Finite Element Analysis Based Optimization of the Journal Bearing Press-Fit

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Abstract

The HVAC compressor which is hermetically sealed uses journal bearings to provide support to the shaft & other rotating parts mounted on it. Journal bearing used in this case is press fitted on the hub and become integral part of the hub. If the fit in the bearing & hub relaxes the bearing will start spinning freely, may walk-in or walk-out of the hub. This leads to efficiency drop in compressor & ultimately leads to compressor non-conformance. So the purpose of this paper is to do an optimal design by using "Finite Element Analysis" of the Journal bearing press fit in hub. We have used FEA to find out the optimum dimensions that will lead us to better press-fit & maximum retention capability of the journal bearing in hub. By using these values further experimentation will be carried out to find the optimum solution for production.

Key words: Contact Pressure, Tangential Loading, Interference, Compressor, Journal Bearing

1: Introduction

HVAC (heating, ventilation, and air conditioning) refers to technology of indoor and automotive environmental comfort. Air conditioning and refrigeration are provided through the removal of heat. The refrigeration cycle uses four essential elements to create a cooling effect. The compressor pumps the refrigerant gas up to a high pressure and temperature. From there it enters a heat exchanger (sometimes called a "condensing coil" or condenser) where it loses energy (heat) to the outside. In the process the refrigerant condenses into a liquid. The liquid refrigerant is returned indoors to another heat exchanger ("evaporating coil" or evaporator). A metering device allows the liquid to flow in at a low pressure at the proper rate. As the liquid refrigerant evaporates it absorbs energy (heat) from the inside air, returns to the compressor, and repeats the cycle.

The compressor is the only moving component in any Refrigeration/ Air conditioning system and anything going wrong anywhere in the system will finally reflect on the compressor performance. It must be understood that related components and system malfunction initiate the compressor failure.

It is therefore essential to go to the root cause if the compressor fails, rather than simply replacing it with a new compressor, as the replaced compressor will also fail, if the root cause remains unattended. In such scenario, to understand the compressor failure in more detail the replication of field failures is carried out in laboratories and the compressor design are targeted to take care of such incidences. To manage the laboratory test in an optimized way we have used the Design of experiments approach to minimize the number of tests and get the right results and the find the parameters that are most affecting for failure of any component.

In this paper we are going to concentrate our study only towards one of the non-conformances and that is of Journal bearing. The common failures in case of journal bearings are bearing spun, walk-in/walk-out or combination of both in the hub where it is press fitted, which leads to compressor non-conformance. Probable reasons of nonconformance could be due to, imperfect press fits in bearing, Deflection of hub at end because of drive load leads to loosening of interference fit, Due to change in temperature leads to uneven expansion of Hub and Journal bearing.

Limitations to improve existing press fit are, It is very easy to say that if the bearings spun or walk-in/ walk-out increase the interference fits between the bearing & hub, however it is practically not feasible since it raises other issues like, leads to increase press force requires process change, difficult to control inner diameter of journal bearing, Higher stress of hub because of higher fit may lead to failure of hub while pressing. Increased interference may lead to higher contact stresses and hence involving risk of cracking cast iron hub.

2. Finite Element Analysis:

Since the bearing is pre-fitted into the hub so there is a contact pressure that gets developed. Larger the interference more will be the contact pressure. Finite element analysis and analytical calculations were carried out for calculating contact pressure at different interference value. The torque required to spin the bearing in the hub at different interference values is achieved through the help of FEA analysis.

2.1 Procedure For FEA

1. Modeling by using ProE Wildfire 2
2. Contact Stress Analysis

Table No. 2.1 Material Properties for Scroll & Bearing

Part	Material	Material Property	
		Elastic Modulus (E) GPa	Poisson's Ratio (μ)
Orbit Scroll	Cast Iron	110	0.27
Bearing Insert	Steel	200	0.3
	Bronze	110	0.34

3. Meshing
   a) Mapped Meshing
   b) Element Type: Solid 186
   c) Noted down no. of elements

4. Application of force: Interference Value
5. Solver or Solution
6. Contact Pressure (MPa)
7. Tangential Force at Min & Max Interference (N)

2.2 Analytical Calculations for Contact Pressure

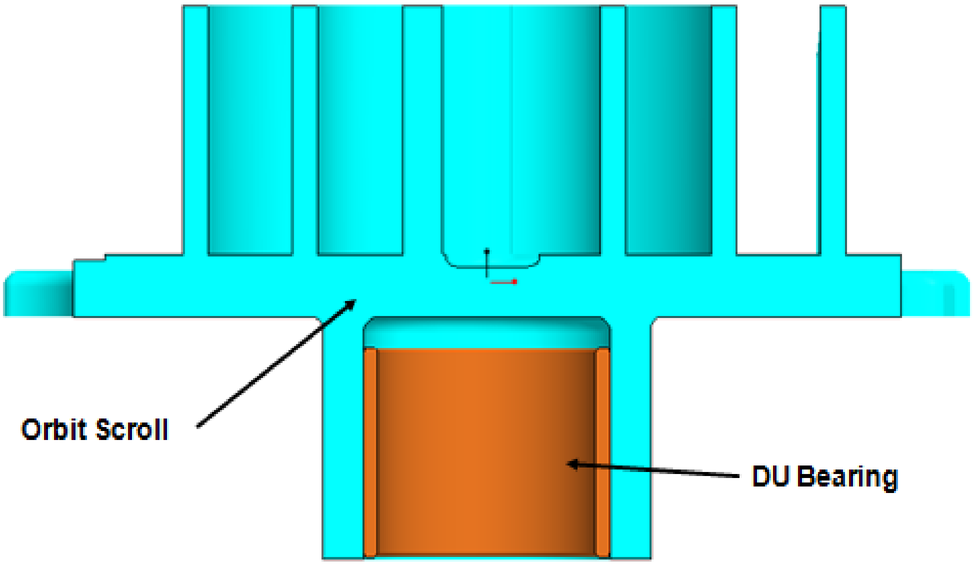


Fig 2.1 Assembled Scroll & Bearing Insert

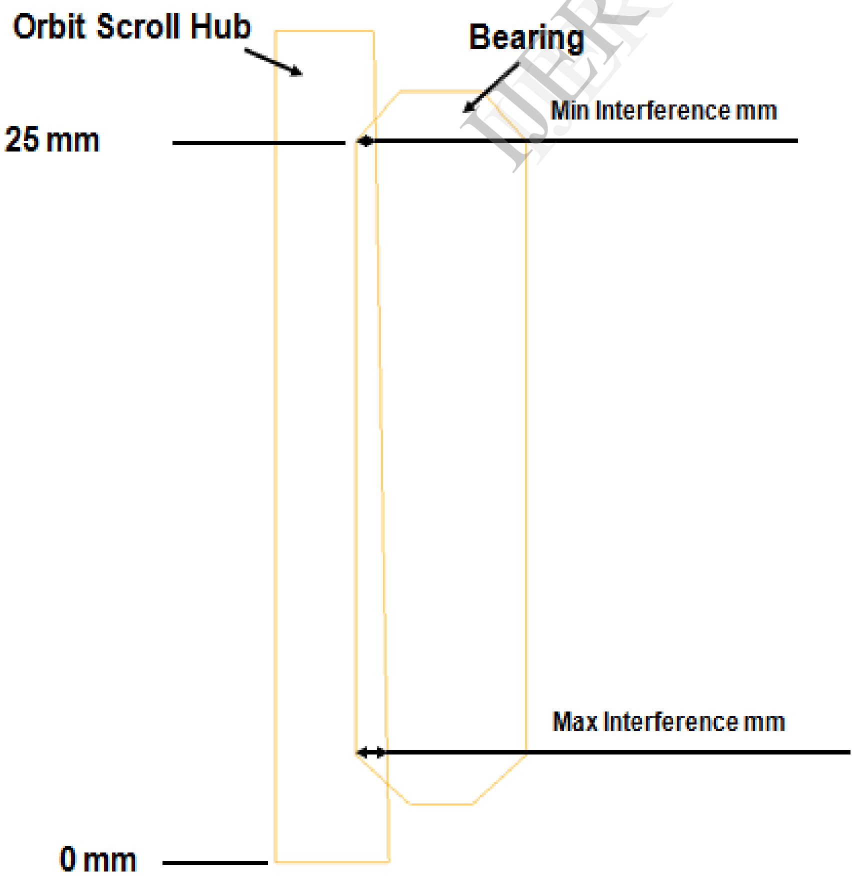


Fig 2.2 Interference between Bearing & Scroll Hub

Contact Pressure Calculations Formula

$$\text{Pressure} = \frac{\Delta}{\left(\frac{D_{I\,Outer}}{E_{Outer}}\right)\left(\left(\frac{D^2_{O\,Outer} + D^2_{I\,Outer}}{D^2_{O\,Outer} - D^2_{I\,Outer}}\right) + \eta_{Outer}\right) + \left(\frac{D_{O\,Inner}}{E_{Inner}}\right)\left(\left(\frac{D^2_{O\,Inner} + D^2_{I\,Inner}}{D^2_{O\,Inner} - D^2_{I\,Inner}}\right) + \eta_{Inner}\right)}$$

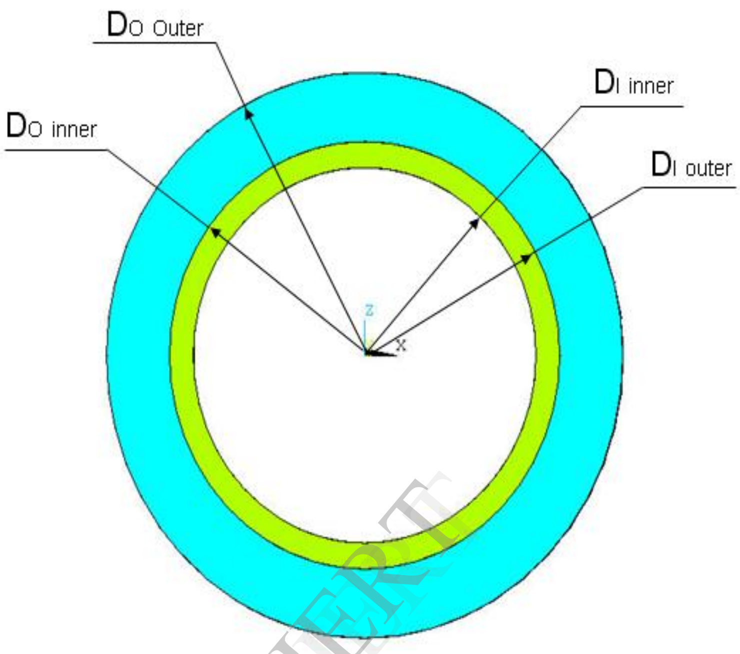


Fig 2.3 Dimensional Representation of Scroll Hub & Bearing

Do Outer = 43.00 mm

Do Inner = Hub Inner Diameter in mm

EOuter = 110000 N/mm2

µOuter = 0.27

Δ = Minimum Radial Interference in mm

DI Outer = Bearing outer Diameter in mm

DI Inner = Bearing Inner Diameter in mm

EInner = 200000 N/mm2

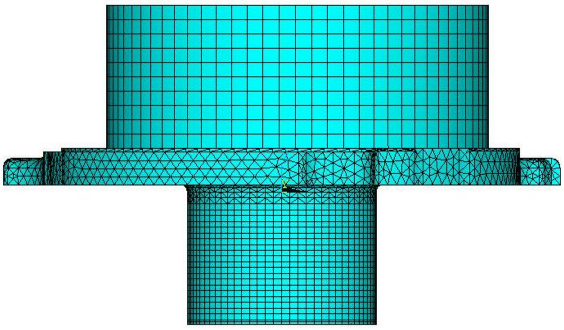
µInner = 0.3

By substituting values in above equation we get,

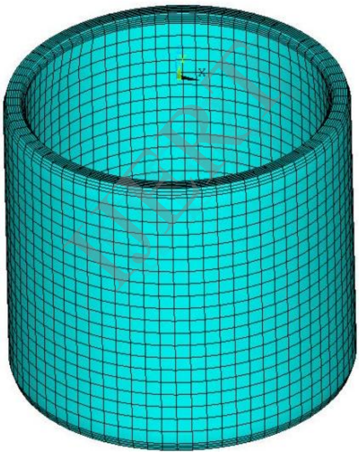
Contact pressure at minimum interference value as **21 MPA**

2.3 FEA Analysis for Contact Pressure at Min & Max Interference

Meshing of Components:



Orbit Scroll: Mapped Meshing At Hub



Bearing Insert: Mapped Meshing 6 Elements Across Thickness

Fig 2.4 Meshed Components

Loading & Boundary Conditions

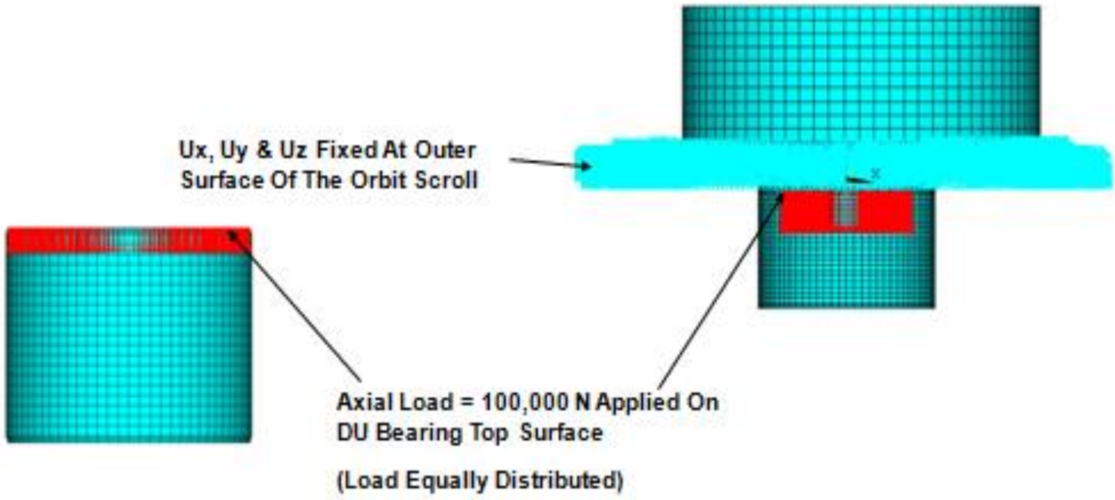


Fig 2.5 Boundary & Loading Conditions

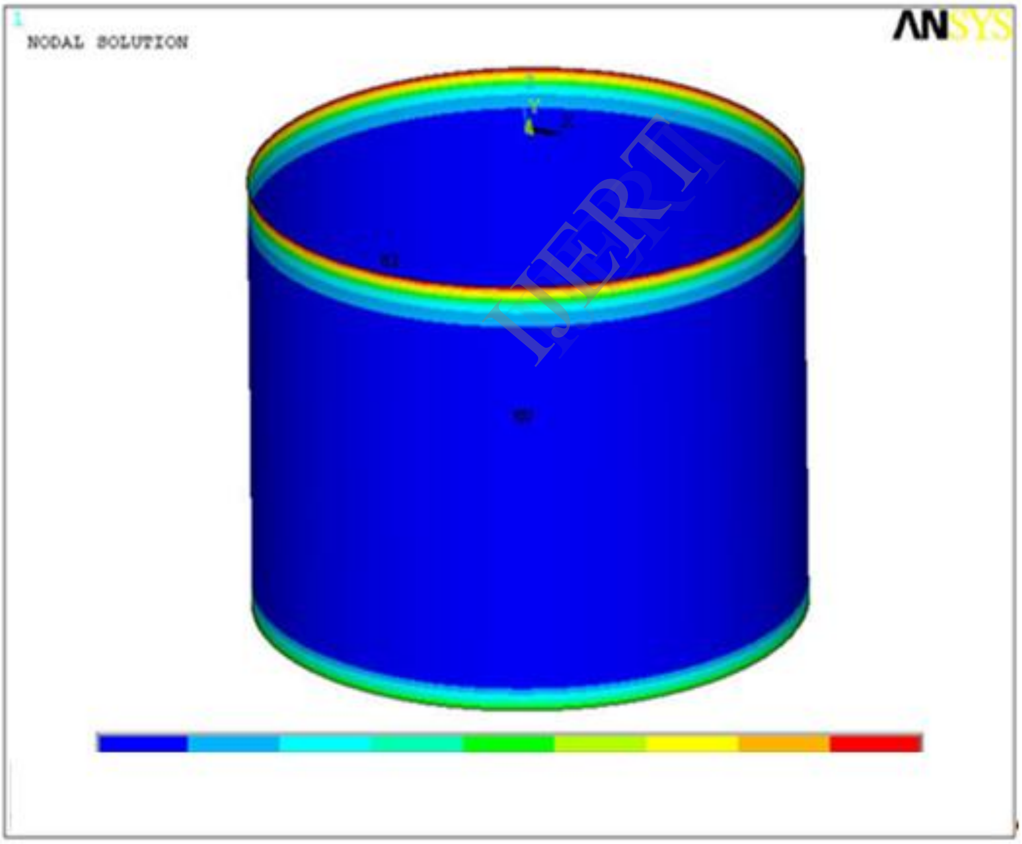


Fig 2.6 Contact Pressure Plot of Hub

From the above analytical calculations & FEA results both the values match closely.

Result Discussion:

a) For Minimum Interference Contact Pressure Matches Closely For FEA Results and Analytical Results.

b) Most Part of the Engagement Length Has Average Contact Pressure

c) Contact Pressure At Top Of Engagement (Near Bearing Top Edge) Are Highest Because Top Edge Is Near To Scroll Base And Hence Offer More Resistance For Deformation Hence Create More Pressure.

Similar Analysis was carried out to find contact pressure at Maximum interference value. These contact pressure values are needed to find the next tangential force needed to spin the bearing in the hub. This is our next level of FEA analysis and explained in detail in next section.

2.4: Tangential force to Spin Bearing at Min & Max interference:

Loading & Boundary Condition

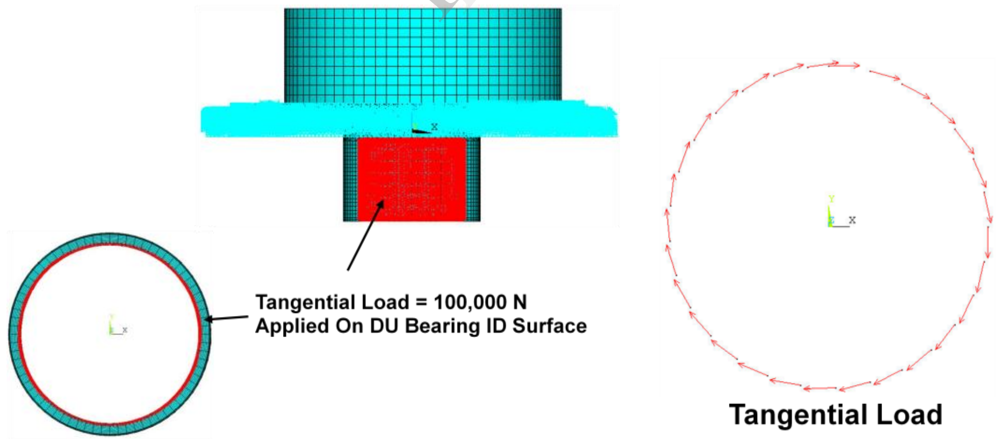


Fig 2.7 Boundary Condition & Loading for Tangential Load

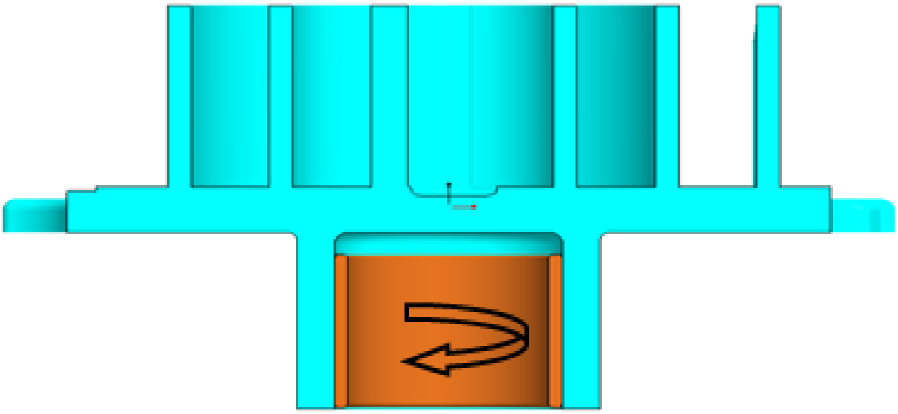


Fig 2.8 Tangential Load Acting in Clockwise Direction

Based on the analysis carried out we got a variation over 150% from the minimum to maximum interference value.

Result Discussion: From the above range it seems that interference value influence greatly for walkout & spin. Based on these results the recommendations were also to find out the variations due to temperature. We have already done the thermal expansion contraction calculations at min and max temperature values we obtained from testing. Based on the output of thermal expansion contraction calculations, it seems that there may be effect of temperature on the tangential force value required to spin the bearing.

4. Conclusion:

FEA for contact pressure & tangential force to spin bearing: From this analysis we identified that the contact pressure is uniform throughout the bearing except higher at the flank bottom areas. Tangential force required to spin the bearing has large influence from the interference value, at the maximum interference value the tangential force is greater than 150%. As further steps to validate these FEA results bench test is planned to understand the interference value & surface roughness phenomena.

5. References:

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