PARAMETRIC INFLUENCE ON COEFFICIENT OF FRICTION OF DRY SINTERED IRON BEARINGS

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ABSTRACT

The friction of sintered bearing materials were studied under dry condition using a dedicated test rig. The materials tested were Fe based alloy and additives added in it through sintering process. The performance of coefficient of friction is evaluated against process and manufacturing parameters. Parametric influences on tribo-characteristics have been evaluated under varying condition of running. Effects of additive concentration have been shown in case of MoS_2 and Zn-stearate impregnated bearings.

Keywords: Sintered bearing, coefficient of friction, process and manufacturing parameter

I.INTRODUCTION

Sintered bearings made with different combination of metals have been studied for some years now and their properties are becoming increasingly well known. They have been developed widely for application in many industrial areas because they have good formability and excellent properties of materials.[1, 2,3,4]

Amsallem et al. demonstrated low wear of Fe alloy sintered material at low speed and Gopinath et al. have derived equations for the friction and wear of Fe alloy material[3]. Bekir Sadik and other researchers[4,5,6,7] concluded that metal based materials with additives like MoS_2 may be used in the industry for wider range of operating condition due to better tribological and mechanical properties and he investigated that copper with zinc and tin based bearing materials were better than those of aluminium and combination of SnPbCuSb bearing materials, particularly at low loads. Cu and Fe are with very high in strength and good bears anti wear property[8,9]. PEEK materials are good in strength but at particular temperature it wears out drastically and gives adverse effect but if added with additives will result into good function with application[13]. Self-lubricating bushing is one of the most attractive applications of porous powder metallurgy (P/M) parts. The most widely used materials for porous self lubricating bushes are bronze and iron–bronze, iron-based powders and nickel-based alloys. Elements like graphite, MoS_2 which have self- lubricating nature, are added to sintered materials to improve the wear characteristics[10,11,12]. However, Fe based sintered alloy with parametric variation have not been studied extensively under different tribological conditions. But in order to meet the requirement of various applications, it is important to choose material with appropriate properties at specified condition of running. This may be achieved by choosing efficient alloying with desirable combinations of elements by varying curing temperature, hardness, compaction pressure and porosity etc. At present, no suitable data are available for commercial use from tribological point of view and it is important to have necessary performance data on such bearings.

The aim of the present study is to investigate the tribological behaviour of Fe based sintered material using a dedicated test rig. The effect of manufacturing and process parameters on the tribo-responses, namely coefficient of friction has been reported.

II.EXPERIMENTAL PROCEDURE

Tribology test

The experiments were carried on a specially designed "Dry bearing test rig", having shaft as counter surface - size 50 mm made up of hardened steel (Rc-65) and surface roughness of 0.45µm (CLA). Test bearing is mounted on the shaft experiencing direct loading under a wide range of speed. Friction force was measured by a load sensor attached to the swinging arm connected to the motor and located in the frame (fig 1b). The unit has got a control panel properly interfaced with the PC for data logging of process parameters. The test rig is shown in Figure 1(a) and 1(b).

Table 1. Operating test conditions

Speed m/s	Specific pressure, N/mm^2	Time of running,
0.5-2	2-8	5-20 min for friction

Figure 1(a). Dry bearing test rig

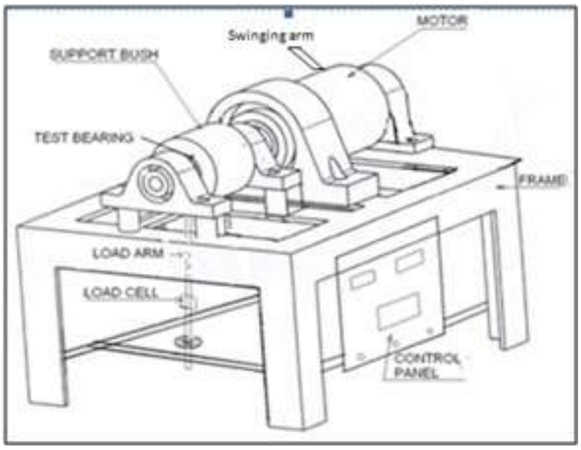

Figure 1(b). Schematic of the test rig

Materials

Dimensions of bearing specimen were as follows: inner diameter 50mm, outer diameter 70mm and length 60mm. The bearings were manufactured by sintering under curing temperature ranging from 800°C to 1100ºC and compaction pressure ranging from 500 MPa to 800 MPa. The chemical composition of iron based sintered bearing was Fe-99%, Cu-1% and density ranging from 6.30-6.40 g/cm^3. Porosity was found to be between 16% to 25%.

III.RESULTS

There are several parameters which change the properties of material during manufacturing i.e. sintering. Among them, compaction pressure, curing temperature, hardness, porosity etc change the properties which in turn affect tribological properties of material. The experimental studies conducted on the mentioned test rig on plain sintered iron bearing within experimental limits (P = 2 N/mm^2 to 8 N/mm^2, v = 0.5 m/s to 2 m/s, T = 5 min to 20 min for friction, 8 hrs to 16 hrs for wear) to see the variation of friction with manufacturing parameters (refer fig.2 to fig.5) as mentioned. Effect of process parameters on coefficient of friction have been analyzed from fig 6 to fig 8. Effect of additive concentration on frictional values has been shown in fig 9.

IV.DISCUSSION ON FRICTION

Figure 2 shows coefficient of friction increases slightly as the compaction pressure increased. This is due to the fact that under high compaction pressure, powder materials have strong bonding and high surface asperity number resulting more resistance to movement. Since curing temperature increase leads to possibly removal of soft surface layers composed of Fe-Cu-S, thus exposing brittle subsurface layers consisting of hard phases such as Fe-Cu with high shear strength, coefficient of friction increases with curing temperature as cited in figure 3.

As evident in figure 4, coefficient of friction increases with hardness and this is due to the fact that hard formation of Cu_2Fe creates high shear strength resulting more resistance in movement.

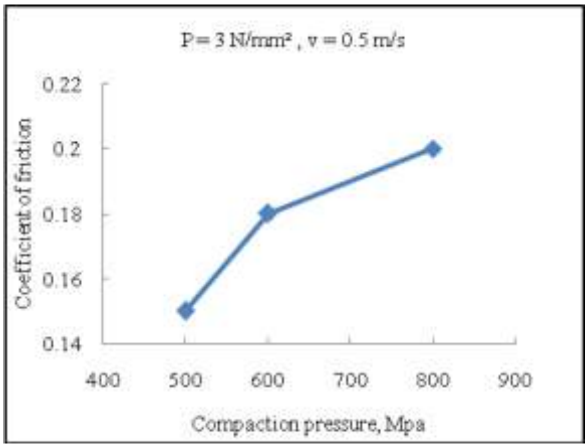

Figure 2. Effect of compaction pressure on coefficient of friction

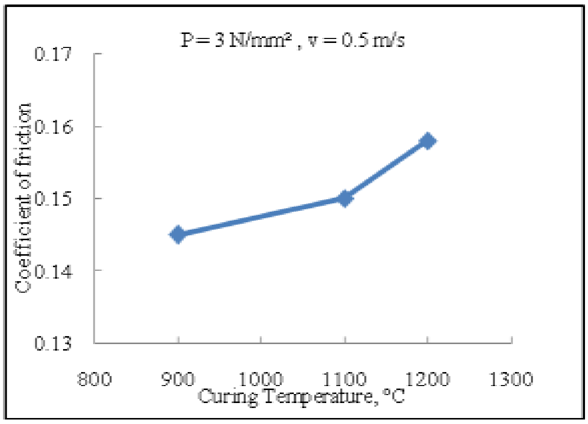

Figure 3. Effect of curing temperature on coefficient of friction

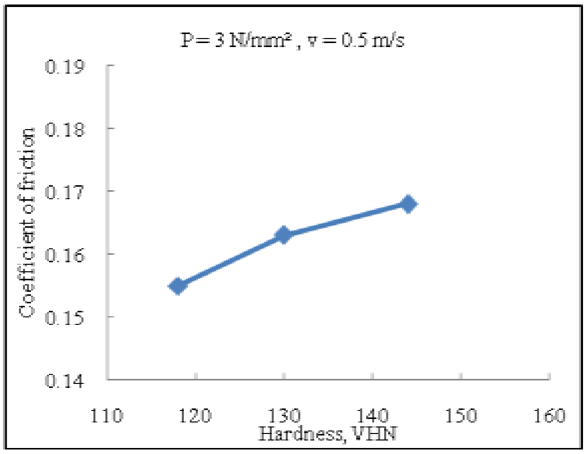

Figure 4. Effect of hardness on coefficient of friction

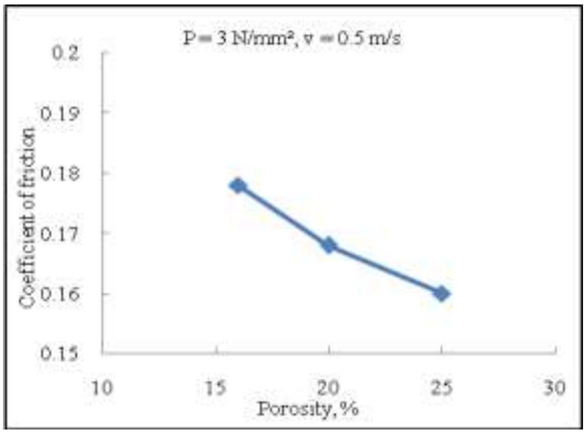

Figure 5. Effect of porosity on coefficient of friction

Figure 5 depicts that increase in porosity leads to less resistance in traversing due to lesser number of metal asperities under contact. Moreover, particles are susceptible to loosen out from the main bond and plastic deformation is rather easy. This phenomenon helps to reduce the friction.

The variation of coefficient of friction with sliding speed is shown in figure 6. It has been seen that with the increase in speed, coefficient of friction also increased. Increase in speed results in removal of oxidation surface layer and also powder particles peel off as a discrete material and act as some sort of hindrances in the movement showing abrasion of the surface.

Figure 7 depicts that as the load increases on bearing, coefficient of friction decreases. This is due to the fact that under load, bulk powder material gets sheared off creating a situation of plastic flow having less resistance. But at very high load, softening of particles tend to increase friction slightly leading to enhanced mechanism of adhesion, abrasion and oxidation thus creating a situation of stiction and agglomeration of particles by emitting coarse particle debris on surface (as evident in SEM analysis- fig 19(b)). Figure 8 represents the effect of running time on coefficient of friction. With time, coefficient of friction does not show much variation.Variation only can be attributed due to the compatibility of the system at the beginning. In general, time of running would not immediately make substantial changes in coefficient of friction until deterioration of surface takes place.

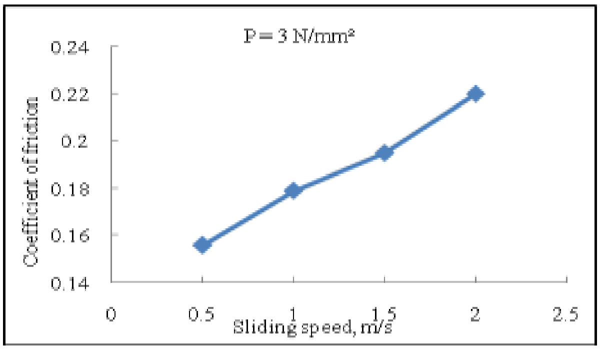

Figure 6. Effect of sliding speed on coefficient of friction

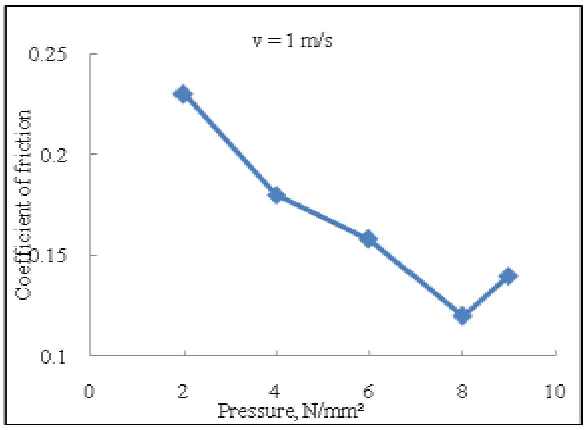

Figure 7. Effect of pressure on coefficient of friction

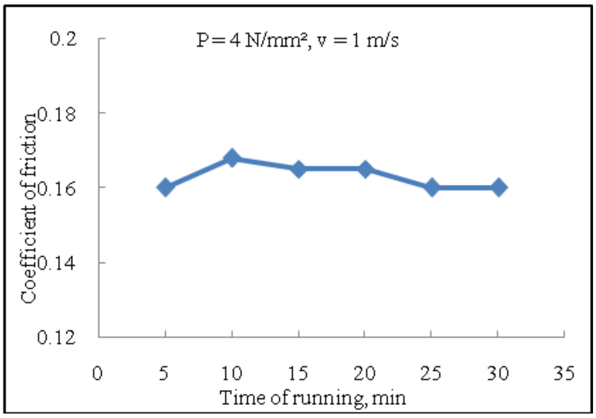

Figure 8. Effect of time on coefficient of friction

In case of bearing with solid lubricant, the author used MoS_2 and Zn stearate for imparting special properties for improvement in tribological condition as demanded. Inclusion of MoS_2 results in little lubricity due to presence of sulphur having lamellar structure and overall reduction of wear due to wear resistant property of Mo additive. Zn stearate provides effective bonding of powder even with increased porosity plus little lubricity effect. This additive is cheaper in cost and hence finds many industrial applications. From figure 9, it has been found that MoS_2 helps to reduce the coefficient of friction to some extent but more addition may not be helpful. Reason behind it lies with the fact that sulphur having lamellar structure influences the friction process and more sulphur may add to the stiction process and hence may not prove to be beneficial.

Addition of Zn stearate basically helps in keeping the bond strength good. More addition makes the material weak in strength but helps the binding of material to be strong so that loose particles could not come out easily making smooth movement of surface. It has been noticed that addition helps to reduce friction to some extent as seen in the case of MoS_2. Zn stearate is comparatively cheap and could be good substitute for MoS_2 but has lower strength and hardness. It has been noticed that addition of 2-3% of Zn stearate is good enough to reduce the coefficient of friction. It is anticipated that more addition of Zn stearate may not be significantly helpful for practical considerations.

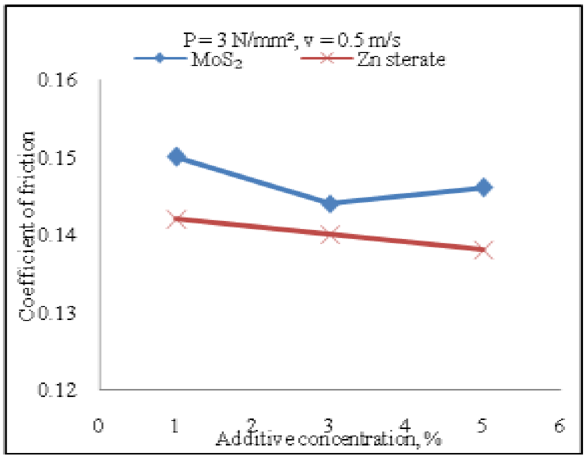

Figure 9. Effect of additives concentration on coefficient of friction

V.CONCLUSION

From this study it can be concluded that:

1. Coefficient of friction increases with compaction pressure, curing temperature and hardness of the material under experimental condition. However increase in porosity leads to decrement in coefficient of friction. These manufacturing parameters are to be judiciously considered for limiting coefficient of friction.
2. Process parameters have got significant effect on coefficient of friction. Sliding speed and pressure have got opposing effect on coefficient of friction. Time of running does not vary coefficient of friction significantly until surface deterioration.
3. Manufacturing parameters affect friction process. High compaction pressure, curing temperature and hardness shows increase in coefficient of friction. However porosity has got positive effect.

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