Scientific Bulletin of the „Petru Maior" University of Tîrgu Mureş
Vol. 10 (XXVII) no. 2, 2013
ISSN-L 1841-9267 (Print), ISSN 2285-438X (Online), ISSN 2286-3184 (CD-ROM)

RESEARCH ON THE WEAR AND MISCROSTRUCTURE OF AS CRANK SHAFT BEARING COATED WITH ALLOYS OF ZN-10C AND ZN-20AL-15C-5O

Hanbey HAZAR[1], Omer CIHAN[2],
[1]*Department of Automotive Engineering, Technology Faculty,*
Firat University, Elazig, Turkey
[1]hanbeyhazar@hotmail.com
[2]*Department of Mechanical Engineering, Engineering Faculty,*
Istanbul Technical University, Istanbul, Turkey
[2]ocihan@itu.edu.tr

Abstract

The experiment of this study consists of coating the 6LD400 Lombardini crankshaft bearing surface with zinc based on two alloys using atmospheric plasma spray. The microstructure of the coatings and matrix have been investigated by the Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS). Compared to the matrix, the coated bearings have a more porous and homogeneous view. During the wearing test, the least mass loss occurred in the alloy Zn-25Cu-10Al-5O-15C, since the zinc-rich bearing surface has a lubricant function. With regard to the crankshaft, the optimum average micro hardness value is 51.5 HV which is seen in the Zn-10C alloy coated bearing.

Keywords: Zinc, Crankshaft Bearing, Wear, Atmospheric Plasma Spray

1. Introduction

Piston axial motions converted to the cycle motions is provided such as crankshaft and cam shaft moving parts carrier of constant parts be defined as bearing and bearing surface is called surface of them which is provided occurring load or power within cylinder in internal combustion engines [1].

Since engine bearings run under high loads, crankshaft bearings are exposed to fatigue resistance. These bearings were required to increase the resistance against the thermal resistance and the wear resistance. Oil thickness between the shaft and bearing decreases with the development of technology. For this reason, there are more difficult operating conditions. As oil film gets thinner, the bearing comes into contact with the shaft. In this case, abnormal wear and bearing failure occurs [2]. Adhesive wear occurs between bearing and the journal.

Adhesive wear originates as a result of incident fusion that especially in metal-metal wear couple acting with one another sliding friction. A very small part of sliding surfaces on each other contacts. Even if in this small surfaces contact stresses reach the limit of the yield stress or exceed. Therefore molecules shows of efficiency coherence force. For this reason, material transfer occurs from one-item to another, and cold welding and cutting of small particles occurs [3].

At work, while journal bearings meet loads from the outside, they are also to prevent force direction movement and permit the movement on the other directions. Energy loss inflicting from friction in operation should be minimized .

Journal bearing materials must have some properties such as: low friction coefficient, high wear resistance, high load capacity, adequate strength versus static and dynamic loads, good thermal conductivity, high corrosion resistance, property of embedment foreign particles and low thermal expansion [4].

At the present time, because of their characteristics, aluminum and aluminum alloys are the most important structures and engineering materials that are used in the industry [5]. Pure aluminum is used more due to specific weight, electric and high thermal conductivity and also due to high corrosion resistance in some technical areas [6]. Today in many areas, zinc-based alloys can be used instead of the conventional bearing alloys [7, 8]. Zinc based alloys are superior to conventional bearing alloys in terms of mechanic and physical properties. The biggest advantage of using the zinc element is that it exhibits high corrosion resistance [9]. In spite of copper solubility limit in the zinc, copper solubility increases depending on the aluminum quantity in the zinc-aluminum alloys. To increase strength and hardness, copper is added within zinc-aluminum alloys [10].

Thus, the bearing materials can be coated with different coating methods. One of these coating methods is atmospheric plasma spray.

Unlike the solid, liquid and gaseous states, a fourth state of substances is called plasma. This state is encountered at very high temperatures. Heated are primarily atomized at the high temperature gases and secondarily cation occurs with breaking of the electrons in the outer orbit from atom [11]. The plasma coating method, the layer of different structure is combined with reinforced surface properties of a layer [12]. Generally plasma has some properties. These are: it is neutral as electrical against outer environment, it is a good electric and heat conductor, turning symmetric property, available high temperature and energy density and compressible as magnetic and thermic [13]. Plasma coating method combines the reinforced surface properties of a layer with a base metal [12].

In this study, the inner surface of 6LD 400 Lombardini of the crankshaft bearing is coated with two zinc based alloy Zn-10C ve Zn-20Al-5O-15C alloys by using the atmospheric plasma spray method. The wear rates of the coated bearings and matrix were tested, microstructures were examined through Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) and afterwards the micro hardness of the samples was investigated. The purpose of this study is to optimize hardness and wear resistance by coating in different ratios two zinc-based alloy on the surface of the bearing. This prolongs the functioning duration of a crankshaft.

2. Materials and Methods

The main bearing and coated powders chemical compositions are: the main bearing occur by 10.45 C, 4.08 O, 0.99 Cu, 7.66 Sn and 76.82 Al. Inner surface of the bearing was coated in determinate mixture ratios by using aluminum powders with %99.0 purity at the particle size of 20 – (-45) and zinc powders with %99.0 purity at particle size of 45 – (-90) µm by atmospheric plasma spray method. As the undercoat powder was used Ni20Cr at the size of 20 – (-53) µm. SEM images of the powders which will be coated on bearing shown in Fig.1, and the mixture proportions of coating powders and matrix were indicated in Table 1.

Table 1: Mixture proportions of coating powders and matrix.

Sample	Mixture proportions			
	Zn	Al	C	O
1	90	-	10	-
2	60	20	15	5

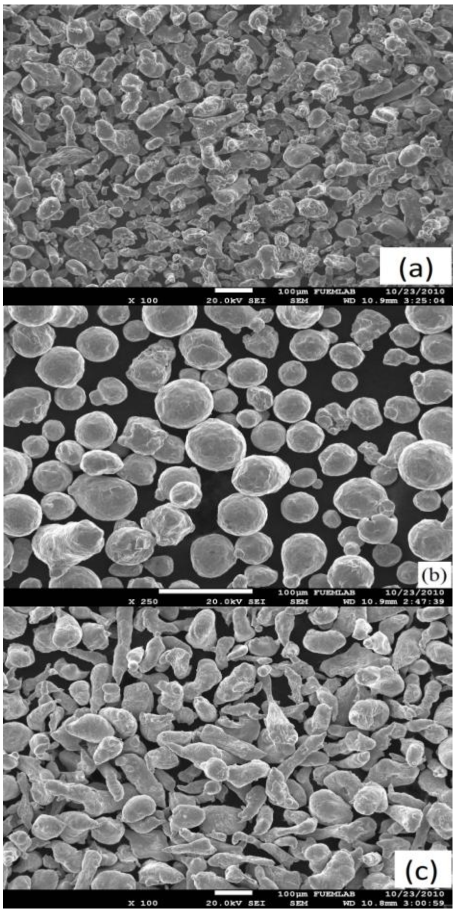


Fig 1: SEM images of powders used at coating: (a) Aluminum powder (b) Zinc powder (c) Ni20Cr powder.

Samples are experimented with provided lubrication between bearing and crank journal, and under static load in the ring on ring wear device. Before the wear experiment, samples are 1/10000 g sensitively weighed in the Sartorius brand sensitive digital scales, thereafter its wear experiments applied on the determined load 42 N, 67 N and 92 N. This wear device stopped per thirty minutes in 1690 m as wear distance. Afterwards samples are taken from this device and after particles and lubricants are washed with alcohol, then weight loss are examined on sample. Ring on ring wear testing device is given schematically in fig 2.

In order to research the microstructure of the samples resulted for wear, snicked bearings are taken erectly bakelite in sequence. In order to examine the surface of the samples, firstly the sample surface is cleaned with 80-100 mesh of sandpaper; thereafter this surface is polished with 60/40 micron of diamond paste. Following this surface is prepared by making chemical etching in alcohol solution 5 gr FeCI3, 10 ml HCI and 240 mI [[14].

For microstructure of samples after wear was analyzed by device Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS). Bearings be subjected to microhardness and values of the hardness is measured. Hence this hardness test is applied along to ten second with load 100 gr move towards bottom edge surface from top edge surface.

The atmospherical plasma model Sulzer Metco 80 KW 9MB gun is used in the coating bearings. This gun's rate of feed per hour is three pound, coating thickness is 280 to 330 micron and distance is 85 mm between gun and sample.

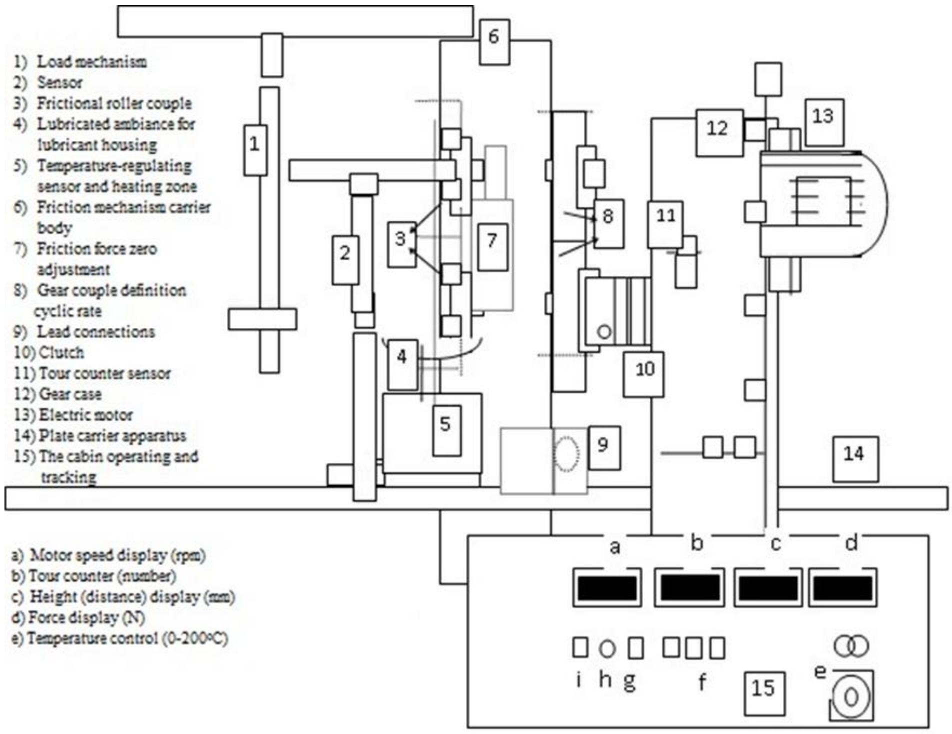


Fig 2: Schematic drawing ring on ring wear device.

3. Discussion

After from wear, Zn-10C, Zn-20Al-15C-5O and matrix weight loss indicated in Fig 3. Here Zn-10C, Zn-20Al-15C-5O and matrix be named respectively as Sample 1, Sample 2 and matrix.

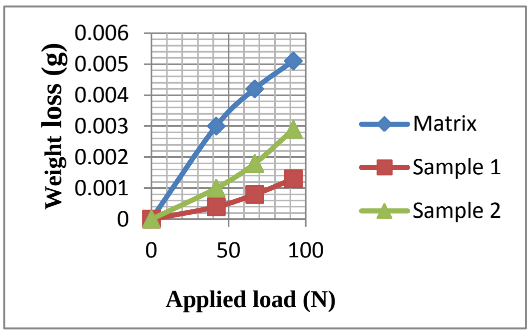


Fig 3: Weight losses of samples in 42N, 67N and 92N.

The weight losses of the samples are examined along with wear distance 1690 meter and thirty minutes time. Matrix is 0,0030, 0,0042 and 0,0051 g weight losses respective in load 42, 67 and 92 N. Zn-10C is 0,0004, 0,0008 and 0,0013 g weight losses respective in load 42, 67 and 92 N. Zn-20Al-15C-5O is 0,0010, 0,0018 and 0,0029 g weight losses respective in load 42, 67 and 92 N.

The more load is applied on bearing, the higher the bearing temperature is. Similarly, the lower the lubricant property, the lower the load capacity of the bearing. [15]. The weight losses will increase in samples with the increase of the applied load [16]. The maximum weight loss is obtained from the matrix in Fig 3. Particularly the temperature remains constant in the inner surface of bearing with the load increase. Additionally, the most wear rate is in the matrix because of the characteristic feature in the structure of the material.

Every passing zinc base alloys are gaining popularity as material journal bearing and also, this alloys perform better than bronze, cast iron, aluminum alloys in various engineering area and tribological area [17, 18]. The main advantages of zinc base alloys are: low cost, high abrasion and wear resistance, durability against excess load and better in dry working characteristics [19].

The bearings generated from zinc-aluminum base alloys, oil free lubrication affect friction layers consisted in slip surface. Thus, friction decreases between bearing-crank shaft and for this reason, bearing alleged occurs of better wear resistance [20]. When viewed from this aspect, coated bearings wear fewer than matrix. On the other hand, matrix weight loss is more than coated bearings, because during working, bearing quicker heats and it loses lubricating property. Eventually matrix wears more than coated bearings.

Sample 1 losses weight less than sample 2 and matrix in Fig 3. So, the sample 1 fewer wears. Zinc particles on the soft bearing showed in the Sample 1 occurred fewer weight losses due to its better load carrying capacity. Otherwise in this study, zinc-oxide layer show claimed that the surface slip facilitating effect with lubricant in particularly border and complex friction state [21]. In this direction, bearing surface of Sample 1 provides slip facilitating with property of lubricant at work. Consequently, Sample 1 weight loss and wear less than Sample 2 and matrix.

After wear testing, SEM micro images are taken from surface of samples as shown in Fig 4. The result of this testing is analyzed samples in the X200 expansion. When images were examined, explicit wear tracks and porous structure could be observed.

In Fig 4 (a), wear tracks are seen in the surface of the coated layer. These metal-metal wear type showed due to the surface along occur wear lines. When examining image; smearing, precipitation or tearing is unseen at the structure of surface. Reinforced aluminum composite bearings of surface adhesive wear less than aluminum alloy bearings [22]. In comparison Fig 4 (a) and Fig 4 (b), coated bearings wear tracks more than matrix. Because, despite metallic friction occurs coated surface of powder particles, yawning is not seen on the bearing surface. This shallow wear lines maybe indicated from rigid material of ruptured aluminum and zinc particles.

Bearing coated with zinc wear tracks more deeply and more specifically than sample 2 and matrix in Fig 4 (b). This state characteristic property of zinc resources. For zinc has soft material of structure, it caused explicit wear tracks at work. On the other hand, friction decreases between bearing and crank journal thanks to zinc property of lubricating.

In Fig 4 (c), lines are seen on the surface of crank pin bearing base aluminum. This wear lines are thought as metal-metal wear in that adhesion wear. Wear testing, source bonds happen in contact points crank against of bearing. After some time, material molecules direct contacts with crank journal and local the source bonds occurs. Thus, material loss consists in bearing.

Lubricant is not provided of bearing during the first start of the engine. Other hands property porous structure is showed in Fig 4 (b). While operating of the engine, lubricant is thought to contribute due to this pores accumulating lubricants [1]. These pores can increase lubricating of bearing both at the first and during work time of engine.

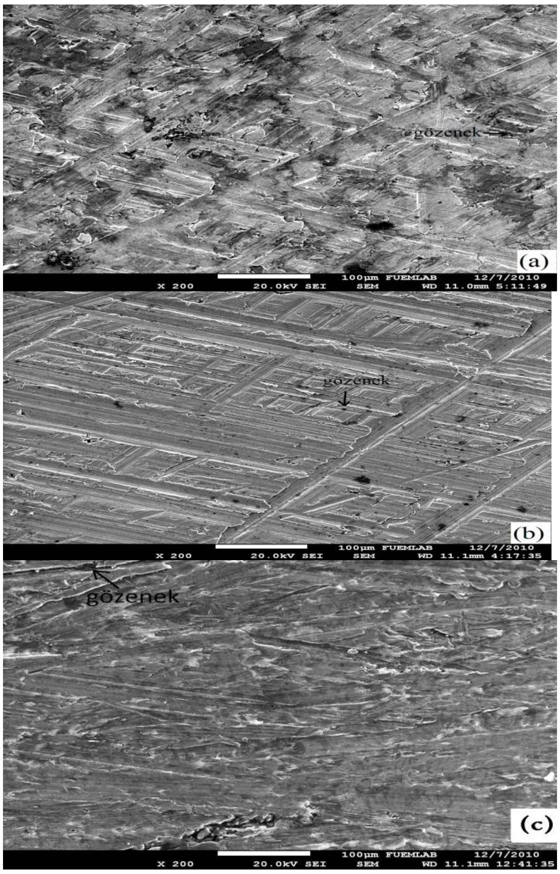
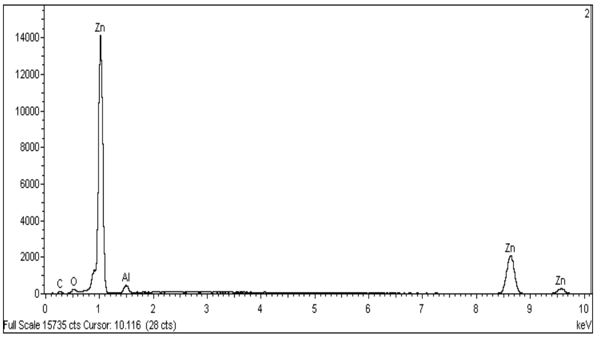
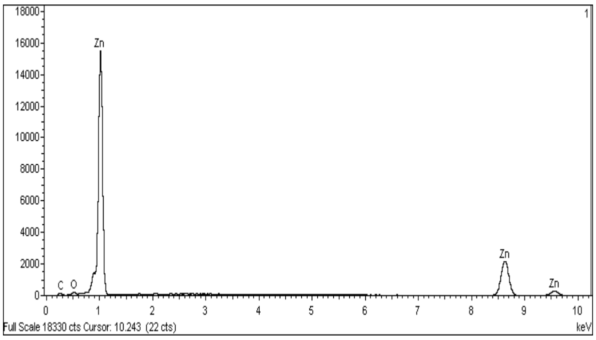


Fig 4: SEM images in samples and matrix of layer (a) Sample 2 (b) Sample 1 (c) matrix.

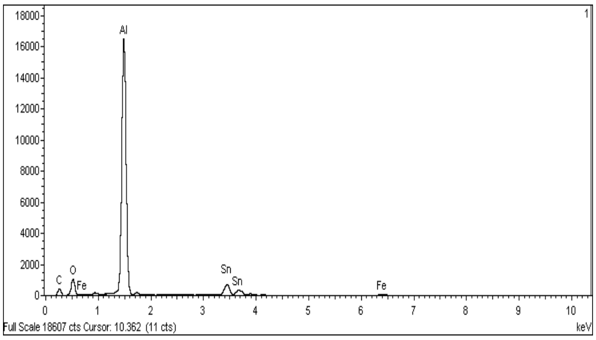
EDS analysis images are given of Zn-20Al-15C-5O, Zn-10C and matrix in Fig 5. The analysis made come up %82.61 Zn, %3.60 Al, %3.75 O ve %10.05 C in Fig 5 (a). Zinc concentration is more excessive than the other elements in the area. Depending on the outcome of EDS analysis is %88.61 Zn, %2.95 O and %8.45 C in Fig 5 (b). Oxidation is showed in this analysis. As a result of the EDS analysis occurred %44.97 Al, %1.54 Fe, %9.96 Sn, %22.34 O, %21.19 C In Fig 5 (c). Substantial aluminum is determined in the area.



(a)



(b)



(c)

Fig 5: EDS analyses (a) Zn-20Al-5O-15C (b) Zn-10C (c) Matrix

Micro hardness test is applied hundred gram load and ten seconds above matrix and coated bearings. For each bearing received measurement from two different places and this average micro hardness values are given in Table 2. Crank shaft found as the hardest material with 221 Vickers hardness (HV) at the tests made. This is an expected situation. Journals of crank shaft must be harder as far as the used bearing material [1]. Thus is obstructed wear of crank shaft. Coated bearings with alloy Zn-20Al-5O-15C and Zn-10C hardness values are respectively 63 and 51.5. Both coated sample are harder compared to matrix. The reason is that zinc characteristic property depends on contacts used as coat powder. Hardness increases in surface of structure bearing because of with zinc-base alloy coated above aluminum-base bearing. As a result of work committed of Savaşkan and Azaklı, SAE 65 bronze bearing coated by zinc-base material and thus bearing hardness increases [23]. When compared both coat bearing, Zn-10C coat bearing has ideal hardness according to Zn-20Al-5O-15C coat bearing from the point of the working conditions crank shaft - bearing. Because Zn-20Al-5O-15C coat bearing is hard against crank shaft due to high aluminum contained in the bearing [24]. Zn-20Al-5O-15C coat bearing occurs more friction than the others during operation. In this way, crank shaft will be worn and consequently, crank shaft will have a shorten the life. When viewed from this aspect, bearing coated with Zn-10C is more feasible than the others in terms of the crank shaft.

Table 2: Average micro hardness values of coated bearings, crank shaft and matrix.

Materials	Average hardness value (HV)
Crank shaft	221.5
Matrix	42
Zn-20Al-5O-15C	63
Zn-10C	51.5

4. Conclusions

Zn-20Al-15C-5O and Zn-10C alloys are coated with atmospheric plasma spray method on bearing. After wear testing, according to the data received from samples and matrix occurs Zn-10C weight losses less than the others at the load 42, 67 and 92 N. Also, the more load increases on the samples and matrix, the more weight losses increases. Weight losses are decreased of the coated bearing with Zn-10C alloy because of zinc element has pretty much percentage rate at the bearing. When examined the microstructure of the samples and matrix, surplus porous structure is seen especially in the coated bearings. The possibility of bearing lubricating increases owing to pores formed in surface. Wear tracks are seen, accordingly to SEM images and these tracks are approved as the metal-metal wear. On the other hand, likeliest sample Zn-10C is displayed with 51 HV in terms of strength of the crank shaft in the micro hardness testing. In shortly, Zn-10C coated sample is ideal than the others in point of working conditions of the crank shaft.

Acknowledgements

The authors would like to thank Firat University (FUBAP –Project No: 2030) for their support.

References

[1] Can, İ. (2005), *The wear behaviour of lead basis crank shaft bearing material*, Master Thesis, Fırat University, Elazığ.

[2] Halamoğlu, T. (2003), *Wear-resistant coatings, metal spray*, Journal of Surface Operations, pp. 154-159.

[3] Özsaraç, U. (1999), *The characterization of wear behaviors of industrial sliding-bearing alloys*, Master Thesis, Sakarya University.

[4] Günther, B. and Kanazawa, I. (1995), *Self-Lubricating Iron Base Materials by Mechanical Alloying*, EURO PM 95 Proceedings, pp. 119-125,

[5] Ekinci, V. Ş. (2007), *Production of Al2O3 reinforced aluminum based composite materials and investigation of their mechanical properties*, Master Thesis, Ankara.

[6] Gürleyik, Y. (1993), *Aluminum and Aluminum Alloys I*, Engineer and Machinery, vol. 34, pp. 25-32.

[7] Gervais, E. and Loong, C.A. (1984), *New ZA alloys in die casting*, 11th International Pressure Die Casting Conference, pp.1-25.

[8] Appelian, D., Palliwal, M. and Herrschaft, D.C. (1981), *Casting with zinc alloys*, Journal of Metal, pp. 12-19.

[9] Czichos, H. (1972), *The mechanism of the metallic adhesion bond*, J. Phys. D: Appl. Phys, Iopscience, vol. 5, pp. 1890-1897.

[10] Kurnaz, S. C. (1993), *Production of saffil (S-AlzO3) fibre reinforced Zinc-Aluminum Alloy (ZA12) matrix composites using infiltration technique and study of their properties*, Master Thesis, İstanbul.

[11] Erdoğan, M., Güneş, İ and F. Develi. (2006), *Plasma spray and uses*, Electronic Journal of Machine Technologies, vol. 1, pp. 61-66.

[12] Lugscheıder, E. and P. Jokıel. (1993), *Plasmaspritzen-Verfahren*, Anwendungen, Entwicklungen, Metall, Heft 3, pp. 230-235.

[13] Thorpe, L.M. (1993), *Thermal spray industry*, Advenced Materials & Processes, pp. 50-60.

[14] ASM Handbook, (2004), *Metallography and Microstructures of Zinc and Its Alloys*, Metallography and Microstructures, ASM International, vol 9, 933-941.

[15] Özçelik, S. (2007), *Experimental examination of wear charecteristics of Cu and Fe based journal bearing materials*, Master Thesis, Selcuk University.

[16] Alam, S., Sasaki, S. and Shımura, H. (2001), *Friction and wear characteristics of aluminum bronze coatings on steel substrates sprayed by a low pressure plasma technique*, Wear, vol. 248, pp. 75-81.

[17] Gervais, E., Levert, H. and Bess, M. (1980), *The Development of a Family of Zinc-Based Foundry Alloys*, Trans. Am. Foundrym. Soc, 183-194.

[18] Lee, P.P., Savaşkan, T. and Laufer, E. (1987), *Wear Resistance and Microstructure of Zn-Al-Si and Zn-Al-Cu Alloys*, Wear, 117, 79-89.

[19] Pürçek, G., Savaşkan, T., Küçükömeroğlu, T., and Murphy, S. (2002), *Dry Sliding Friction and Wear Properties of Zinc-Based Alloys*, Wear, 252, 894-901.

[20] Pürçek, G. (2000), *Examination of tribological properties of bearings produced from zinc-aluminum based alloys under static and dynamic loading*, PhD thesis, Karadeniz Technical University, Trabzon, Turkey.

[21] Marczak, R.J. and Ciach, R. (1973), *Tribological Properties of The Concentrated Al-Zn Alloys*, Proct. 1st Europe Tribology Congress, London, 223-227.

[22] Ünlü, B.S., and Atik, E. (2009), *Tribological properties of journal bearings manufactured from particle reinforced Al composites*, Materials and Design, vol. 30, pp. 1381-1385.

[23] Savaşkan, T. and Azaklı, Z. (2008), *An Investigation of Lubricated Friction and Wear Properties of Zn–40Al–2Cu–2Si Alloy in Comparison with SAE 65 Bearing Bronze*, Wear, 264, 920-928.

[24] Hazar, H. and Cihan, Ö, (2012), *Investigation of wear properties of crank arm coated with alloys Zn-10C ve Zn-20Al-15C-5O* " International Iron & Steel Symposium, April 02-04, 632-638, Karabuk University, Karabuk.