Modeling, simulation and stress Analysis of Integral Shaft Bearing Using Ansys Benchworks 14.0

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Abstract

An integral shaft bearing is main component of machine and carrying higher specific load capacity, preventing misalignment defects in compression to any other bearings. Integral shaft bearing is reduce rotational friction and support, axial and radial loads which generate friction and increased temperature and vibration inside the bearings. If the generated heat and vibration cannot be properly removed from the inside bearing, the temperature might exceed certain limit. Due to which the bearing should be fail. That why I analyze vibration in 10 step ,heat flow, temperature distribution in a bearing system, a typical integral shaft bearing and its environment has been design and analyze the system using the famous finite elements tool ANSYS workbench 14.0. In this research, vibration and thermal characteristics performance of integral shaft bearing to Analyze vibration, thermal elongation and temperature distribution due to friction and frequency also its effect on bearing clearances, and vice-versa, has been investigated on stainless steel materials with different parameters .

Keywords: *Integral shaft bearing, Modeling ,Structure Module*

Introduction

A bearing is a machine element that provide relative motion between one part to the another part of the machine, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. bearings hold rotating components such as shafts or axles within mechanical systems, and transfer axial and radial loads from the source of the load to the structure supporting it. The term "bearing" is derived from the verb "to bear"a bearing being a machine element that allows one part to bear (i.e., to support) another. The simplest bearings are bearing surfaces, cut or formed into a part, with varying degrees of control over the form, size, roughness and location of the surface. Other bearings are separate devices installed into a machine or machine part. The most sophisticated bearings for the most demanding applications are very precise devices their manufacture requires some of the highest standards of current technology.

.The invention of the rolling bearing, in the form of wooden rollers supporting, or bearing, an object being moved is of great antiquity, and may predate the invention of the wheel. Though it is often claimed that the Egyptians used roller bearings in the form of tree trunks under sleds, this is modern speculation.They are depicted in their own drawings in the tomb of Djehutihotep as moving massive stone blocks on sledges with liquid-lubricated runners which would constitute a plain bearing. There are also Egyptian drawings of bearings used with drills. The earliest recovered example of a rolling element bearing is a wooden ball bearing supporting a rotating table from the remains of the RomanNemi ships in LakeNemi, Italy. The wrecks were dated to 40 Bc.

Leonardo da Vinci incorporated drawings of ball bearings in his design for a helicopter around the year 1500. This is the first recorded use of bearings in an aerospace design. However, AgostinoRamelli is the first to have published sketches of roller and thrust bearings. An issue with ball and roller bearings is that the balls or rollers rub against each other causing additional friction which can be reduced by enclosing the balls or rollers within a cage. The captured, or caged, ball bearing was originally described by Galileo in the 17th century,

The first practical caged-roller bearing was invented in the mid-1740s by horologist John Harrison for his H3 marine timekeeper. This uses the bearing for a very limited oscillating motion but Harrison also used a similar bearing in a truly rotary application in a contemporaneous regulator clock. The term “rolling bearing” includes all forms of roller and ball bearing which permit rotary motion of a shaft. Normally a whole unit of bearing is sold in the market, which includes inner ring, outer ring, rolling element (ball and roller) and the cage which separates the rolling element from each other.

Rolling bearings are high precision low cost but commonly used in all kinds of rotary machine. It takes long time for the human being to develop the bearing from the initial idea to the modern rolling bearing. The reason why bearing is used is that first it can transfer moment or force. Secondly and maybe more important is that it can be interchanged easily and conveniently when it’s broken. In the mechanical system, it is also possible to amount the shaft directly with housing. However, when this mechanism has some problem, the only possibility to recover the function of this system is to re4plece the housing or the shaft. From the mechanical engineer point of view, both of them are not only very expensive but also time consuming to manufacture a new housing or shaft with the same parameters. However when the bearings are used between them, the situation will be different. Normally there is no relative motion between shaft and inner ring or the outer ring with housing. So it has less possibility for the shaft or housing to be worn out. Usually the bearing first cracks and then the shaft or housing is broken. If the above situation happens it is really easy to it out. Just buy a new bearing from the market with the same parameter and replace it.

Water pump bearings are double row bearings and, in contrast to conventional double row bearings, do not have an inner ring but raceways machined directly into the surface of the shaft. As a result, there is more space available for the rolling elements, giving a higher specific load carrying capacity than that of solutions with conventional single bearings. Furthermore, it is possible in this type of bearing to achieve economical combinations of ball and roller rows. In a small design envelope, this gives a broad range of load carrying capacities. The use of a common outer ring for two rows of rolling elements prevents misalignment defects, eliminating the risk of undesirable distortion of the bearings. In water pump bearings, the ends of the shaft normally extend beyond the outer ring on both sides. The length and diameter of these extended sections are matched to the specific application. This results in a simple, ready-to-fit bearing unit that is primarily used in water pumps for road vehicles.

2- Objective of project

- To design of integral shaft Bearing for turbine
- To vibration analysis and temperature distribution for integral shaft bearing
- Thermal elongation of component in Integral Shaft Bearing at different temperature & its effect on bearing clearances

3-FEA ANALYSIS

3.1 Geometric Model

Integral shaft bearing product details as shown in table 3.1 as per Industrial requirements figure 3.1 shows the complete assembly of integral shaft bearing.

Bearing type	Integral shaft bearing
Type of rolling elements	Roller/ Ball
No. of rolling elements	15
Components details of assembly	Shaft, ball cage, roller cage, rollers, balls, Sleeve
Sleeve diameter	30 mm
Ball diameter	15.918 mm
Shaft diameter	6.35 mm

Table 3.1

Part geometry of complete Bearing created in CAD environment of CATIA v5 is successfully imported to ANSYS environment.

3.2 STRESS ANALYSIS

Finite element method is a numerical methods for solving a differential or integral Equation. It has been applied to a number of physical problems, where the governing differential equations are available . The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the function in a manner that reduces the error in the solutions. Here we have to fine maximum stresses in each component of bearing, and to safe design of components material maximum stress should be less than allowable stress design allowable stress 6 all = yield strength or ultimate strength* factor of safety . Assume factor of safety is 1, Allowable stress of material used in assembly is calculated in following table 3.2

Material Allowable Stress Table 3.2

Material	Components	Modulas of elasticity (GPA)	Yield Strength(Mpa)	Ultimate Strength(Mpa)	Allowable Stress (Mpa)
Chromium steel	Shafts, Balls,Rollers,Sleeve	210	260	460	460
Nylon 101	Ball & Roller cage	36	80	NA	80
1060Aluminum Alloy	Housing	71	280	310	310
Nitrile butadiene rubber	Shield of bearing	NA	20	NA	10

Finite Element Analysis Of Intigral Shaft Bearings

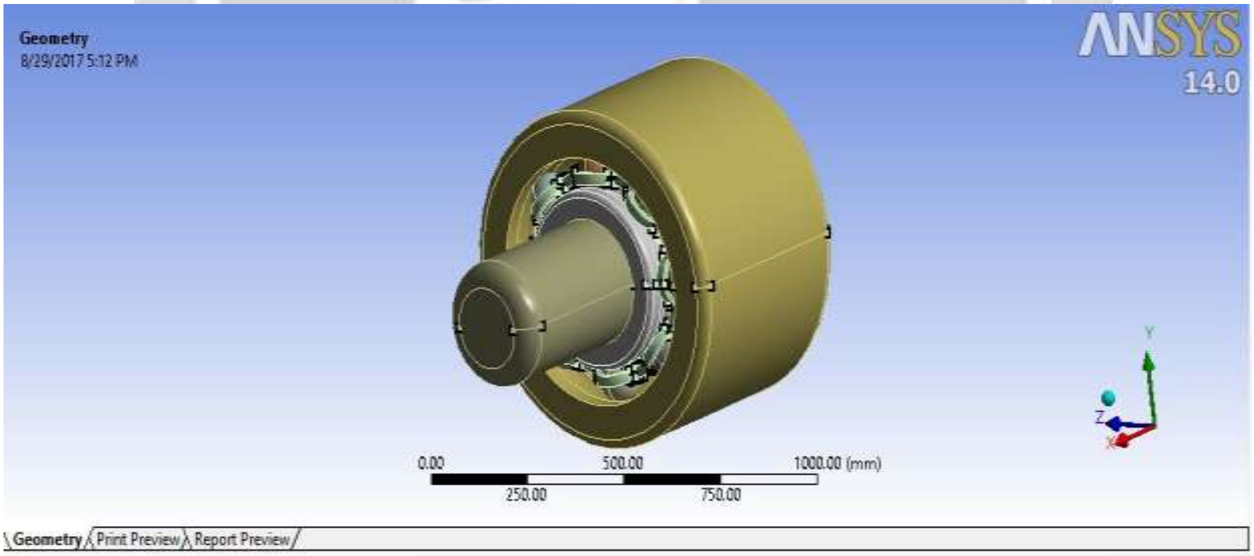
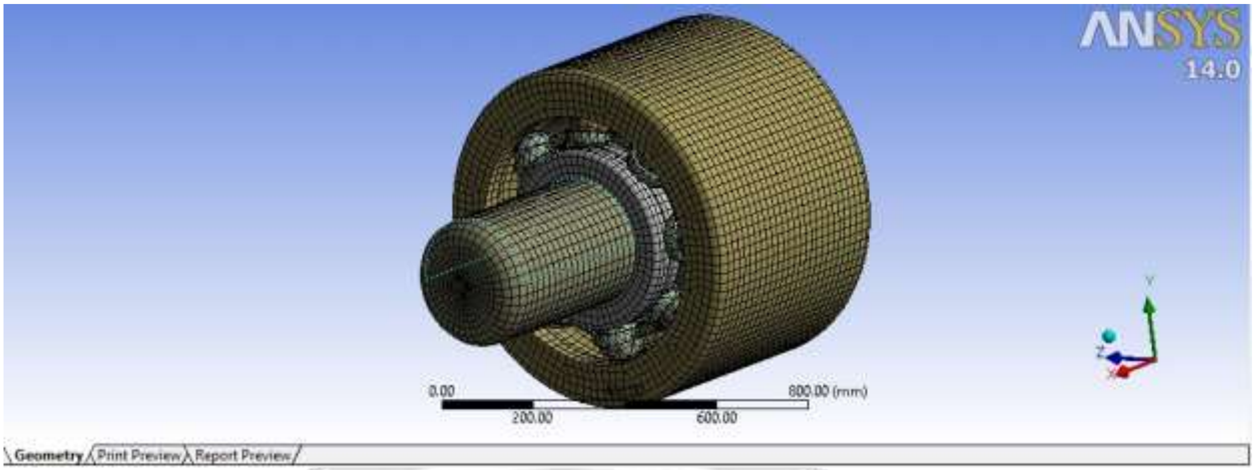


Fig.3.1 Integral Shaft Bearing

3.3 -Mesh Generation:

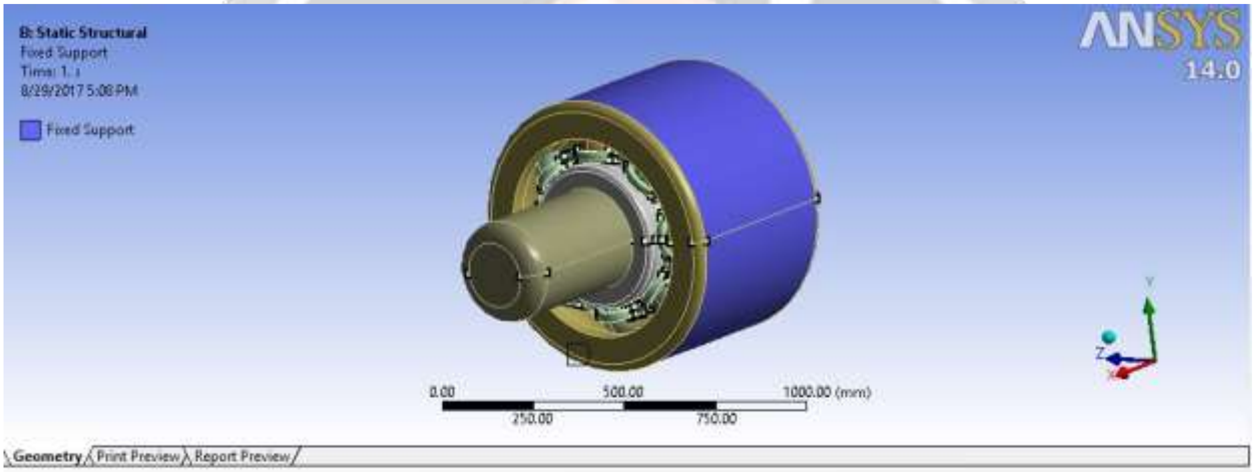
In this analysis mesh generation is auto mesh generation with element size is 15mm. This element size is used for all the body of Integral Shaft Bearing. Hex-dominant method is used for all the parts of Integral Shaft Bearing



Mesh Generation of whole Assembly Fig. 3.3

3.4 Boundary Conditions:

3.4.1 Fixed support


B: Static Structural
Fixed Support
Time: 1. s
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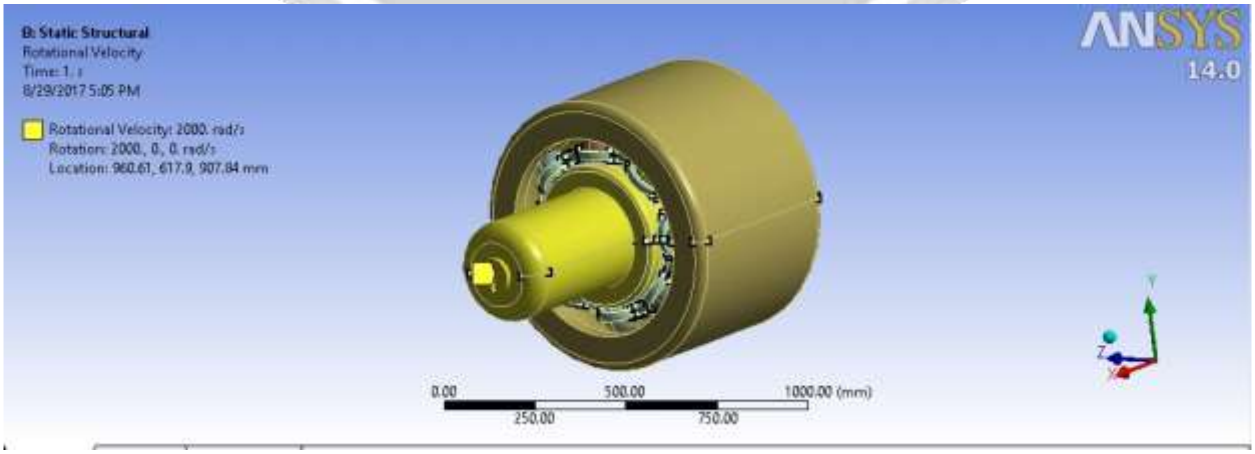
🟦 Fixed Support

3.4.2 Rotational velocity


B: Static Structural
Rotational Velocity
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🟨 Rotational Velocity: 2000. rad/s
Rotation: 2000., 0., 0. rad/s
Location: 960.61, 617.9, 907.84 mm

Fig3.4 Loading & Boundary Conditions

Table 3 Loading & Boundary Condition

Speed (RPM)	HUB Load N	% Use	Water Pump Temperature	Fit Conditions	Housing diameter	Sleeve OD	Radial Clearance(Ball)	Radial Clearance (Roller)
1800	600	19.7	-30	Max. Interference condition	Max Interference condition		Minimum Clearance	
					29.90	30	.02	.02

Thermal Condition:

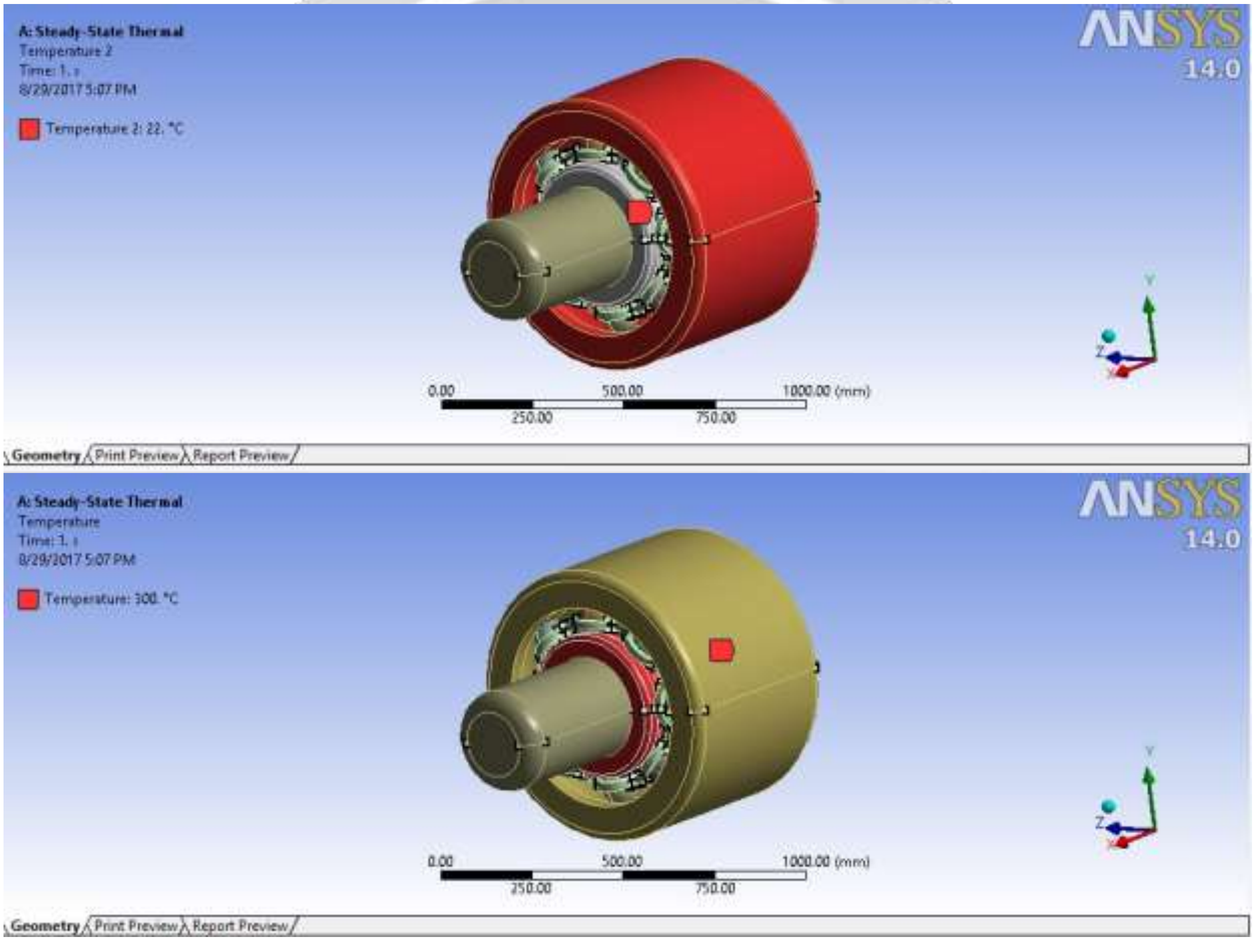
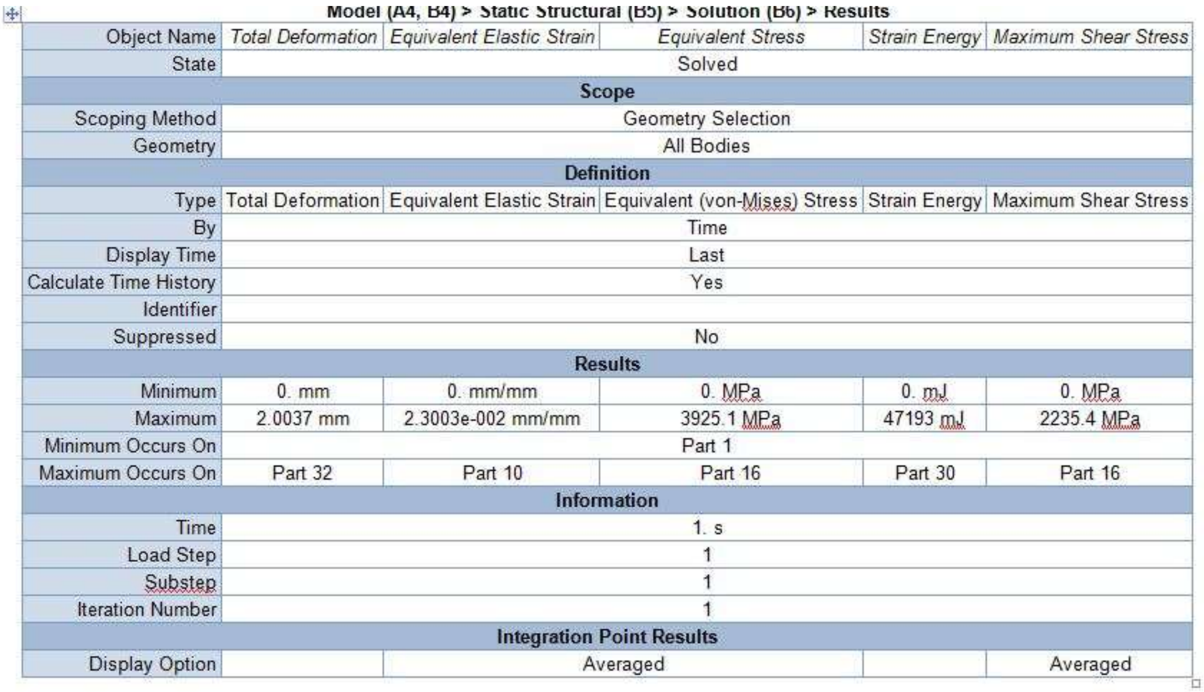


Fig. 3.5

Solution:

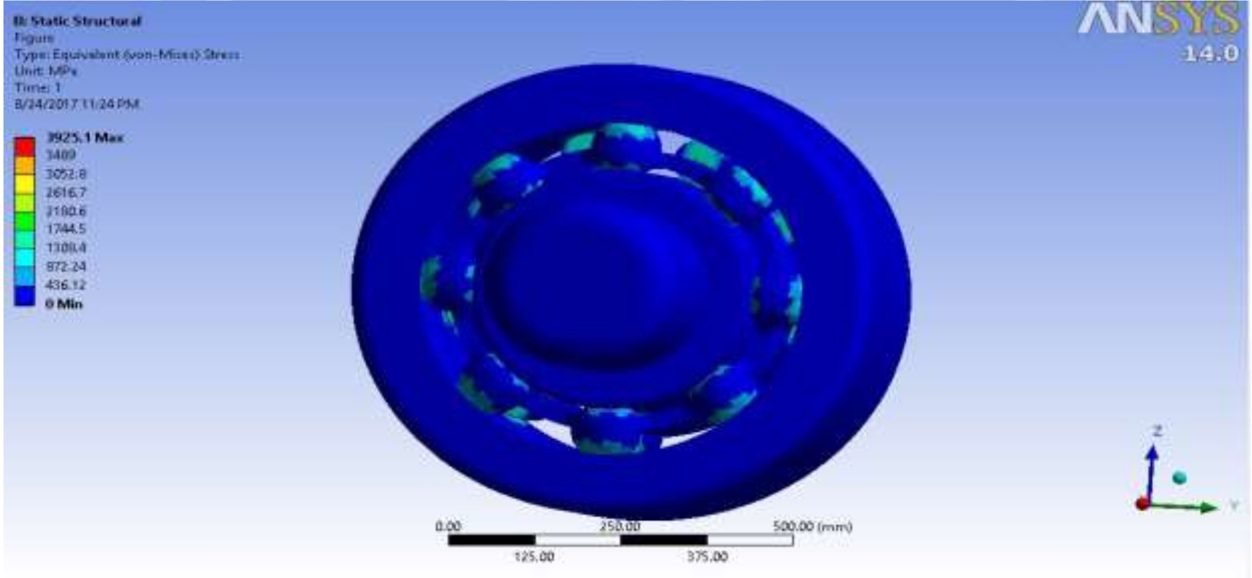
After running the solution of above model we get different values of solutions such as, Maximum principle stress, Equivalent Stress, Total deformation and equivalent strain. All the results are described below



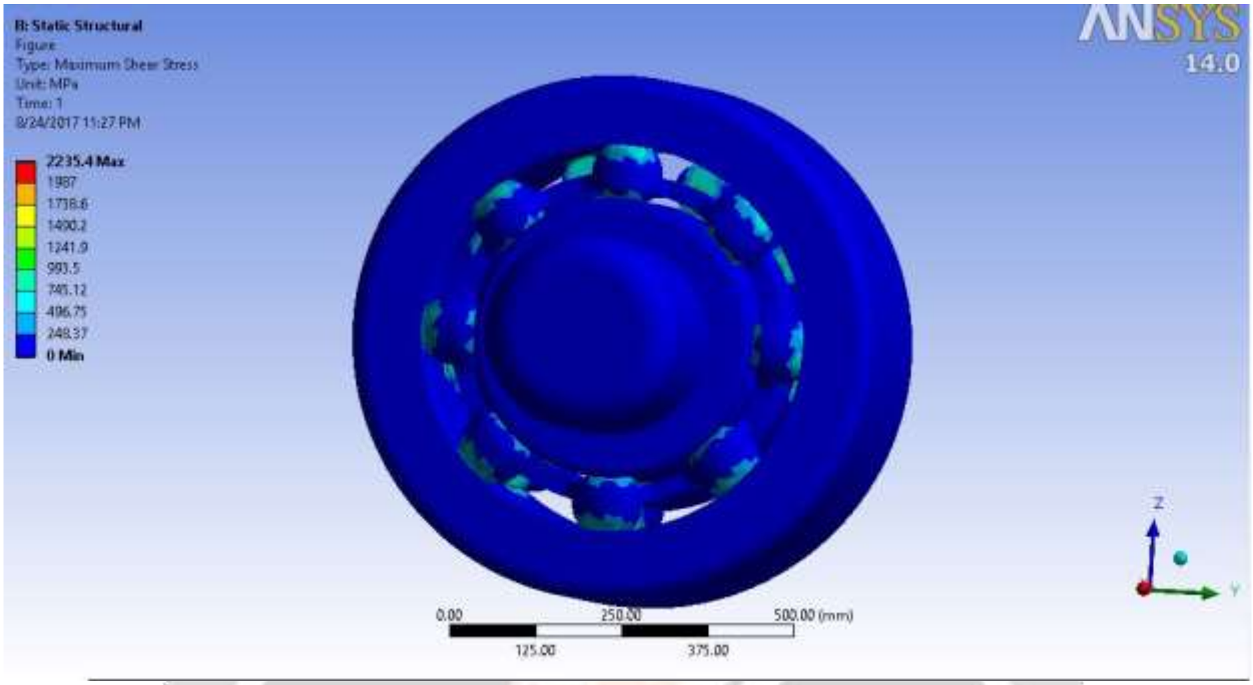
Model (A4, B4) > Static Structural (B5) > Solution (B6) > Results

Object Name	*Total Deformation*	*Equivalent Elastic Strain*	*Equivalent Stress*	*Strain Energy*	*Maximum Shear Stress*
State	Solved				
Scope					
Scoping Method	Geometry Selection				
Geometry	All Bodies				
Definition					
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Strain Energy	Maximum Shear Stress
By	Time				
Display Time	Last				
Calculate Time History	Yes				
Identifier					
Suppressed	No				
Results					
Minimum	0. mm	0. mm/mm	0. MPa	0. mJ	0. MPa
Maximum	2.0037 mm	2.3003e-002 mm/mm	3925.1 MPa	47193 mJ	2235.4 MPa
Minimum Occurs On	Part 1				
Maximum Occurs On	Part 32	Part 10	Part 16	Part 30	Part 16
Information					
Time	1. s				
Load Step	1				
Substep	1				
Iteration Number	1				
Integration Point Results					
Display Option		Averaged			Averaged

Equivalent Stress: 3925.1 Mpa (max)



Maximum shear stress 2235.4 Mpa



B: Static Structural
Figure
Type: Maximum Shear Stress
Unit: MPa
Time: 1
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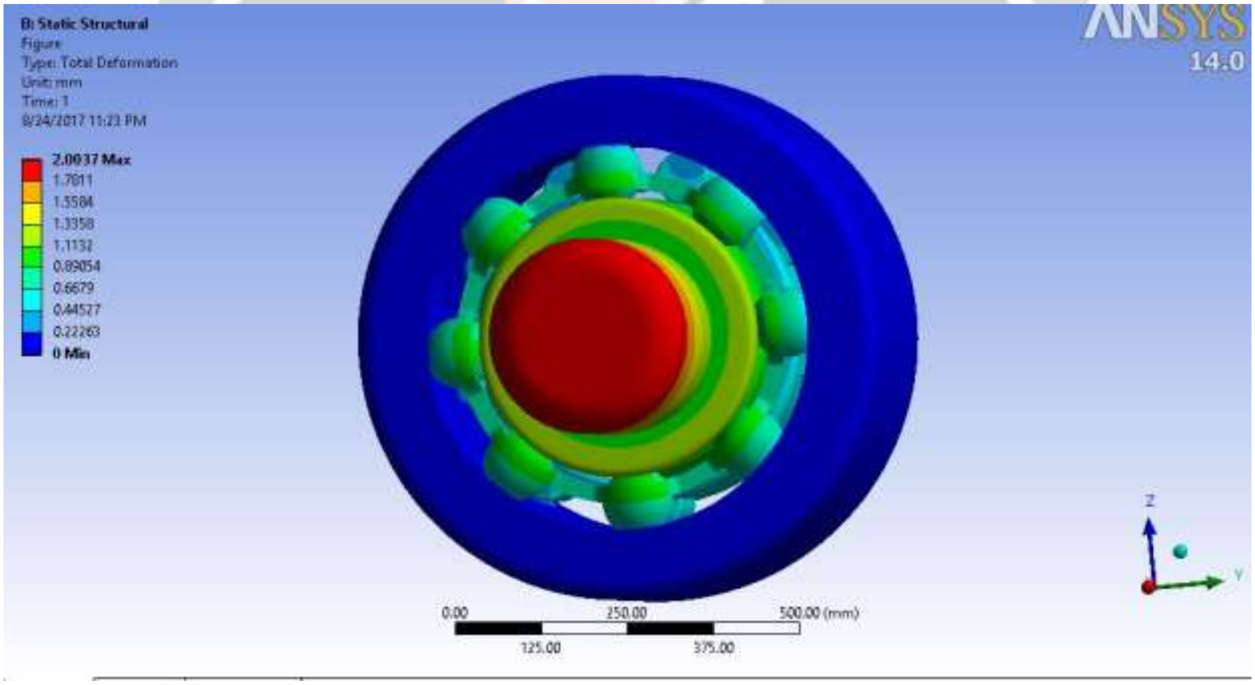
Total deformation 2.0037mm max



B: Static Structural
Figure
Type: Total Deformation
Unit: mm
Time: 1
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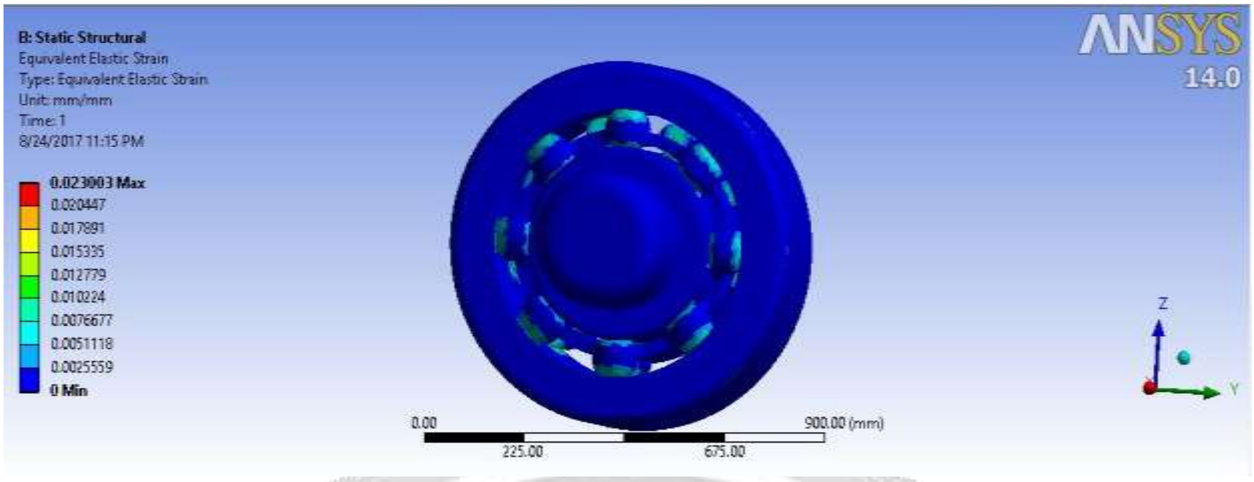
Elastic strain 0.020447 max



4. ANALYTICAL CALCULATIONS

4.1. Life of Bearings

The life of the bearing decreases with an increase in the load.

$$\frac{L_d}{L_e} = \left(\frac{C_d}{P_d}\right)^{k}$$

k = 3 for ball bearings

=10/3for rollerbearing
Ld = desired life

Lc = life from the table (manufacturers catalog)

Cd = dynamic rating from manufacturer

Pd = design load

The equations can be rewritten as depending upon the variable to be calculated

$$C_d = P_d \left(\frac{L_d}{L_e}\right)^{1/2} \quad L_d = L_e \left(\frac{C_d}{P_d}\right)^{k}$$

4.2. Equivalent Combined Radial Load For combined radial and thrustloads

P = V X R + Y Ft

P = equivalent radial load

R = actual radial load

Ft = actual thrust load

X = radial factor (usually 0.56)

V = 1.0 for inner race rotating

= 1.2 for outer race rotating

Given Data:

Dynamic Rating from Manufacturer: 13500 N

Radial Load Fr = 650 N

Axial Load Fa = 190 N

Radial Factor = 0.56

There for, equivalent radial load, P = 0.56*1.2*650+2*190

P = 816.8 N

4.3. Life of Bearing

$$L10 = \left(\frac{C}{P}\right)^3$$

$$= \left[\frac{13500}{737.152}\right]^3$$

L10 = 4514.96 million rev.

4.4. Bearing Life in Hours L10h

L10h= L10 * 106 / 60 n

Where n = Integral Shaft Speed= 1800rpm

L10h = 53176.195 hrs.

5. DISCUSSION OF RESULTS

After calculate the total deformation ,stresses, strain and strain energy found that the results are safe at these boundary condition and 2000 rpm speed of the bearing.

5.1. Bearing Clearances Effects

Clearance between rolling element like rollers/ balls and sleeve is most critical area of Integral Shaft bearing. Friction occurs between rolling element and sleeve there is chances of failure of bearing. As per bearing design clearance is 0.02 mm we have to compare this clearance after thermal expansion of bearing components.

5.1.1 At Ball side Clearance (All dimensions are in mm)

Before and after thermal expansion effect on dimensions of Shaft, Ball and Sleeve given in Table 4.

Table 4 dimensions comparison after deformation at ball side

Component	Diameters	Deformation	diameter after deformation
Shaft	14.225	0.004086	14.229086
Balls	6.35	0.00935	6.35935
Sleeve	26.925	0.00315	26.92815

Clearance between ball and sleeve after deformation: 26.92815-[14.229086+(6.35935*2)]
Clearance =0.019363 mm < 0.2 mm

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