The Effect Of The Thickness Of The Lower Raceway, The Thickness And Material Of The Third Raceway Of The Bearing Set On The Efficiency Of A Reciprocating Compressor

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ABSTRACT

The thrust ball bearing set in the reciprocating compressor is used to reduce the friction between the crankcase and the rotating crankshaft. The bearing set consists of two raceways that sandwich the ball bearing. The upper raceway is attached to the crankshaft and this raceway rotates with the crankshaft. The balls of the bearing also rotate and revolve with the crankshaft. These balls rotate on the lower raceway. The lower raceway is the subject of the axial load, which includes the mass of the crankshaft and the rotor. The thickness of the lower raceway will be studied to improve the absorption of the axial load by the lower raceway. The more the load is absorbed by the lower raceway the less the load is exerted on bearing balls, hence improving the life of the bearing set. Moreover, an additional third raceway is used under the lower raceway. This is made of an elastic material and it acts as a damper. This accompanies smooth rotation of the crankshaft especially during the tilt motion of the crankshaft, hence improving the efficiency of the compressor. The elastic raceway deforms and retains its shape, hence preventing the loss of energy from the system. Different materials for the third raceway and their thicknesses will be studied to bring forth an optimum combination of the bearing set.

1. INTRODUCTION

From the beginning of 1990s, researchers are trying to develop technologies to improve the design of ball bearings in refrigerant compressors. A refrigerant gas and an oil are used to lubricate the ball bearings. Wardle *et al.* (1992) have studied the effects of the dilution of the gas in the oil and its results on the performance and life of the ball bearings.

Lawson (2021) states that the compressor industry consumes approximately 20% of all the energy produced. To reduce this consumption of energy, the COP of the compressors must be improved. The usage of ball bearings improves the COP of the compressors by reducing the friction coefficient. Without the ball bearing, the crankshaft rotates on the crankcase and there is sliding friction between the surfaces. With the bearing, there is rolling friction between the balls of the bearing and the crankshaft and crankcase. Since the rolling friction is less than the sliding friction, the COP of the compressor can be increased using a ball bearing.

In this paper, the effect of the lower raceway's thickness, a third raceway and the third raceway's material on the performance of the compressor will be studied.

2. DESCRITPION AND ANALYSIS

The axial thrust ball bearing used in this example of reciprocating compressor consists of an upper raceway, ball bearing, lower raceway and a third raceway placed under the lower raceway. The assembly of the bearing is as shown in Figure 1. The upper raceway, lower raceway and the balls of the bearing are made of GCR15 Steel. The cage of the bearing is of material PA66.

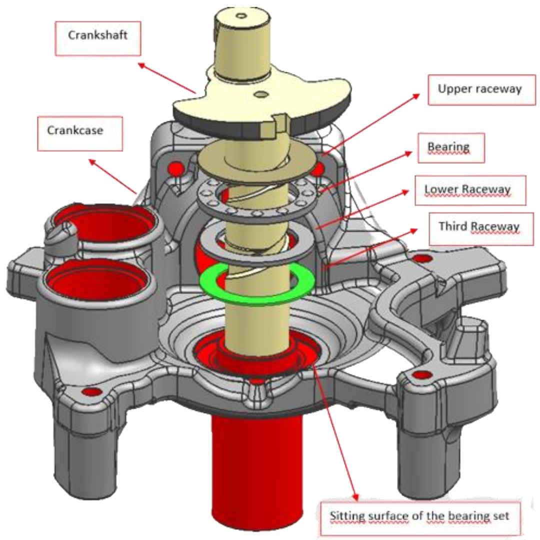

Figure 1: Schematic of the bearing set

Trials with two different thicknesses of lower raceway are conducted: 0.8 and 1.25 mm. Two different materials for the third raceway are tried: N-8092 CT and CMP-4000. The number of combinations tried are as mentioned in Table 1. The upper raceway and the bearing are kept constant. **Note that all these models have the third raceway**.

Table 1: Combination of bearing sets tried

	Model 1	**Model 2**	**Model 3**	**Model 4**
Lower Raceway	thickness 0.8 mm	thickness 1.25 mm	thickness 1.25 mm	thickness 1.25 mm
Third Raceway	N-8092, thickness 0.40 mm	N-8092, thickness 0.40 mm	N-8092, thickness 0.6 mm	CMP-4000, thickness 0.5 mm

A linear static analysis was conducted in HyperMesh. Freeze contact was given between the upper raceway and the bearing balls, the lower raceway and the bearing balls, and between the lower raceway and the third raceway. A force of 10 bars is applied normal to the surface of upper raceway and a fixed constraint is applied to the third raceway. All of this is illustrated in Figure 2.

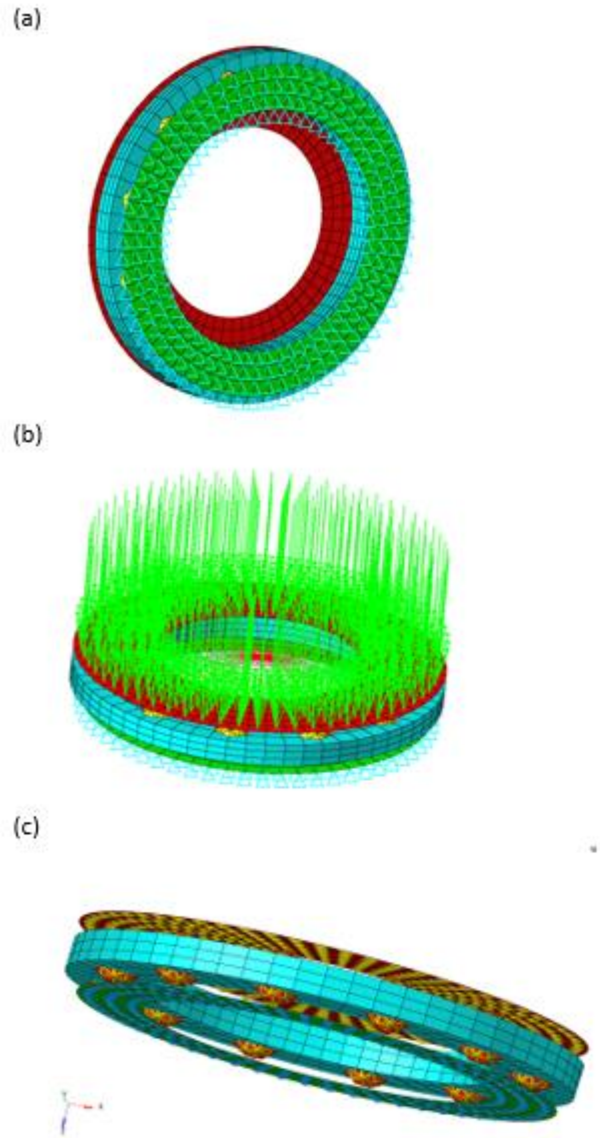

Figure 2: (a) Fixed constraint on the lower raceway (b) 10 bar pressure on the upper raceway (c) Freeze contact.

Calorimetry test under ASHRAE conditions was done to understand the difference in COP of the compressors assembled with models of the bearing sets mentioned in Table 1.

2. RESULTS AND DISCUSSION

The calorimetry test results to understand the change in COP are as shown below in Figure 3 for compressor speed of 1300, 3000 and 4500 rpm. The compressor taken as a baseline **does not** have a bearing set, and the remaining parts are the same as the compressor with the bearing set. All the tried models **have** a bearing set with the third raceway.

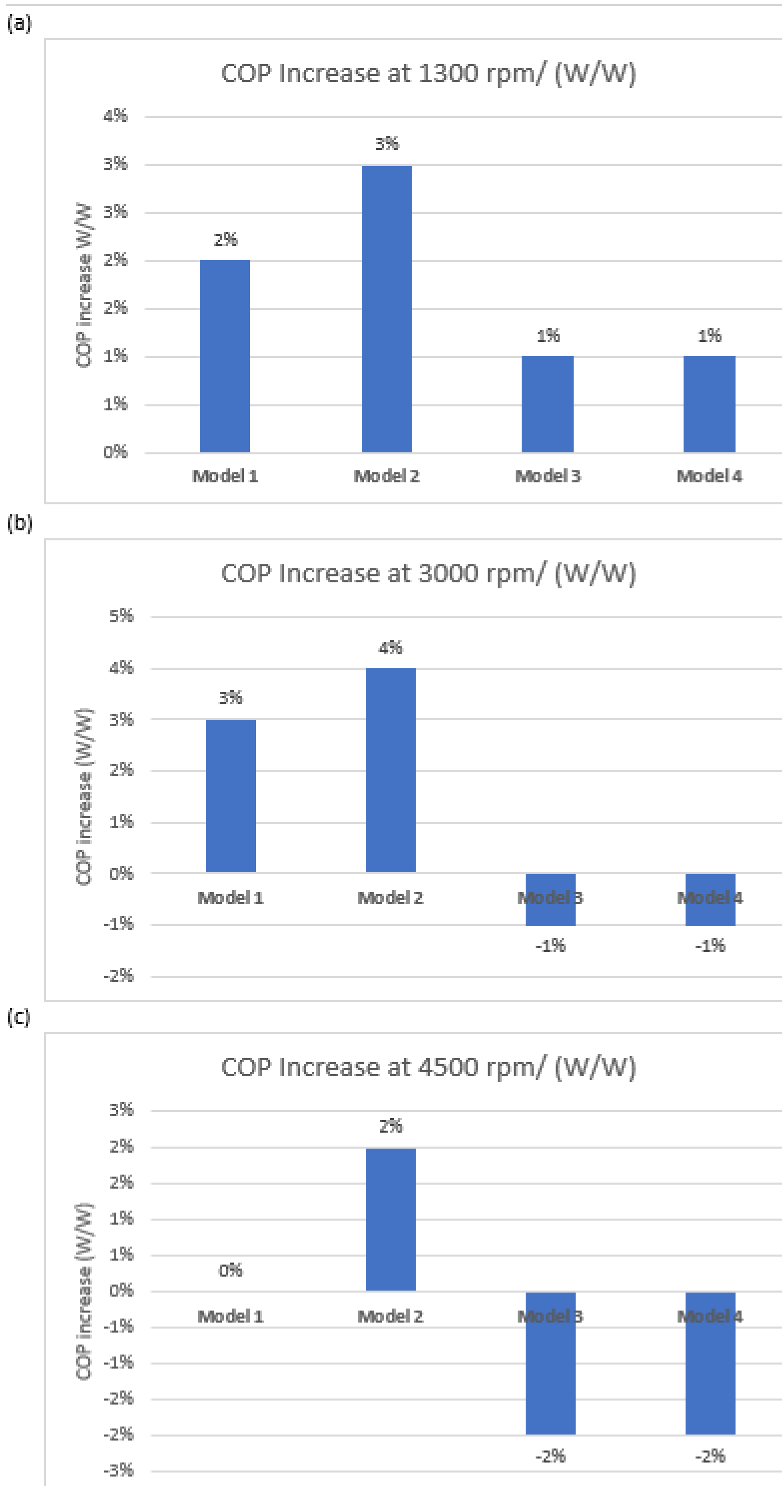

Figure 3: (a) Change in COP at 1300 rpm (b) Change in COP at 3000 rpm (c) Change in COP at 4500 rpm

The displacement and Von-Mises stress on the balls of the bearings are as shown below in Figure 4.

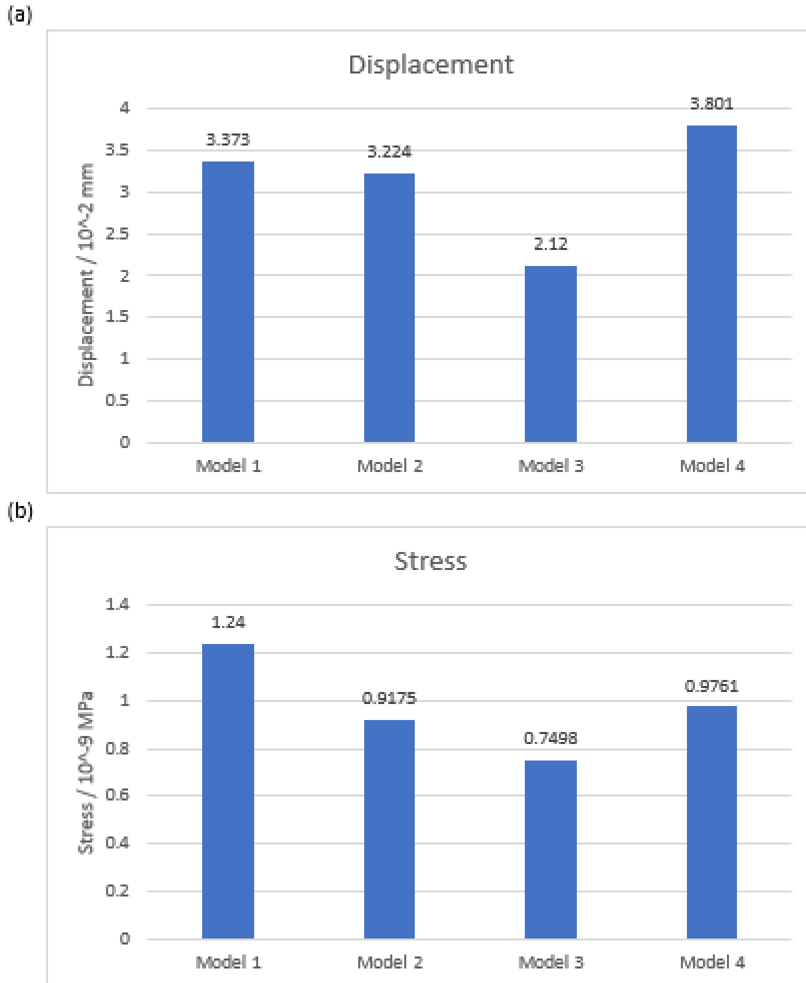

Figure 4: (a) Displacement of the balls of the compressor (b) Stress on the balls of the compressor

According to the real-life test results, the Model 2 is the most efficient. According to the basic static analysis, Model 3 has the least stress and displacement for the balls of the bearing followed by the 2nd model. According to the static analysis, it seems that increasing the thickness of the N-8092 third raceway, the system becomes more efficient. But the real-life calorimetry test results show a different story. Especially at 3000 and 4500 rpms, the test results clearly show that the Model 2 is the most efficient. This shows that the there is a room for improvement in the analysis. Since the analysis environment is static, there is clearly an opportunity for changing the analysis environment. A transient analysis at different speeds of crankshaft mut be done. The analysis must include the 3D models of crankshaft, crankcase, piston, connecting rod and the raceways and bearings must be modeled as springs in the future to better simulate the real-life conditions. A better simulation will bring forth an opportunity to optimize the axial thrust bearing set with respect to material and thicknesses of the lower raceways.

For model 2, the stress and displacement results are as shown below in Figure 5.

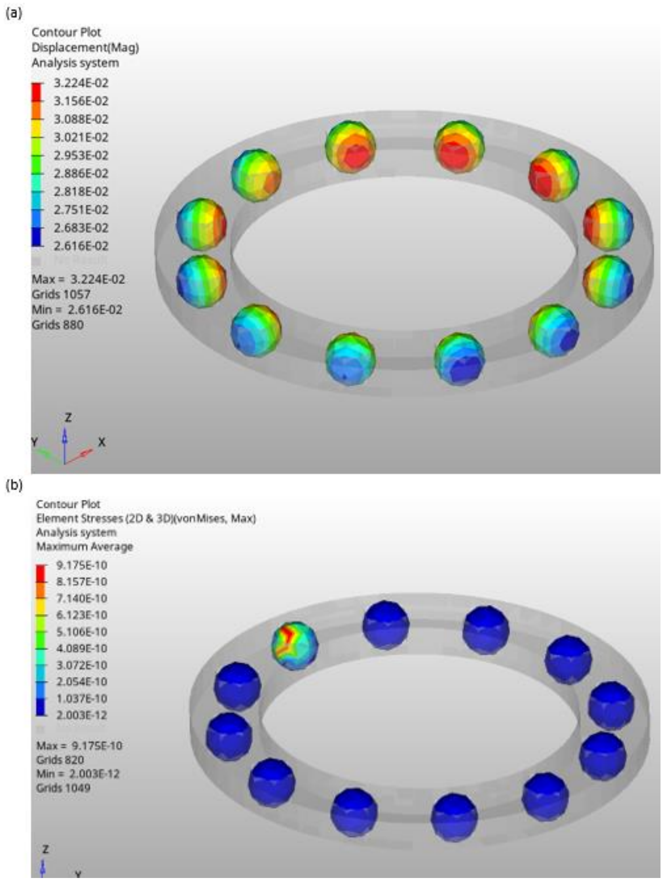

Figure 5: (a) Displacement on the balls of the bearings (b) Stress on the balls of the bearings

6. CONCLUSIONS

- Thickness of the lower raceway has a clear effect on the COP of the compressor. The thicker lower raceway gives better performance.
- The third raceway's effect on the COP is observed, especially at 3000 and 4500 rpm. Its material and thickness is critical in order to improve the performance of the compressor. The N-8092 material raceway with a thickness of 0.40 mm gives better performance results.
- A new analysis must be conducted by including piston, connecting rod, crankshaft, crankcase and the raceways and bearing must be modelled as springs (by determining their spring constants.) The analysis must be a transient in order to include different crankshaft rotting speeds.

NOMENCLATURE

COP	Coefficient of Performance
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers

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