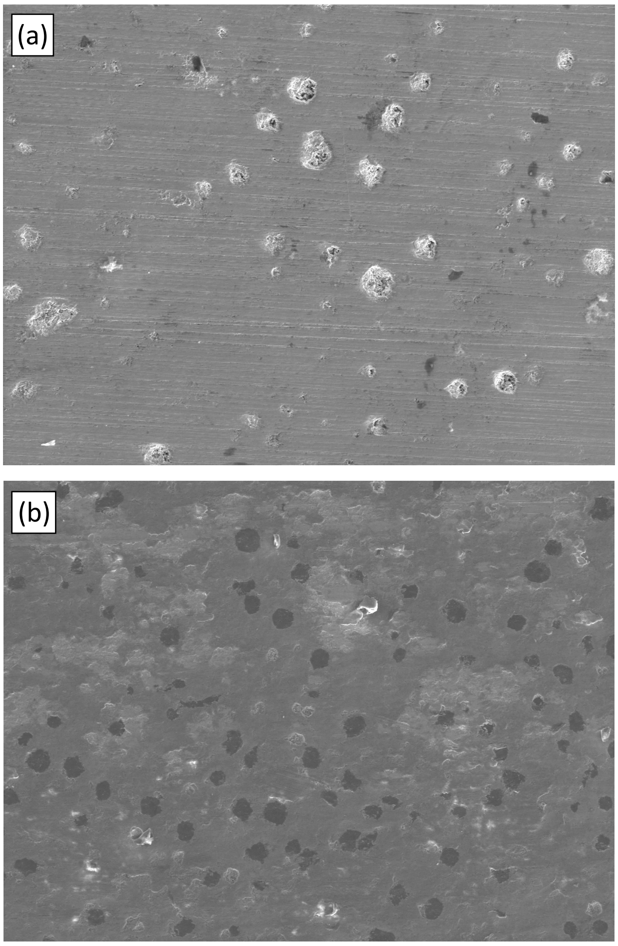

Figure 3. SEM images of disks surface, 250 ×: (a) austempered and (b) MnP coated

Table 2. Properties of compressor oil

Oil	Density at 15 °C [kg/m^3]	Kinematic viscosity at 40 °C [mm^2/s]	Kinematic viscosity at 100 °C [mm^2/s]	Yield point [°C]
WF 5 A	827	5.0	1.7	– 45

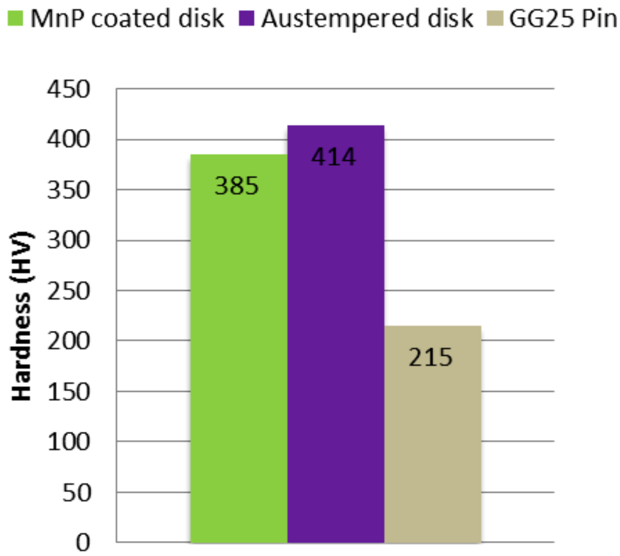

Figure 4. The variation of materials hardness

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Friction tests

As a result of systematical experiments, at first step the variations of coefficient of friction with sliding speed were determined in both dry and boundary lubrication conditions. These variations presented in Figures 5 and 6 for MnP coated and austempered disk, respectively. Experiments were repeated under 10 N, 20 N and 40 N normal loads.

As seen from Figures, MnP has a constant friction coefficient after 0.6 m/s sliding speed, and after this speed value its friction coefficient remains constant. In general, as the normal load increase, the resulting coefficient of friction decreases to a some. Magnitude of sliding speed does not affect the value of friction coefficient remarkably.

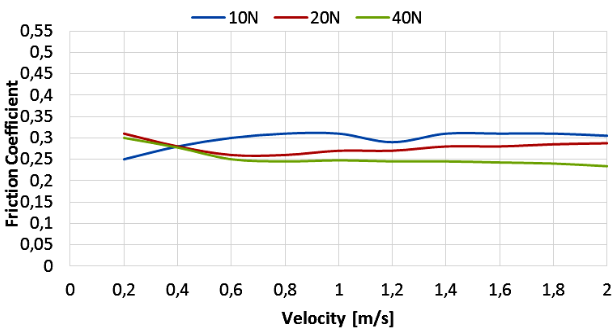

Figure 5. Friction coefficient of MnP coated disk on dry conditions

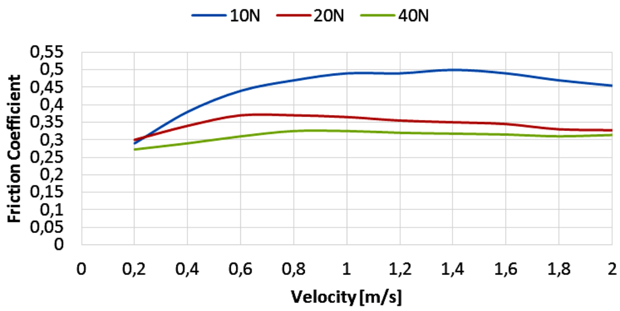

Figure 6. Friction coefficient of austempered disk on dry conditions

As seen from Figure 6, the friction coefficient of austempered ductile iron disk increases with increasing sliding speed for low values of speed. After a certain speed around 1 m/sec, variation coefficient of friction with sliding speed diminishes. The change of friction coefficient with normal load takes place similarly with former disk. As the normal load increases, resulting friction coefficient decreases. Friction coefficient reduces at a lower rate from 0.6 m/s on 20 N and 40 N load conditions.

On Figures 7 and 8, the variations of friction coefficients of MnP coated disk against same pin on boundary lubrication conditions. MnP coated cast iron has a stable curve for all load conditions. Friction coefficient does not change remarkably with speed.

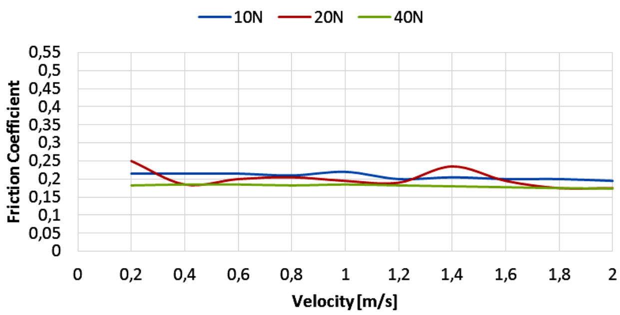

Figure 7. Friction coefficient of MnP coated disk on boundary lubrication conditions

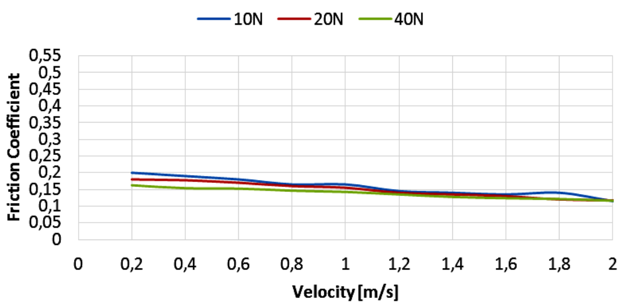

Figure 8. Friction coefficient of austempered disk on boundary lubrication conditions

Friction coefficients of austempered ductile cast iron decreases as the speed increase for all normal load conditions. Variation curves seems almost identical for all cases. The reason for this condition is the lubricating effect of compressor oil.

As seen from Figure 9, austempered ductile cast iron has better friction coefficient from MnP coated ductile cast iron for all normal load conditions. In particular, the difference increases with the rate of speed increase in 10 N and 40 N load conditions.

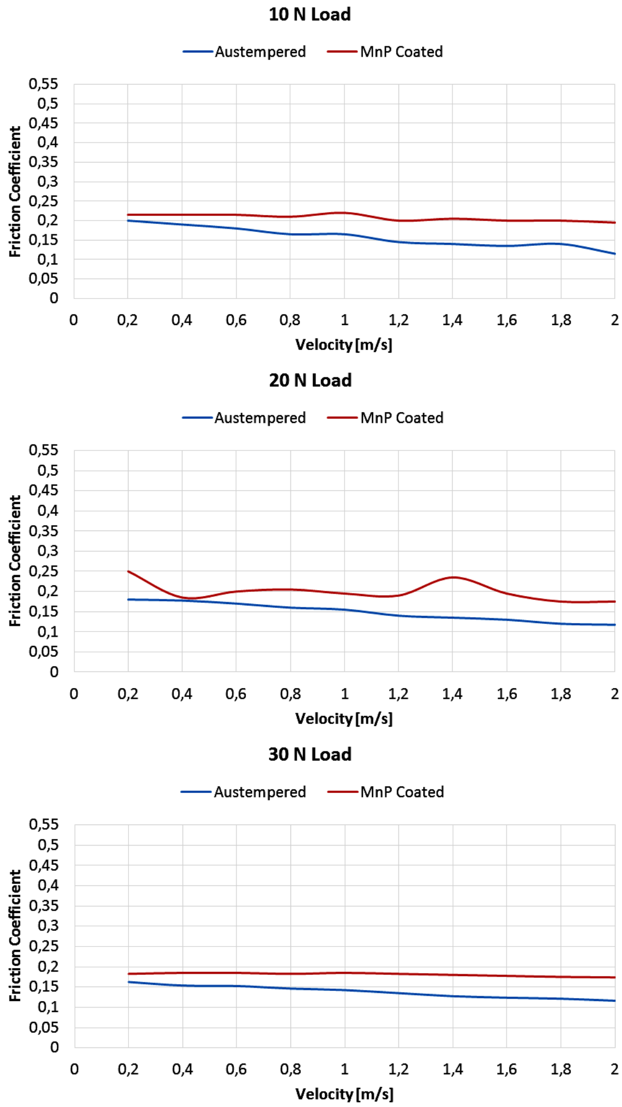

Figure 9. Comparison of disk materials on different normal load conditions

On boundary lubrication condition, friction coefficient of MnP coated ductile cast iron decreases when compared dry running conditions as expected, but the decrease on austempered ductile cast iron is much more drastic.

Austempered ductile cast iron gives a little bit small coefficient of friction values with respect to MnP coated one (Fig. 10).

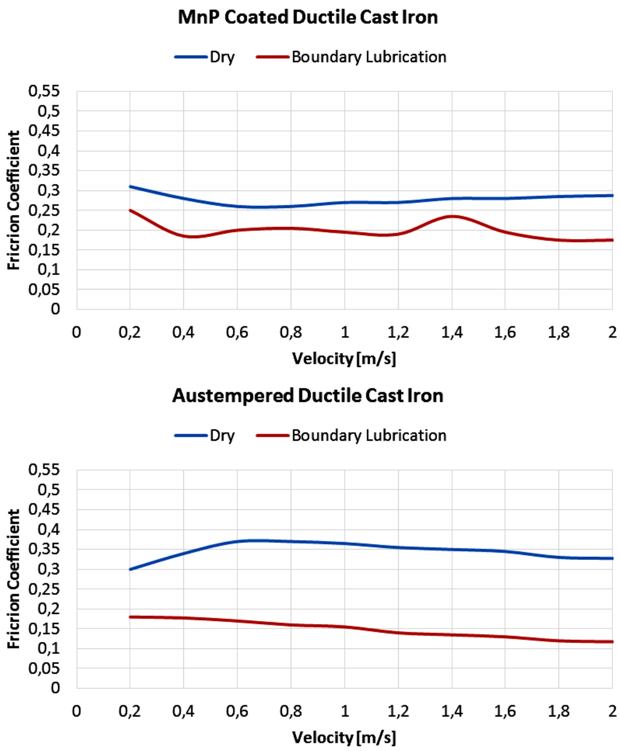

Figure 10. Comparison of test materials on dry and boundary lubrication conditions

3.2 Wear tests

Wear tests were performed with 20 N normal load, 0.5 m/s sliding speed and 3000 m sliding distance on dry running conditions. The variation of the friction coefficient along the sliding distance is shown on Figure 11. There is no significant changes on friction coefficient with sliding distance as can be seen from the Figure. Result of wear tests is given in the

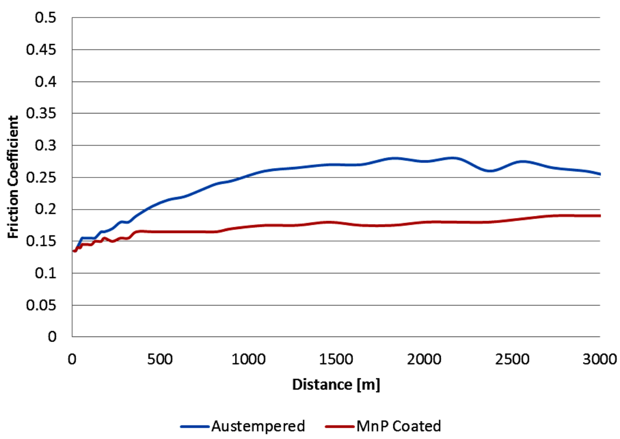

Figure 11. Variation of friction coefficient during a wear test

Figure 12 as mass loss. It has been observed that the pin material showed more material loss when sliding against austempered disk when compared to sliding against MnP coated disk.

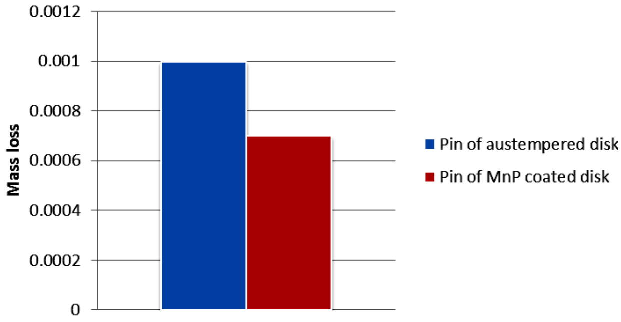

Figure 12. Mass loss on pins

An example of wear traces of pin can be seen in 250 × SEM image of pin, on Figure 13. In Figures 14 and 15, optical micrographs of worn pin sliding against MnP coated and austempered cast iron disks are shown respectively. In these micrographs, wear marks are clearly visible.

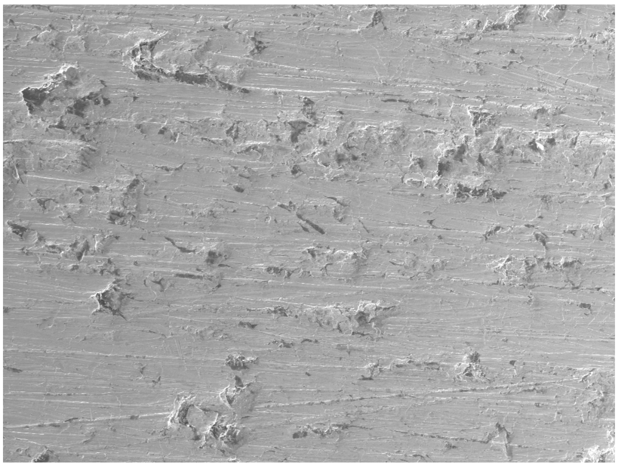

Figure 13. Wear traces on pin

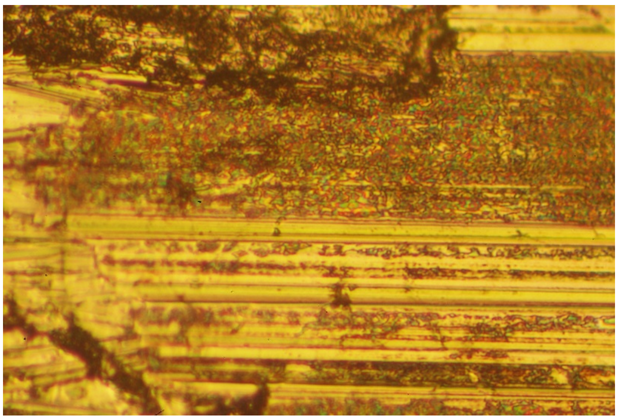

Figure 14. Pin surface against to MnP coated disk

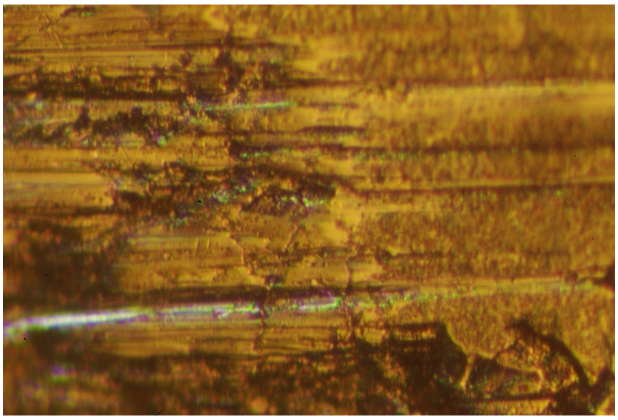

Figure 15. Pin surface against to austempered disk

4. CONCLUSION

In this study, a comparison was made between MnP coated ductile cast iron and austempered ductile cast iron on dry and boundary lubrication conditions as alternative crankshaft materials. MnP coated disk has better results on friction and wear tests in dry conditions, but in boundary lubrication conditions austempered disk has significantly better results than MnP coated disk.

Since the compressor crankshaft operates in an environment containing mineral oil, experimental results suggest that austempered ductile cast iron is a better choice for compressor crankshaft with respect to MnP coated ductile cast iron.

In order to get a more detailed information about the usage of austempered ductile cast iron as compressor crankshaft material, it should be tested under real operating conditions.

ACKNOWLEDGEMENT

In our study, we appreciated ARÇELİK Inc. allowing us to material and laboratory support, Trakya Döküm Inc. for material support and Poziterm Heat Treatment for process support.

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