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Weight Optimization of Deep Groove Ball Bearing

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Abstract — Ball bearing is the rotating assembly constitute with the four main components as bearing outer, bearing inner, bearing ball and bearing cage. This research study has been carried out for the optimization of the deep grooved ball bearing. The optimization of the bearing means, to reduce the output of the bearing among the stresses generated due to load and the overall weight of the bearing. In this research work the bearing weight optimization has been performed by keeping the results of the stresses has been same as the generated in the existing bearing design. The weight is the most effecting parameter which is affecting on the life of the bearing and cost of the bearing. The saving in the weight of the bearing means reduction in the overall weight of the bearing.

Keywords*-Component, Rotational, Friction, Weight, Stresses*

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I. INTRODUCTION

To reduce the failure of bearing, static temperature of bearing should be less than critical temperature of bearing. [1] Rotational speed, oil viscosity and thermal boundary conditions as the critical parameters which should be considered to avoid the thermal failure of the ball bearings. [2] Corroboration with the energy dissipation criterion offers a better evaluation of the bearing performance related to scuffing. [3] The predicted trends of increasing temperature and heat generation with increased shaft speed and of decreasing temperature and increasing heat generation with increased lubricant flow rate were verified by the experimental data. [4] The temperature gradient through the bearing increases with increasing effective mounted contact angle. [5] In research study the bearing weight has been reduce by keeping constant temperature generated in bearing.

II. DESIGN CALCULATION

The basic model for the bearing has been prepared based on the reverse engineering of the bearing, and based on the basic dimension of thermal calculation has been prepared and compared with the analysis performed in the ANSYS for the initial analysis.

following Bearing data have been selected for calculations: Selected DGBB No= 6016 Bearing OD (D) =125mm Bearing ID (d) =80mm Bearing Width (B) =22mm Mean Diameter of bearing (d_m) = 102.5 mm Radial Load on Bearing (F_r) = 30000 N Basic dynamic load rating (C) = 37000 N Basic static load rating (C_0) = 33000 N Bearing rpm (n) = 1000

Calculation of the Frictional Moment:

The frictional moment M of a rolling bearing, i.e. the sum total of rolling friction, sliding friction and lubricant friction is the bearing's resistance to motion. The magnitude of M depends on the loads, the speed and the lubricant viscosity. So that the frictional moment comprises a load-independent component M_0 and a load- dependent component M_1.

Calculation for load-independent component of the frictional moment M_0:

Operating Temperature (t) = 40 °C, Index for bearing type and lubrication type for oil lubrication for deep groove ball bearing (f_0) = 1.5, Index for bearing type and lubrication type for grease lubrication for deep groove ball bearing (F_0) = 1.5/2 = 0.75. Required viscosity at 1000 rpm of speed = 18 mm^2/s.

Selected base oil / grease ISO VG 22.

Operating viscosity of the oil or grease base oil / grease lubrication ISO VG 22= 22 mm^2/s

Load-independent component of the frictional moment (M_0)

$$Mo = Fo \times 10^{-7}(v \times n)^{2/3} \times d_m^3$$
$$= 0.75 \text{ X } 10^{-7} (22 \text{ X } 1000)^{2/3} \text{ X } 102.5^3$$
$$= 63.413 \text{ Nmm}$$

Calculation for load-dependent component of the frictional moment M_1:

Index taking into accounts the amount of load for DGBB (f_1)

$= 0.0005 \text{ X } (P_0/C_0)^{0.5}$

$= 0.0005 \text{ X } (30000/33000)^{0.5}$

= 0.00045

Load ruling P1 = Total load on Bearing = Fr = 30000 N

Total frictional moment of the bearing

$Mi = f_l \text{ x } P_l \text{ x } d_m$

= 0.00045 X 30000 X 102.5

= 1384.42 Nmm

Total frictional moment of the bearing

$M= M_0 + M_1$

= 63.413 + 1384.42

= 1447.856 Nmm

The Heat Flow due to this frictional moment (Q_R)

$Q_R=1.047\times10^{-4} \times n \times M$

$= 1.047 \text{ X } 10^{-4} \text{ X } 1000 \text{ X } 1447.856$

= 151.59 Watt

For steady state condition of Bearing

Heat Flow due to this frictional moment (Q_R) = Heat Flow from Bearing (Q_L)

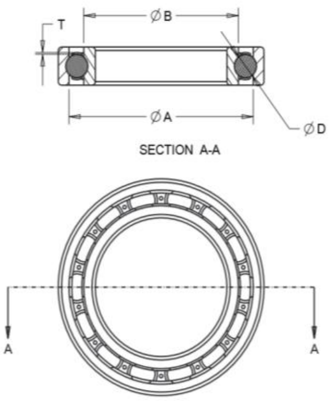
Heat Flow from Bearing (Q_L) = 151.59 Watt

III. EXPERIMENTATION :

some of the dimensions accepted without change during the optimization process, such as the bearing outer dimension, bearing inner dimension and the bearing width, and other dimensions are change because they are related to the bearing itself not related to the assembly fitment. The dimensions which will decide to change are mentioned as under.

Changed geometry parameters & applied variable combinations of bearing assembly with their changed dimension for this research work as following;

- Cage
- Inner ring
- Outer ring
- Ball Diameter



TRIAL NO.	ØA	ØB	ØD	T
1	111	94	13.494	1.0
2	112	94	13.494	0.9
3	111	93	13.494	0.9
4	112	93	13.494	1.0
5	111	94	13.594	0.9
6	112	94	13.594	1.0
7	111	93	13.594	1.0
8	112	93	13.594	0.9

BEARING NO= 6016

Figure 1.Experimental setup

ANALYSIS USING MINITAB SOFTWARE:

Effect of the bearing dimensions on the temperature is shown as follows. The effectiveness of the above four geometrical parameters on temperature was established by run the analysis setup in the MINITAB software.

After run the setup in the MINITAB software, following results has been predicted. The relationship between temp, outer id, inner od, ball diameter and the sheet thickness are derived as under.

Factorial Fit: TEMP versus OUTER ID, INNER OD, BALL DIA, STRIP THICKNESS

Estimated Effects and Coefficients for TEMP (coded units)

Term	Effect	Coef	SE	T	P
Constant	55.4819	0.004049	13704.19	0.000	
OUTER ID	0.0038	0.0019	0.004049	0.46	0.675
INNER OD	1.1877	0.5939	0.004049	146.69	0.000
BALL DIA	-0.1982	-0.0991	0.004049	-24.48	0.000
STRIP THICKNESS	-0.0032	-0.0016	0.004	-0.40	0.715

S = 0.0114510 R-Sq = 99.99% R-Sq(adj) = 99.97%

From the above output received from the MINITAB software, the most effective parameters are Inner OD and the Ball diameter of the bearing. Another two parameters Outer ID and Strip thickness is not effective on the temperature of the bearing.

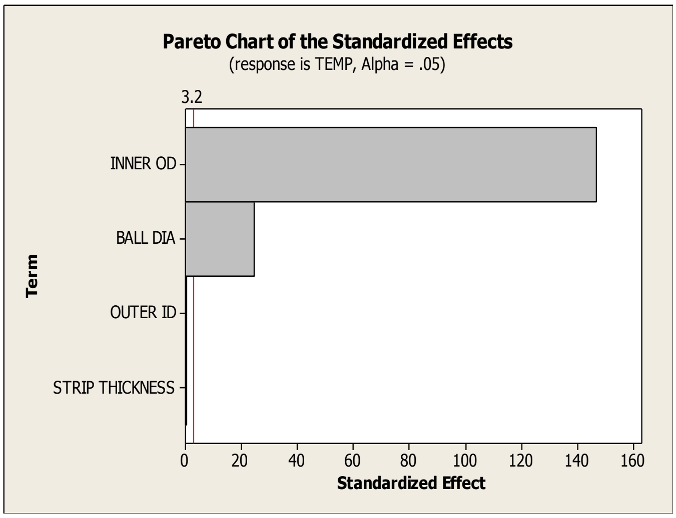


Figure 2. Pareto chart of the standardize effect

Figure 2 shows pareto chart shows the, the parameter INNER OD and BALL DIA are the parameters which are most effective, and the work has been started on these two parameters.

From these results it has been conclude that when optimization has been carried out for that change OUTER ID and STRIP THICKNESS, Which is not much affected on bearing temperature as it was seen in Paratoo from that the work go for DOE analysis.

ANALYSIS OF DGBB 6016

After performing the all calculations and modeling of the ball bearing using Pro-E creo 2.0 and, the analysis has been performed for the existing case of the analysis.

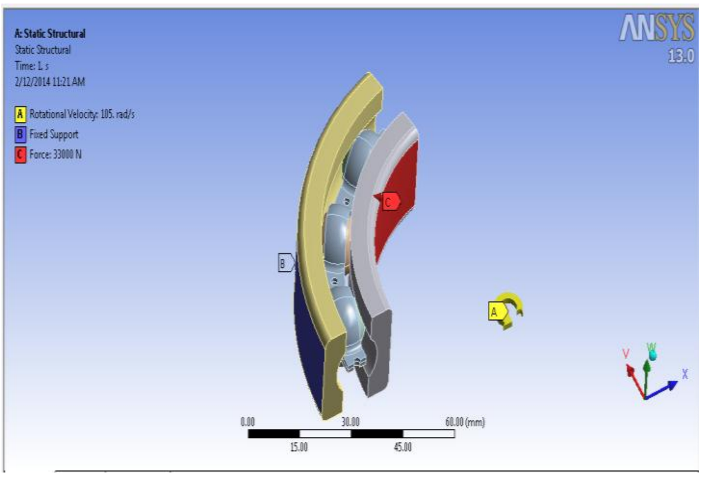


Figure 3. Boundary Condition applied on the Ball Bearing model

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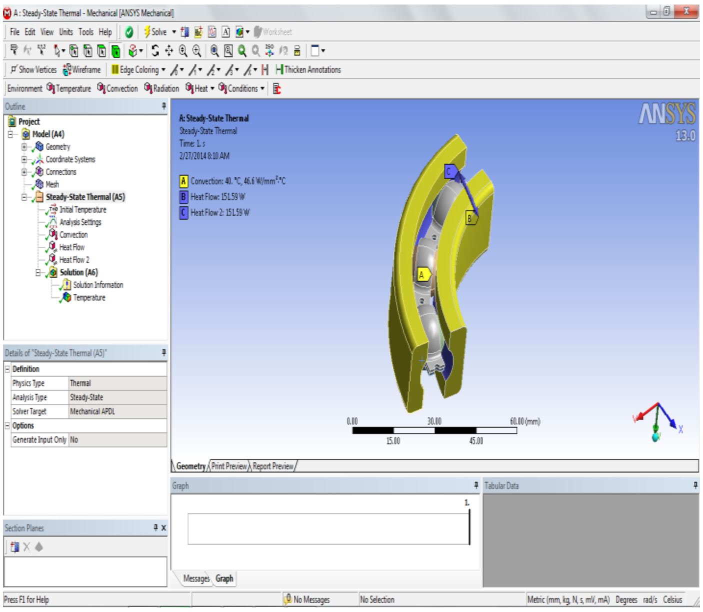

Figure 4. Boundary Condition applied on the Ball Bearing model

After applying the mesh on the CAD geometry of the model prototype, the boundary condition has been applied on the model. In the model, the rotation velocity applied up to 105 rad / sec and similarly the bearing is fixed supported from the inner face and load applied on the outer race of the bearing. The 33000 N load applied on the bearing.

TABLE 1.Comparison of analysis of deep groove ball bearing

ANAYSIS	EXISTING DGBB 6016		NEW OPTIMIZED DGBB	
	MAX	MIN	MAX	MIN
Von-Misses stress.	795.570	0.12181	792.06	0.11583
Max Shear Stress.	432.41	0.067101	430.12	0.066792
Total Deformation.	0.017763	0	0.01856	0
Temperature.	54.977	39.704	54.984	39.982

IV. CONCLUSION

Minitab software gives the optimum trial run in a table form.

This research work has been done by analysis on basis of data gathered from Minitab software & get temperature variation.

TABLE 2.MINITAB RUN ORDER

RunOrder	OUTER ID	INNER OD	BALL DIA	STRIP THICKNESS	TEMP	TOTAL WEIGHT
1	112	94	13.49	0.9	54.984	0.8388
2	111	94	13.49	1	54.977	0.8592
3	111	93	13.59	1	55.973	0.848
4	112	94	13.59	1	54.799	0.8456
5	111	94	13.59	0.9	54.792	0.858
6	112	93	13.49	1	56.185	0.8288
7	112	93	13.59	0.9	55.967	0.8276
8	111	93	13.49	0.9	56.178	0.8412

From this research work optimum bearing part dimension have been made and bearing weigh has been reduced up to 0.0204 Kg compared to the standard bearing.

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