International Journal of Advance Industrial Engineering
E-ISSN 2320 –5539
Available at http://inpressco.com/category/ijaie/

Research Article

Experimental Study on Hybrid Bearing

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Accepted 25 March 2015, Available online 31 March 2015, **Vol.3, No.1 (March 2015)**

Abstract

The present paper presents experimental studies conducted on hybrid bearing which includes magnetic repulsion and hydrodynamic actions together into a single sleeve configuration. Such bearing configuration provides non-contact support with minimum possible friction. An experimental setup, designed and developed to investigate the performance characteristics of the different configurations of hybrid bearing, has been described. To examine the performance of hybrid bearing, it was operated at low rotational speed and the performance of different configurations were evaluated by measuring the shaft displacement in X and Y directions using two displacement sensors. The comparison in form of orbit plots has been presented.

Keywords: *bearing, Wear, Permanent Magnetic Bearing, Hydrodynamic Bearing, Hybrid Bearing.*

1. Introduction

Hydrodynamic journal bearing [Hirani, 2009, Hirani *et al*, 2000, Hirani *et al*, 1999, Hirani *et al*, 1998, Muzakkir *et al*, 2011, Hirani, 2005, Hirani *et al*, 2001, Muzakkir *et al*, 2013, Hirani 2004, Muzakkir *et al*, 2015, Hirani, Verma, 2009, Hirani, Suh, 2005, Hirani *et al*, 2001, Rao *et al*, 2000, Hirani *et al*, 2000, Hirani *et al*, 2002, Burla *et al*, 2004, Hirani and Goilkar, 2011, Goilkar and Hirani, 2010, Hirani and Goilkar, 2009, Goilkar and Hirani, 2009, Goilkar and Hirani, 2009] are well established bearings. The high load carrying capacity at high rotational speed, soaring damping and simplicity in structure make these bearings admirably popular. The inadequacy of the hydrodynamic journal bearing lies in its lack of film formation at lower speed that makes it vulnerable to wear.

On the other hand, permanent magnetic bearings [Hirani, Samanta, 2007, Lijesh, Hirani, 2015, Lijesh, Hirani, 2014, Shankar *et al*, 2006, Lijesh, Hirani, 2015, Muzakkir *et al*, 2014, Lijesh, Hirani, 2015] are the choice due to zero wear and friction characteristics. However low load carrying capacity and negligible damping of magnetic bearings restrict their usage. In addition permanent magnetic bearing designed to support radial load imposes an axial force and makes system instable.

An experimental study to combine the advantages of magnetic and hydrodynamic bearings has been performed by (Q.Tan el al, 2002). However, in their experimental work magnetic-bearing and hydrodynamic-bearing were arranged side-by-side. Such an arrangement requires more space that is undesirable from practical point of view. To deal with axial force (generated by radial magnetic bearing) they used the thrust bearing which increases the friction.

In the present work, an experimental study has been carried out to explore the viability of combining magnetic and hydrodynamic effects in single bearing arrangements. Four working models of bearing arrangements have been presented. An experimental setup, designed and built to explore the fruit of hybrid (magnetic + hydrodynamic) bearing arrangement, has been described. All the experimental results are reported in the present paper.

2. Experimental Setup

The experimental setup, shown in Figure 1 consists of motor-drive, shaft-bearing, and lubrication subsystems. The shaft-bearing subassembly has stainless steel shaft, disk (8kg), two aluminum housings, rotor magnets, and stator magnets. The rotor of rare-earth permanent magnet (Neodymium Iron Boron) is mounted on the shaft. The displacement of the shaft can be measured by the displacement sensor mounted on the stand. The motor-drive subassembly consists of 2 H.P. 3-phase AC motor and frequency drive. The frequency drive allows rotating motor shaft between 115 rpm to 6000 rpm. The motor-drive and shaft-bearing subassemblies are connected through flexible aluminum spiral coupling. This type of coupling is not only able to take the bending load but misalignment also up to around 7 degrees can be tolerated. The lubrication subassembly contains rotary

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pump, DC motor, DC motor drive, flexible pipe and oil filter. The pump can be operated at variable speeds by DC motor drive. The required amount oil is supplied to the bearing clearance by this rotary pump. Before send the oil to the clearance, oil is filtered at each circulation.

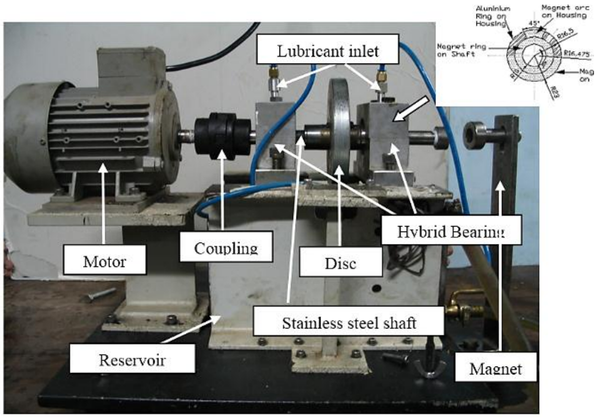

Fig.1 Hybrid Bearing test setup (Lijesh *et al* 2015)

3. Experimental Observations

To check the feasibility of hybrid (magnetic + hydrodynamic) bearing, experiments were carried out in four different stages.

Stage-I

In the first stage, experiments were performed on conventional hydrodynamic bearing with aluminum ring. The bearings having OD of the rotor 39.94± 0.02 mm and ID of the bearing 40.0 mm were used. To check the hydrodynamic action of this bearing configuration, the setup was run at different speeds. The displacement readings of the shaft in vertical direction have been shown in figure 2. The curves show that as speed of the shaft increases, the shaft-position is moved towards the sensor direction, i.e. as the speed increases film pressure increases.

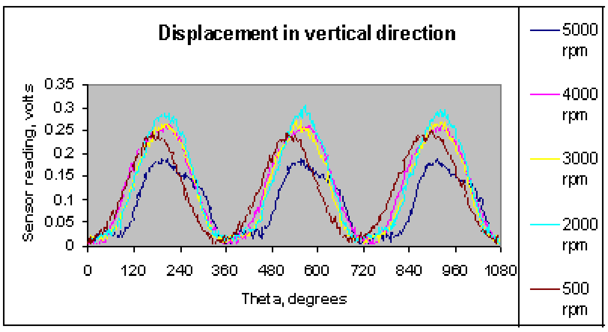

Fig. 2 Displacement signal in vertical direction

To check the performance of this conventional bearing at low speed, the setup was run at speed of 115 rpm continuously for 3 hours and inner surface of the bearing was examined. The considerable wear at the inner surface of the bearing as shown in figure 3 was noticed. These experiments confirm the inability of low speed operation of the conventional journal bearing.

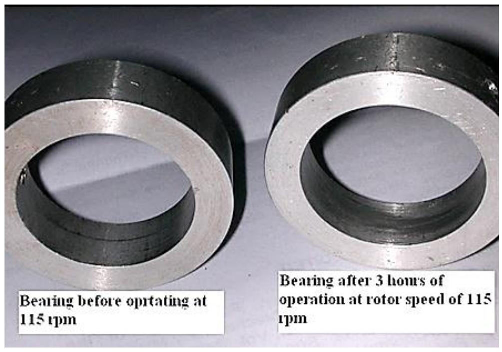

Fig. 3 Bearing before and after performing experiments for 3 hours (Hirani and Samanta, 2007)

Stage-II

In second stage, a full cylindrical rare-earth magnet (Neodymium-Iron-Boron, Grade-N-35) was used as a stator (ID = 40.0±0.02 mm) along with rotor (OD = 39.94± 0.02 mm) magnet of same material in repulsive mode in order to generate the initial lifting of the disk as well as the shaft, hence reduce the initial starting torque as well as frictions. With this bearing arrangement, the setup was run at speed of 115 rpm with oil and without oil. The displacement readings in x-y directions have been shown in figure 4. In this figure, the plots with oil and without oil superimpose to each other, i.e. there is a no film formation in oil conditions. Also curves are instable in nature.

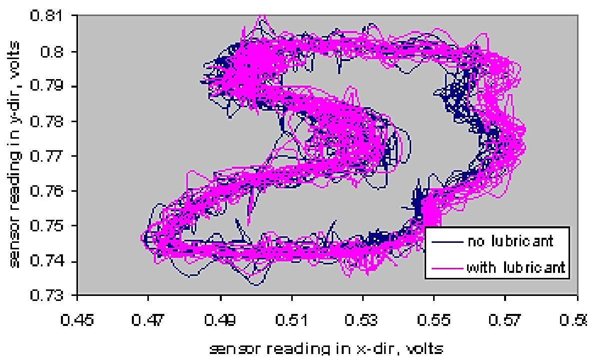

Fig. 4 Orbit plot for full ring magnetic and Hybrid bearing

To understand the physics of bearing configurations, a theoretical study using the established formulation (Hirani and Samanta, 2007) was carried out. The results have been plotted in figure 5. The results are matching with the results of (Mukhopadhyay *et al*, 1997). In the configuration half circle with 45 degrees arc bearing was used for developing hybrid bearing as this configuration provided load carrying capacity without losing stiffness (Mukhopadhyay *et al*, 1997).

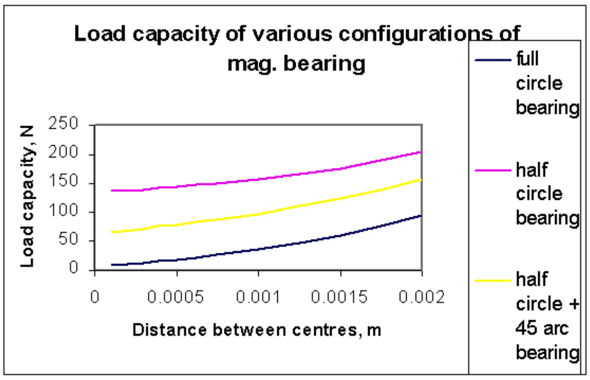

Fig. 5 Load configuration for different configuration

Stage-III

In this stage, bearing configuration (half circle along with 45 deg. arc), as shown in figure 6, was developed. The bearing having rotor-OD = 39.94± 0.02 mm and stator-ID= 40.0±0.02 mm was used. With this bearing setup was run at a speed of 115 rpm. The displacement readings have been shown in figure 7.

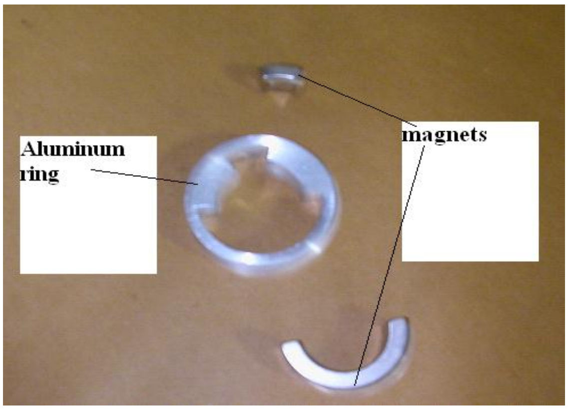

Fig. 6 magnetic bearing with half circle along with 45 deg. arc

Figure 7 shows the instability of the bearing configuration. With this configuration it was difficult to confine the magnets in the proper places in the aluminum ring and difficult to form inner smooth surface suitable for film formation.

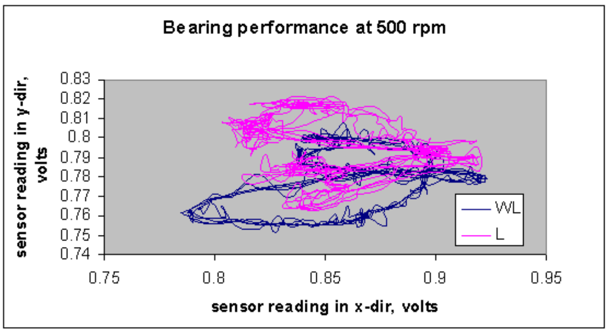

Fig. 7 Orbit plot for full ring magnetic and Hybrid bearings with half circle along with 45 deg. arc

Stage-IV

In this stage Teflon was coated on the abovementioned bearing. The coated magnet was been magnetized in axial direction. The setup was run at different speed to check the compatibility of hydrodynamic action of the configuration along with magnetic action. Displacements of the shaft have been plotted in figure 8. This figure shows that, with increase in the shaft-speeds, lift towards upward direction due to formation of lubricant film occurs.

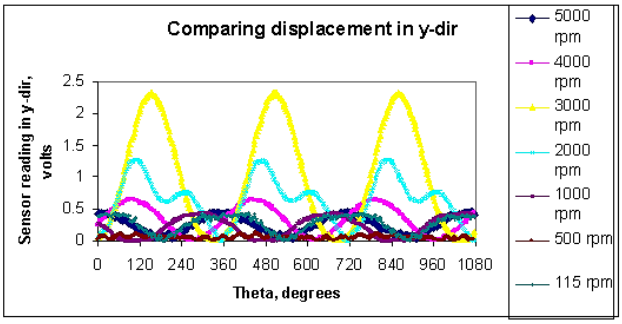

Fig. 8 Displacement in Y direction

Conclusions

Experiments performed on hydrodynamic bearing at low rotational speed resulted in wear. Hybrid arrangement made of hydrodynamic and full ring magnets provided no change in the load carrying capacity. In fact such configuration axially disturbs the shaft and reduces the wear performance of bearing. Such arrangement should not be used. The experimental study performed on the hybrid bearing made of magnetic pieces (half ring and 45 degrees arc magnets) showed improvements in the load carrying capacity. Such bearing configuration lacks stability. To improve the performance further the magnetic bearing was coated with Teflon. The experiment results showed improvements both in load carrying capacity and stability of the bearing. Finally it is concluded that hybrid bearings are feasible.

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