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Analysis and Estimation of Stiffness of Outer Race of Aircraft Bearings

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Abstract: **The prime objective of the project is to determine the stiffness of the outer race of the aircraft bearing used in auxiliary gearbox. The main need of the project reflects in the conclusion derived from the data after calculation and analysis that it gives the minimum necessary value and maximum limits of the dimensions, and stiffness for the given material required for the outer race of the bearing which was designed and analyzed based on the data. Other data such as Bulk modulus, Rigidity modulus etc., could be calculated from the Stiffness found out for the bearing. Here the changes are made to the dimensions of the outer race in the design stage and the results are simulated in software solution, based on which we can reach a conclusion. Respective data for designing the outer race such as dimension, material of the outer race, standard procedures for design and analysis were followed by reference from standard books, papers and under guidance and discretion of respondents at CVRDE.**

Keywords: **Aircraft Bearings, Loading, Deflection, Moment of inertia, Stiffness.**

1. INTRODUCTION

Bearings are mechanical components whose prime objective is to reduce the frictional motion between rotating components, thereby eliminating power loss due to friction and to ‘bear’ the loads acting on the rotational components. Normally the bearings are subject to axial and radial loads. There are different types of bearings such as:

i. Rolling-element bearing

ii. Fluid bearing

iii. Magnetic bearing etc.,

These bearings vary on a wide range from size, load capacity, friction element used, material, fluid used, speed of operation etc., depending on their application. Bearings have a vast area of applications including automobile, machinery and aero-space solutions. The basic components of bearings include Inner race, Outer race, Rolling or Sliding or Fluid element, which reduces friction and capable of withstanding necessary loads. Usually they are used to provide rotation constraint or free rotation of the shaft. But the main differences between conventional bearings and aircraft bearings are material, design, load capacity, mounting etc., Bearings that are used in aircraft should have a basic operation criteria as listed below:

i. Smooth operation at high speeds

ii. Capacity to operate at extreme temperatures and pressures

iii. Heavy load capacity

iv. Light weight

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Apart from these basic criteria the aircraft bearings should be easy to maintain, operation at high altitudes. This criterion is necessary because the viscosity of the fluid changes in case of fluid bearings from fluid to fluid and at different temperatures and pressures. As the aircraft climbs or descends it passes through different regions of the atmosphere which have varying conditions.

2. CAUSES SPECIFIC TO OUTER RACE FAILURE

Damages caused to the outer race could be attributed to few factors like:

1. Faulty mounting
2. Improper lubrication
3. Contamination of bearing lubricant
4. Irregular maintenance etc.,

Other reasons for outer race failure (and aircraft bearing failure) could be pointed out for at certain factors like: Abrasive Wear, Brinelling, Corrosion or Rust, Flaking, Pickup, Scoring, Pitting, Overload failure, Non-Bearing quality steel, Internal damage etc.,

3. OUTER RACE DESIGNED, ANALYSED AND VERIFIED

The bearing under discussion is used in auxiliary gear box of the aircraft engine. The shafts in the gear box are mounted on both the ends using the bearings. So it is highly essential that the outer race of these bearings does not fail as it is a crucial component as discussed previously.

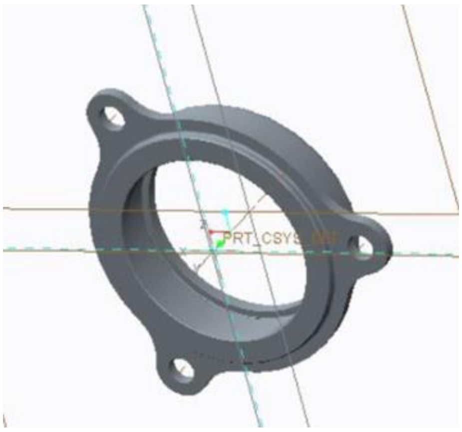

Figure 1: CREO MODEL OF Aircraft Outer Race

The Outer race is modelled according the given dimensions using CREO and saved in STEP and IGES formats for future use (Fig. 1).

The STEP file is imported and analysed for bearing load under static loading conditions for a load magnitude of 1000N along the radial direction only in the lower half (180° to 360° (0°)). Then the deflection was found out. This deflection was then used to determine the stiffness and the stiffness value which was found out was verified using calculation. The Load variation along different angles is shown in Chart 1 and ANSYS result in (Fig. 2).

In order to apply load in bearing load is selected and then radial load along the lower raceway is applied. We can see that the load is a Uniformly Variable load (UVL) as the load varies along different angles. But, if the cross section of the outer race is seen, then the Uniformly Variable Load at different points is a Uniformly Distributed Load (UDL) distributed for certain length along a Cantilever beam. The cross section is seen as a cantilever because the flange has three holes through which fasteners can be inserted and the bearing can be fixed in single place. As the bearing is fixed on one side using flange the bearing is viewed as a cantilever beam with UDL.

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ANGLE	LOAD(N)
0° (360°), 180°	0
337°30'0"	382.683
315°	707.106
292°30'0"	923.879
270	1000
247°30'0"	923.879
225°	707.106
202°30'0"	382.683

Using these parameters and data the bearing is modeled in CREO and analyzed in ANSYS to find deflection and consecutively stiffness of the outer race of the aircraft bearing.

DESIGN PARAMETERS OF THE BEARING OUTER RACE:		
S.NO.	**Description**	**Value / Detail**
1	Bearing Type	Flanged, Rolling element
2	Rolling element	Rollers
3	Diameter of Outer Ring	52 *mm*
4	Thickness of outer ring	4 *mm*
5	Race way Dimension	8.76 *mm*
6	Flange thickness	2.5 *mm*
7	No. of Holes in Flange	3
8	Diameter of Flange hole	5.7 *mm*
9	Diameter of Flange	58 *mm*
10	Diameter of hole centres	66 *mm*
11	Maximum Flange Diameter	78 *mm*
12	Shoulder Diameter	41.2 *mm*
13	Raceway Diameter	44 *mm*
14	Bearing Overall Length	15 *mm*
15	Diameters of Rollers	8.74 *mm*
16	Length of Rollers	4.37 *mm*
17	No. of Rollers	12
18	Outer Race material	Steel
19	Roller Material	Steel
20	Usage	Mounting Shaft in Auxiliary Gearbox of Engine

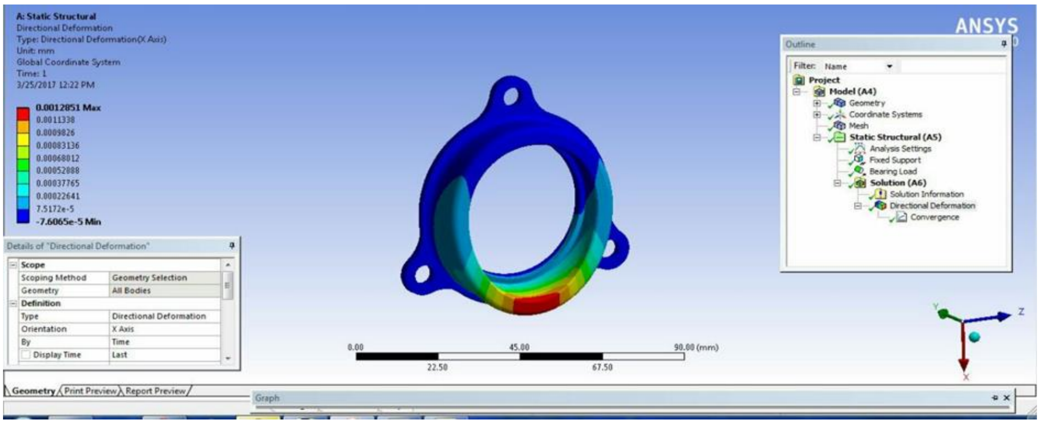

Figure 2: Aircraft bearing simulation result for deflection

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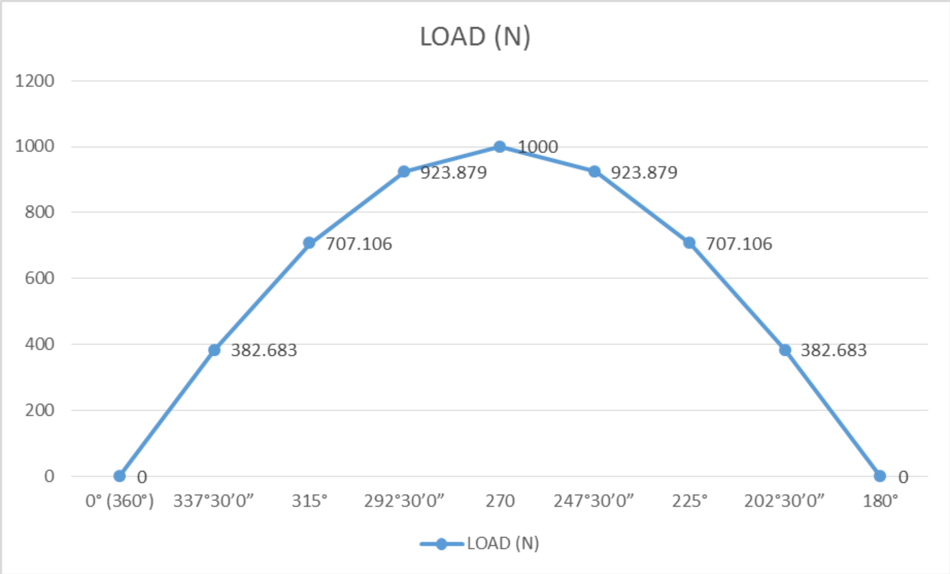

CHART 1: Load Variation Curve along different angles

The deflection value would be maximum at the point where load is maximum. This can be seen from above Fig.2 and Chart 1.

$$Stiffness\ (K) = \frac{load\ (W)}{Deflection\ (\delta)}$$

$K = 1000/ 1.3 \times 10^{-3}$

$K = 769.230 \text{ X } 10^{3}$ N/*mm*

4. THEORETICAL VERIFICATION BY CALCULATION

In order to calculate the stiffness we need deflection. Deflection is calculated theoretically as follows.

$$\delta = \frac{wa^4}{8EI} + \frac{Wa^3}{6EI}(l - a)$$

Where,

w = Load per mm

a = Length of UDL

E = Young's Modulus

I = Moment of Inertia of Cross-Section

of the cantilever beam

l = Length of the cantilever beam

Values are found out to be:

UDL Value (*w*) = 1000N/*mm*

UDL length (*a*) = 8.76*mm*

l = 10.5*mm*

$E = 200000\ N/mm^2$

$I = 3.1459 \text{ X } 10^3\ mm^4$

Deflection, $\delta = 1.4797 \times 10^{-3}$ *mm*

$$Stiffness\ (K) = \frac{load\ (W)}{Deflection\ (\delta)}$$

$K = 1000N / 1.4797 \times 10^{-3}$ *mm*

$K = 675.813 \times 10^{3}$ N/mm

5. CONCLUSION

Thus, from the above results (calculated and ANSYS) we can infer and conclude that the stiffness values does not differ much (approximately 100N/*m)* between the calculated value and ANSYS value and is within the range of the bearing steel 645N/*m* and *785N/m.* And the stiffness value of the designed aircraft bearing made of steel is found out to be 769.23 X 10^3N/*mm.* Thus, using stiffness value the change in length of different dimensions of bearings can be found out for the same material. Other than this we can use the material stiffness value of the bearing to study about the behavior of the bearing under different thermodynamic conditions.

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