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DEVELOPMENT OF SELF LUBRICATING SINTERED STEELS FOR TRIBOLOGICAL APPLICATIONS

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ABSTRACT

Complex shaped gears and bearings can be economically manufactured using powder metallurgy process. The tribological behavior of sintered steels decides the performance of these machine elements. Solid lubricant containing sintered steels suitable for use in gears and bearings are developed. Iron carbon copper alloys with and without molybdenum disulphide were developed using the conventional mixing, blending, compacting and sintering. The pore distribution, density, dimensional variations and microstructure of the compacts are studied. Friction and wear tests were performed using a pin-on-disc tribometer. Tests were conducted at different normal loads at room temperature under unlubricated dry conditions. The coefficient of friction and wear loss measurements carried out indicate the improved tribological performance of solid lubricant added samples.

Keywords: Sintered steels, solid lubricant addition, friction, wear

1. INTRODUCTION

Sintered steels are increasingly used in light and medium duty gears and bearings because of both technical and economical advantages. For new and wide applications of sintered steels it is necessary to develop a new material composition to improve the friction and wear resistance characteristic. Sintered materials have inherent porosity and the presence of pores have both beneficial and detrimental role on the part performance. The pores act as stress concentration zones and reduce the mechanical strength and ductility. However, the presence of pores acts also contribute to the reduction in noise and vibration also serve as lubricant pockets in lubricated contacts. Sintered bearings and gears are also used in many applications where the external lubrication is not possible or not preferred. Various elements were added for improved compactability, hardness and strength [1]. Tribological properties of sintered steels are studied by few researchers. Under dry sliding conditions there are several mechanisms contributing to the wear behavior of sintered steels. Melt wear, oxidation dominated wear and mechanical wear process depending on wear condition, metallurgical structure, composition and porosity of were observed in powder processed steels [2]. The detached and trapped wear particles present within the contact region influence the wear process [3].

An attempt is made to develop solid lubricant added compositions for tribological applications. The friction and wear characteristics of sintered steels containing of solid lubricant molybdenum disulphide (MoS_2) studied using a pin-on-disc tribometer are reported in this paper.

2. TEST MATERIALS AND EXPERIMENTAL PROCEDURE

Iron Copper Carbon system (with and without solid lubricant) is considered for development. Water atomized iron powder [ASI 100.29] is used for manufacturing the sintered steel pins. Copper and carbon powders of particle size less then 150 µm were used. Zinc stearate was used as a lubricant to reduce the die wall friction during compaction. Molybdenum disulphide powder (≈ 5 µm) is added during mixing stage. The nominal composition of sintered steel pins is shown in Table 1. All powders were mixed by using a double cone mixture for 30 min. The weighed powder mixture was compacted in a hydraulic press; cylindrical pins of dimensions 5 mm diameter and 15 mm length were compacted. Sintering was carried out in a sintering furnace at 1348 K in nitrogen atmosphere. The density of the sintered steel pins was measured as per the ASTM standard [4].

The friction and wear behavior of sintered steel pin when slid against hardened steel, En 31, disc was studied using pin-on-disc wear test rig. Tests were conducted at a constant sliding velocity and at different normal loads. Tests were conducted at the room temperature under unlubricated dry sliding conditions. Sliding wear tests were conducted for a sliding distance of 4000m. During the experiments the friction force was continuously measured. The wear loss was calculated from the mass loss of materials measured before and after testing. The specific wear rate of the sintered steel test pins was evaluated from the volume of the worn out material and sliding distance.

3. RESULTS AND DISCUSSION

The density measurements carried out on the sintered compacts of the two different test compositions are shown in Table 2. The final part density of the developed compacts ranged within ± 0.2 g/cc. Materials containing the solid lubricant showed marginally less density due to addition of MoS_2. The interconnected porosity of both the compacts ranges between 10 and 12 %. The pores are irregular in shape and are homogeneously distributed. The copper particles are found occupied in pores. During sintering swelling takes place and copper particles found spread around the pores [5]. But in the composition Fe-Cu-C-MoS_2 there is no reddish color and the pore distribution is uniform in the entire section.

Figure 1 shows the variation of coefficient of friction during tests. The coefficient of friction for both the samples rises during the initial sliding and reaches the steady state value. This behavior is normally observed during sliding tests due to initial run-in behavior. After the asperities smooth down, the coefficient of friction stabilizes. The steady state coefficient of friction of the solid lubricant added sample is marginally less compared with the base composition. Presence of the solid lubricant contributes in the reduction of the coefficient of friction. The solid lubricant particles get on the containing surface during the sliding process and reduce the friction. The oxide formation in the Fe-Cu-C-MoS_2 composition may be reduced due to presence of the MoS_2 which also layer influences the coefficient of friction.

The mass loss quantified during the wear tests for the Fe-Cu-C-MoS_2 and Fe-Cu-C are shown in Fig. 2. The Fe-Cu-C-MoS_2 samples exhibit a low mass loss compared with the Fe-Cu-C pins indicating a high wear resistance. The presence of the solid lubricant although marginally reduces the coefficient of friction, significantly decreases the wear loss. Fig. 3 shows the wear rate measured at different applied normal loads for the two compositions. The Fe-Cu-C composition showed an increase in wear rate with increasing applied normal loads. The wear rate of Fe-Cu-C-MoS_2 marginally increases with applied normal loads. For materials containing solid lubricant a decreased wear rate can be observed due to small amount of plastic deformation. This is due to the severe action of shearing and plastic deformation. In Fe-Cu-C-

MoS_2, the wear occurs by the deformation mode that only results in the formation of groove. The deeper grooves were formed in the composition Fe-Cu-C. This groove indicates a severe wear condition. At all normal loads the composition Fe-Cu-C-MoS_2 exhibits a better wear behavior because of the smaller grooves formed. Surface roughness measurements carried out on the worn out surfaces using a surface profilometer indicates a smoother worn surface and wear track in the pins made of Fe-Cu-C-MoS_2. The average centre line surface roughness is about 0.015 µm, whereas a rough wear track indicating deeper grooves and irregularities was observed in the Fe-Cu-C alloys. The average centre line surface roughness is about 0.17 µm, significantly higher compared with the MoS_2 added material tested at similar conditions.

Fig. 4 shows the worn surfaces of sintered steel pins containing of MoS_2. The worn surfaces also show the smeared pores. A deeper wear track can be seen in the Fe-Cu-C alloys indicating severe wear due to combined action of shearing and abrasion. The copper wear debris formed in the contact surface and produces the severe abrasive action on the surface [6]. The copper particles adhere temporarily to one of the sliding surface and plows out as a groove. In the two different compositions tested, the worn surface appearance looks like a serrate edge and this is higher in the Fe-Cu-C because of the copper wear debris formed in between the contact zone. This harder wear debris gets trapped in between two sliding surfaces [7]. The hard particles impinge on the contact surface and causes more wear. But in the Fe-Cu-C-MoS_2 this effect was very low, due to presence of the solid lubricant MoS_2.

4. CONCLUSIONS

The new alloys based on Fe – Cu – C system containing solid lubricant MoS_2 were prepared using single stage compaction and sintering. The solid lubricant containing alloys exhibits a low coefficient of friction. The solid lubricant added samples also showed high wear resistance at normal loads investigated. A smoother wear tracks were observed in the solid lubricant added samples indicating the beneficial role played by the solid lubricant.

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TABLES

Table 1 Nominal chemical composition (wt. %) of test materials

Fe	Cu	C	MoS_2
Bal	2.5	0.6	3
Bal	2.5	0.6	-

Table 2 Density (ρ) and interconnected porosity (P) of sintered steel pins

Composition	Density, ρ (g/cm^3)	Interconnected porosity P (%)
Fe-Cu-C-MoS_2	6.10	12.03
Fe-Cu-C	6.39	10.79

FIGURES

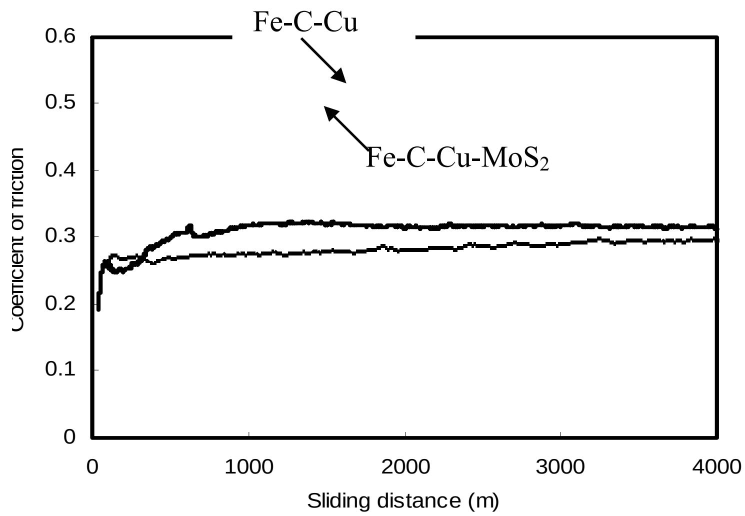


Fig.1 Variation of coefficient of friction at the normal load of 10N.

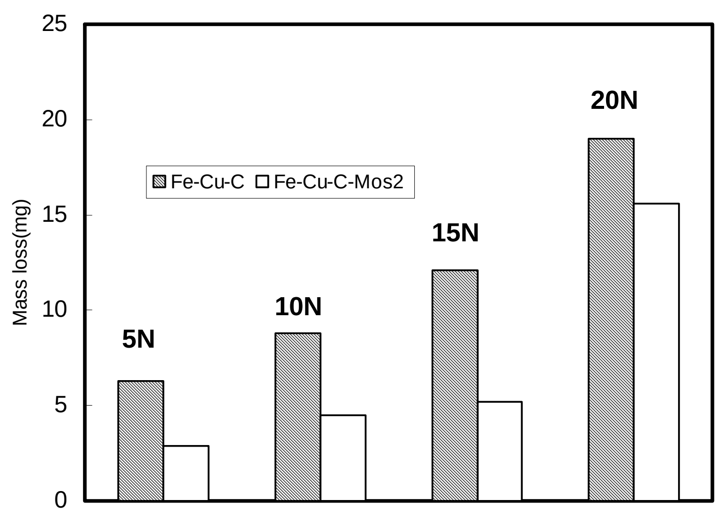


Fig. 2 Mass loss variation with the varying applied normal loads.

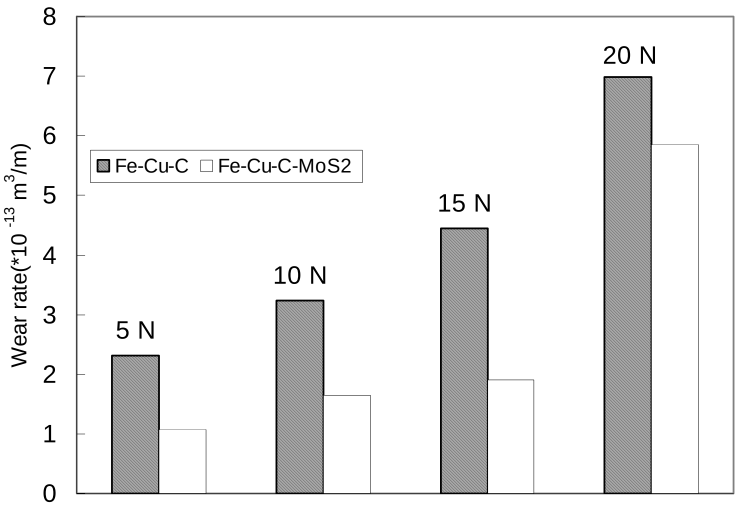
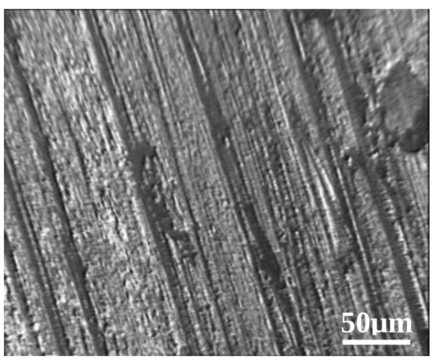
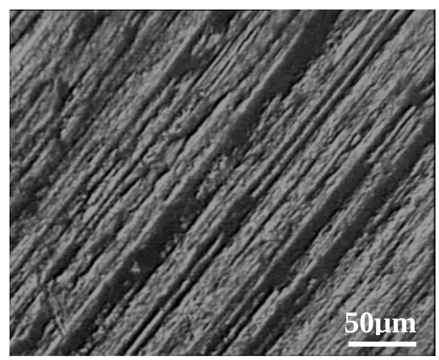


Fig .3 Wear rate of test samples measured at different normal loads



Fe-Cu-C-MoS2



Fe-Cu-C

Fig.4 Worn surface of test pins (tests conducted at 20 N load) for test samples.