OPTIMIZATION OF THICKNESSES OF INNER AND OUTER RACES OF A DEEP GROOVE BALL BEARING USING FEM (ANSYS)

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Abstract— ***3d model of the roller ball bearing was created in ANSYS workbench. The thicknesses of the inner and outer races of the bearing were to be optimized using parameterization in ANSYS workbench. The basic methodology adopted was the contact stress analysis between the races and the balls. The outer race was kept fixed whereas the inner race was subjected to radial loading and rotation from the shaft. The inner diameter of the bearing and the outer diameter of the bearing were kept fixed according to the application. The bearing ball diameter was also kept fixed. The only variables were the thicknesses of the inner and outer races. The thicknesses were parameterized by varying the centre to centre distance between the shaft and the bearing balls while maintaining contact between the balls and the grooves of the races. The optimum thicknesses were chosen. Further, material removal from the bearing was also studied.***

Keywords— ***Deep Groove Ball bearing, contact stress analysis, inner race, outer race, bearing balls.***

I. INTRODUCTION

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the ballsare rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other all bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races [2]. The thicknesses of the races of the ball bearing are a very important parameter as they decide the weight of the ball bearing. Moreover, optimum thickness also avoids penetration of the balls through the races of the bearing.

II. PROBLEM STATEMENT

A single row deep groove ball bearing is subjected to a pure radial load of 3KN from a shaft that rotates at 600rpm. The expected life L_{10h} of the bearing is 30000h. The minimum acceptable diameter of the shaft is 40 mm. To select a suitable bearing from the bearing catalogue and optimize it for the thickness of the inner and outer races.

III. SELECTION OF BEARING [1]

The bearing was selected according to the required application from P.S.G data book of mechanical design.

- Inner Diameter: 40mm
- Outer Diameter: 80mm
- Ball Diameter: 10mm
- Axial Length of bearing: 18mm

IV. ANSYS PARAMETERS

- Contact type: Bonded (balls and groove in the races)
  since there is no separation allowed and no sliding allowed
  between the contact surfaces.
- Contact Body: Grooves of bearing balls
  Target Body: Bearing Balls
- Bearing Load: 3000 N (radial)
- Angular Velocity: 62.83 rad/sec
- Fixed Support: Outer race

V. PARAMETERIZATION OF INNER AND OUTER RACE THICKNESSES IN ANSYS

The following table compares the various values obtained for variable thickness of inner and outer races of ball bearing. (ANSYS Parametric table) The material used for the analysis is stainless steel.

able of Design Points

	A	B	C	D	E	F	G	H	I	J
1	Name	P10 - innerrace	P11 - outerrace	P26 - cage	P12 - Equivalent Stress Minimum	P13 - Equivalent Stress Maximum	P14 - Total Deformation Maximum	P15 - Safety Factor Minimum	P16 - Geometry Mass	P17 - Geometry Volume
2	Units				Pa	Pa	m		kg	m^3
3	Current	34	34	34	2116.4	3.5857E+07	1.915E-06	5.7729	0.34325	4.429E-05
4	DP 1	32	32	32	13532	3.8085E+07	2.0799E-06	5.4352	0.35661	4.6014E-05
5	DP 2	30	30	30	13402	4.0472E+07	2.7272E-06	5.1146	0.36997	4.7738E-05
*										

Table 5.1: Parameterization of inner and outer race thicknesses in ANSYS

The basic methodology adopted behind the selection of thickness is the contact stress analysis of inner and outer races of the ball bearing. The thicknesses of the races are linked to the centre of the bearing balls, such that, varying the centre to centre distance between the shaft and bearing balls varies the thicknesses of the races, for e.g: Increasing the centre to centre distance leads to decrease in the thickness of the outer race and increase in the thickness of the inner race as the radius of the bearing balls remain constant and the contact is to be maintained. The stress analysis in ANSYS for the radial load and angular velocity showed that the fixed outer race encountered minimum stresses and deformation whereas the inner race encountered maximum stress and deformation. Hence, the inner race was made thicker compared to the outer race. The thinner outer race leads to material saving since it has a larger diameter. After comparing the values in table no. 5.1, the ball centre is selected to be at a distance of 34mm from the radial centre of the shaft. This lead to a better factor of safety, lesser weight, least deformation and lesser stresses in the bearing as shown in the table below.

Ball centre distance (mm)	Total deformation (m)	Max stress (Pa)	F.O.S	Total weight (Kg)
34	$1.91*10^{-6}$	$3.58*10^{7}$	5.77	0.3432

Table 5.2: Result for optimized thicknesses of races

Inner diameter	Outer diameter	Centre to centre distance (shaft to ball)	Ball diameter	Inner race thickness (radial)	Outer race thickness (radial)	Bearing thickness (axial)
40	80	34	10	10	2	18

Table 5.3: Optimized bearing dimensions (All dimensions in mm)

VI. LOADING AND ANALYSIS OF DEEP GROOVE BALL BEARING IN ANSYS (OPTIMIZED THICKNESS)

The application of ANSYS parameters mentioned previously are shown below for the optimized bearing.

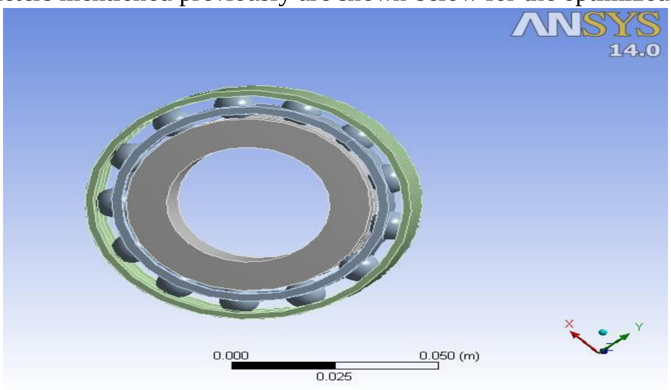

Fig. 6.1: CAD model of deep groove ball bearing

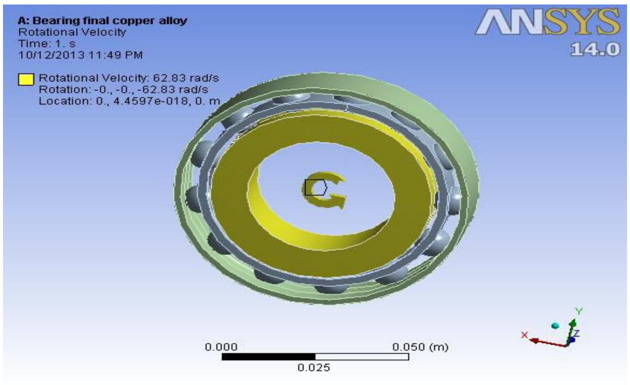

Fig. 6.2: Application of angular velocity in ANSYS

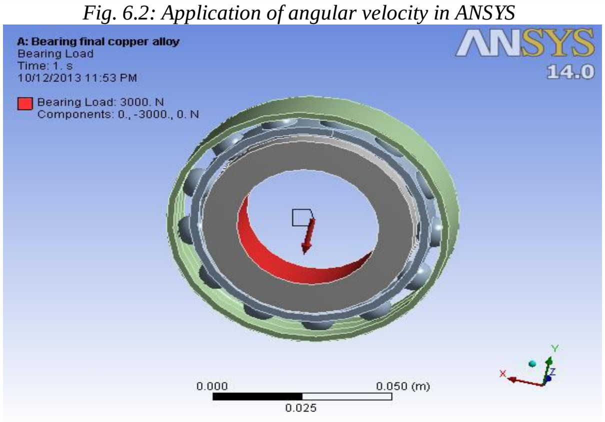

Fig. 6.3: Radial shaft load on the inner race

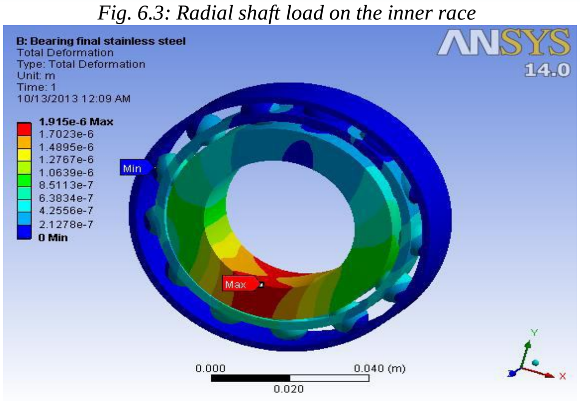

Fig. 6.4: Total Deformation

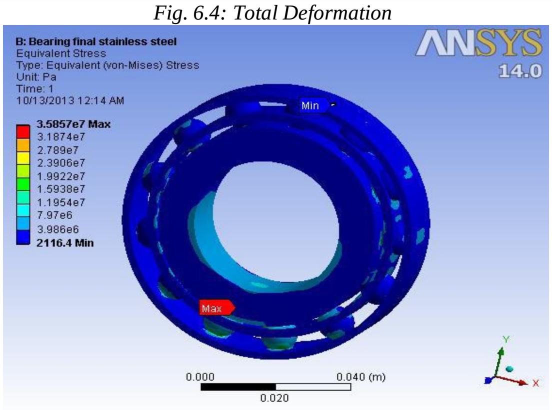

Fig. 6.5: Equivalent Stresses

VII. MATERIAL SELECTION

Further, copper alloy material was selected and analysed.
*C.Y.S: Compressive Yield Strength

The above data was calculated on ANSYS.

Material	*C.Y.S (N/m^2)	Max. Deformation (m)	Max. Stress (N/m^2)	Total Weight (Kg)	Factor of Safety
Copper alloy	$2.8*10^8$	$3.3251*10^{-6}$	$3.5299*10^7$	0.3676	7.93
Stainless Steel	$2.07*10^8$	$1.915*10^{-6}$	$3.5857*10^7$	0.3432	5.77

Table no. 7.1: Comparison between properties of Stainless steel and Copper alloy

Conclusion: Copper alloy and stainless steel both show very good properties. The overall properties of Copper alloy are better (F.O.S, C.Y.S). However, considering the cost aspect, stainless steel is cheaper compared to Copper alloy and gives almost similar results. Moreover the bearing is approximately 20 gms lighter if stainless steel is selected as the material for the bearing. Hence, considering cost and weight **stainless steel** material is selected for further optimization.

VIII. MATERIAL SAVING

The optimized bearing for the thickness of races is then subjected to material removal. Material was removed at suitable areas from the inner race to reduce the weight of the bearing keeping the factor of safety above 4.

Bearing type	Weight (gms)
Without material removal	300 gms
With material removal	343 gms

Table no. 8.1: Comparison of weight (Pre and Post material removal)

Total weight reduced: 343-300=43 gms.

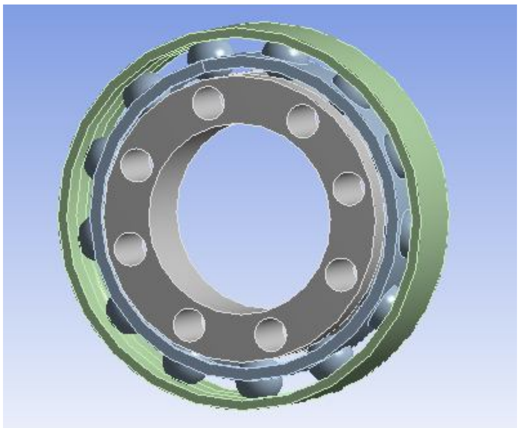

Fig. 8.1: CAD model of bearing with material removal

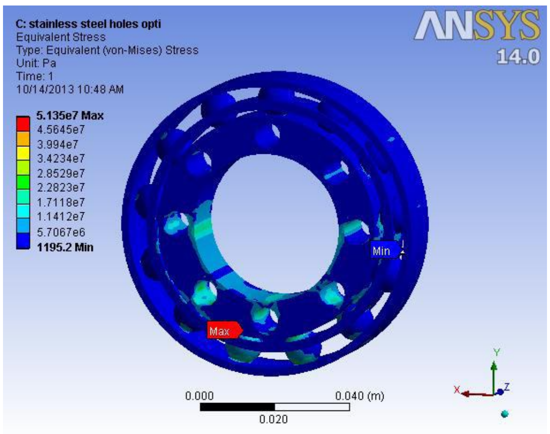

Fig. 8.2: Equivalent stresses in the bearing

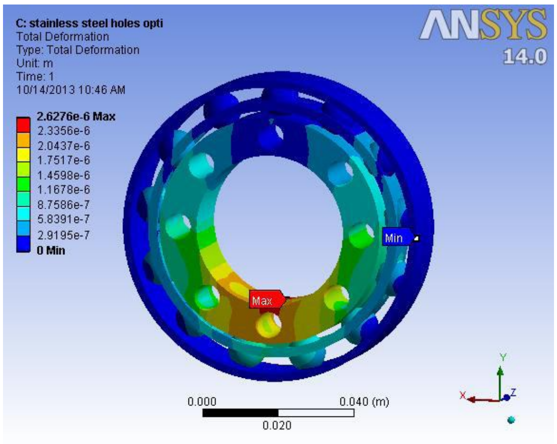

Fig. 8.3: Total deformation in the bearing

IX. CONCLUSION

1. The successful results show that the boundary conditions were correctly selected for the analysis.
2. The thicknesses of the races of the bearing were optimized using FEM method (ANSYS).
3. Parametric analysis was successfully demonstrated in the selection of optimum thicknesses of the bearing races.
4. The inner race bears considerable amount of loading compared to outer race when the outer race is fixed. The outer race and inner race have to be checked for the penetration of bearing balls.
5. Material removal showed that weight can be reduced from the ball bearings but, weight reduction is very small. Moreover, there is increased stress concentration near the holes. This may lead to premature fatigue in the ball bearings. Thus, material removal is not feasible for the deep groove ball bearing.

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