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FEA Study on Vibration Analysis of Tapper Roller Bearing

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ABSTRACT

Tapered roller bearings have tapered inner and outer ring raceways and tapered rollers. They are designed to accommodate combined loads, i.e. simultaneously acting radial and axial loads. The projection lines of the raceways meet at a common point on the bearing axis to provide true rolling and low friction. Tapered-roller bearings are the most widely used bearings in railroad cars. In this project, a tapered roller bearing used on rail road cars is modeled in 3D modeling software Pro/Engineer. The most used material for tapered roller bearing is High Chromium Steel. In this project structural and vibration analysis is done to compare Steel, Aluminum, Brass, High chromium Steel, Babbit.CFD analysis is done on the bearing to evaluate the pressure and temperature by changing the lubricants. The lubricants considered are fluid lubricants Oil, Grease lubricants. The modeling is done Using Pro-Engineer and Analysis in Ansys.

Keywords: Chromium Steel, Vibration Analysis, Tapper rolling Bearing, Radial and axial loads.

INTRODUCTION

BEARING

A bearing is a device to allow constrained relative motion between two or more parts, typically rotation or linear movement. Bearings may be classified broadly according to the motions they allow and according to their principle of operation as well as by the directions of applied loads they can handle.

Parts of bearing

A bearing can reduces friction between moving parts. The design of the bearing may 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. Many bearings also facilitate the desired motion as much as possible, such as by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts.

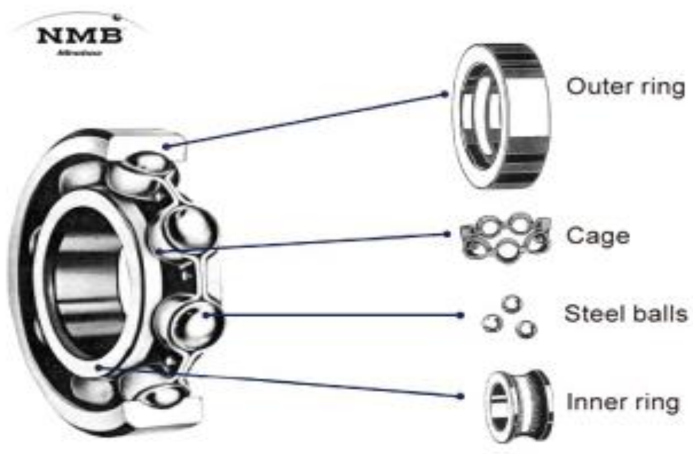

Fig : Parts of bearing

Generally 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.

Roller Bearing

Rolling bearings are bearings with two components that move in opposite directions. These parts are the inner and outer ring, and they are separated by rolling elements. The rolling elements roll between the two rings during operation. This occurs on hardened steel

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surfaces called raceways. The friction generated here is significantly lower compared to plain bearings.

Fig (a) Roller bearing

Fig (b) parts of rolling bearing

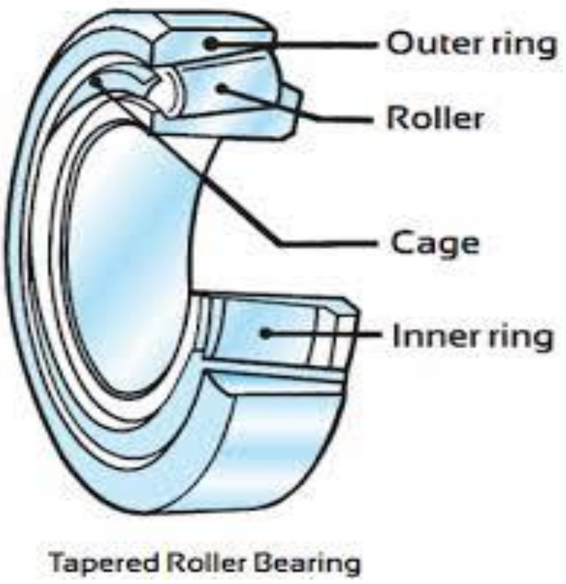
Rolling bearings generally comprise two bearing rings with integral raceways. Rolling elements are arranged between the rings and roll on the raceways. Rolling elements can be balls, cylindrical rollers, needle rollers, tapered rollers or barrel rollers. The rolling elements are generally guided by a cage that keeps them at a uniform distance from each other and prevents them coming into contact with each other. In needle roller bearings and rib less spherical roller bearings, the cage also ensures that the rolling element axis is positioned correctly. Where bearings can be dismantled, the cage holds the rolling elements together and gives easier fitting of the bearings. For particular applications, rolling bearings with a full complement of balls, cylindrical rollers or needle rollers may be used.

The standard material for sheet metal cages is steel, while brass is also used for some applications. Solid cages are made from brass, steel, laminated fabric and other materials. Cages made from thermoplastic materials are also widely used, especially those made from polyamide reinforced by glass fiber.

Tapered Roller Bearing

The tapered vertex of the rollers and raceway surface of the outer and inner rings is designed to intersect a point on the centerline of the bearing. The rollers therefore are guided along the raceway surface by being pushed against the inner ring rib by synthetic power received from the outer and inner ring raceway surfaces.

Because component force is produced in the axial direction when a radial load is received, the bearings must be used in pairs. The outer and inner rings with rollers come apart, thus facilitating mounting with clearance and preload. It is however difficult to control the clearance. Tapered roller bearings are capable of receiving both large radial and axial loads.



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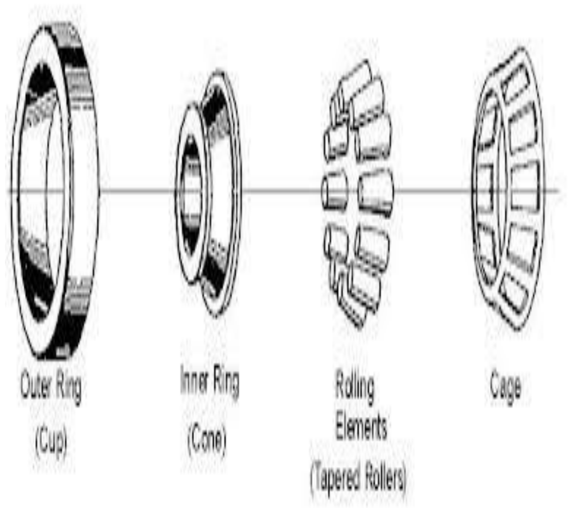


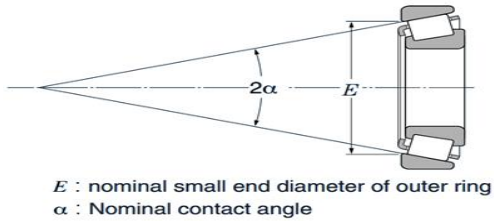
Fig. Tapered roller bearing

Basic tapered roller bearing design

Because of their geometry and design features, Timken tapered roller bearings provide several important and unique performance characteristics to meet a wide range of application requirements. Tapered roller bearings consist of four basic components. These are the cone, the cup, tapered rollers and a cage (roller retainer). Under normal operating conditions, the cone, cup and rollers carry the load while the cage separates the rollers. The cone, rollers and cage are referred to as the "cone assembly" and this is usually separable from the cup, facilitating equipment assembly.

Fig. TDB Basic parts

Tapered roller bearings are designed in such a way that vertices of the cone for each roller and those for the inner and outer raceways coincides on the bearing axis or extensions of the raceways and rollers converge at a common point on the axis of rotation. This results in true rolling motion of the rollers on the raceways at every point along the rollers.The tapered roller bearings support radial loads and axial loads from one direction only. The line contact between rollers and raceways provide the bearings with a high load carrying capacity. Steep angle tapered roller bearing with exceptionally steep cone angle enables the bearings to take heavier axial load. The bearings are of separable type, enabling separate mounting of cups and cones.



Since the tapered roller bearings can absorb thrust loads in one direction only, these bearings should generally be installed as opposed mountings. The correct amount of radial and axial clearance is obtained by adjusting the two bearings against each other.

True rolling motion

The extensions of the raceways and rollers of a tapered roller bearing are designed to converge at a common point on the axis of rotation called the apex . This results in true rolling motion of the rollers on the raceways, at every point along the roller body.

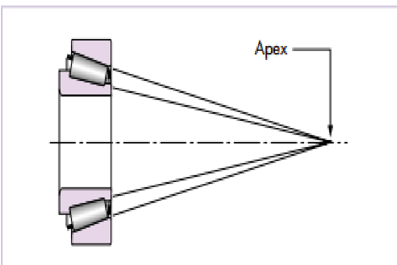


Fig. On-apex design results in true rolling motion at all points long the roller body

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Combined radial and thrust load capability

The angled raceways allow the tapered roller bearing to carry combinations of radial and thrust loads. The greater the angle between the cup and bearing centerline, the greater the ratio of thrust to radial load capacity .Long line roller/race contact gives the tapered roller bearing a high load carrying capacity. This and the capability to carry radial loads, thrust loads, or any combination of the two, makes tapered roller bearings the ideal choice for most applications. For a given bore, it is possible to select a light or heavy section to meet application load/duty requirements.

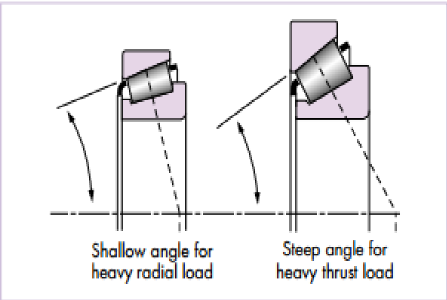


Fig. (a) Designs to support radial and thrust loads in any combination

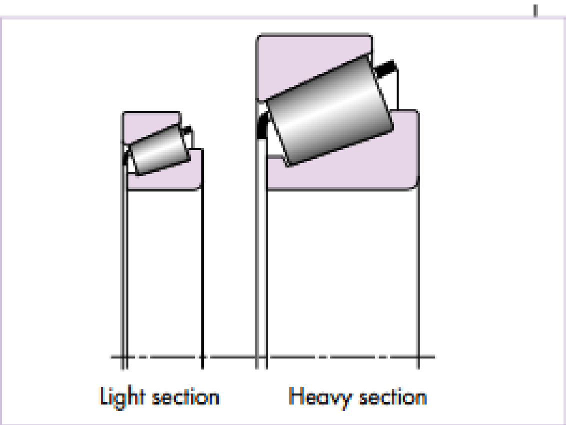
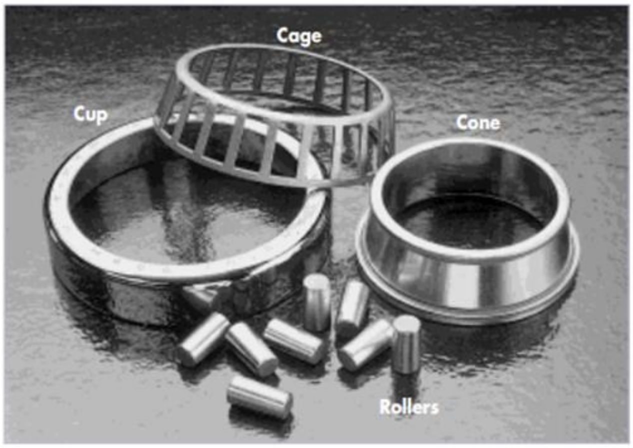


Fig. (b) Designs to suit the space available

Components Of Tapered Roller Bearing:

Tapered roller bearings consist of four basic components including the cone (inner ring), the cup (outer ring), tapered rollers, and a cage (roller retainer). The cone, cup and rollers carry the load while the cage spaces and retains the rollers on the cone. The cone, rollers and cage components of our tapered roller bearings are referred to as the cone assembly.

This conical geometry is used as it gives a larger contact patch, which permits greater loads to be carried than with spherical (ball) bearings, while the geometry means that the tangential speeds of the surfaces of each of the rollers are the same as their raceways along the whole length of the contact patch and no differential scrubbing occurs. When a roller slides rather than rolls, it can generate wear at the roller-to-race interface, i.e. the differences in surface speeds creates a scrubbing action. Wear will degenerate the close tolerances normally held in the bearing and can lead to other problems. Much closer to pure rolling can be achieved in a tapered roller bearing and this avoids rapid wear.



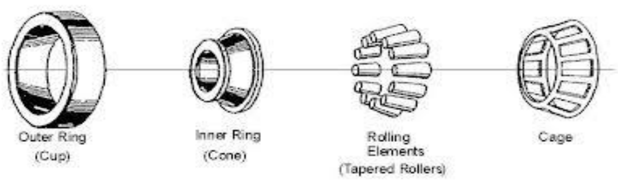


Fig. Components of tapered roller bearing

Tapered Roller Bearing Terminology

Within the cup/cone assembly there are many other terms used to define the various elements of the product. Below is a diagram which labels the various parts of the cup and cone. Each of these elements are important in the design and manufacture of the

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product. The concept behind a bearing is very simple: Things roll better than they slide. The wheels on your car are like big bearings. If you had something like skis instead of wheels, your car would be a lot more difficult to push down the road.

That is because when things slide, the friction between them causes a force that tends to slow them down. But if the two surfaces can roll over each other, the friction is greatly reduced.

Bearings reduce friction by providing smooth metal balls or rollers, and a smooth inner and outer metal surface for the balls to roll against. These balls or rollers "bear" the load, allowing the device to spin smoothly.

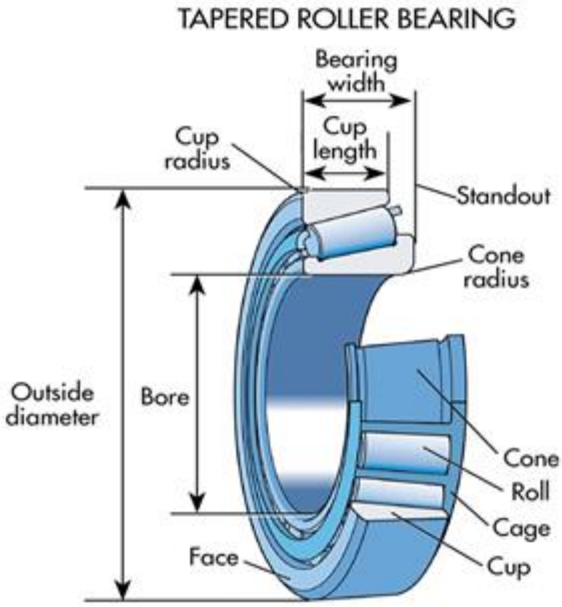


Fig (a)TRB

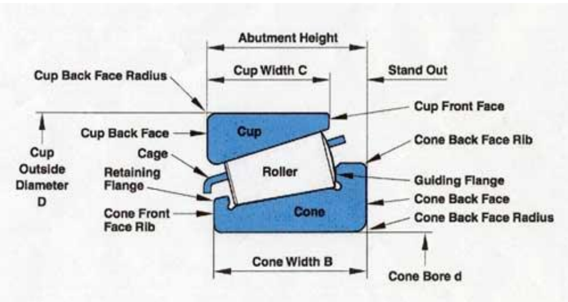


Fig (b) Terminology

Friction

Reducing friction in bearings is often important for efficiency, to reduce wear and to facilitate extended use at high speeds and to avoid overheating and premature failure of the bearing.

Speeds

Different bearing types have different operating speed limits. Speed is typically specified as maximum relative surface speeds, often specified ft/s or m/s.

Stiffness

The stiffness of a bearing is how the distance between the parts which are separated by the bearing varies with applied load. With rolling element bearings this is due to the strain of the ball and race. With fluid bearings it is due to how the pressure of the fluid varies with the gap (when correctly loaded, fluid bearings are typically stiffer than rolling element bearings).

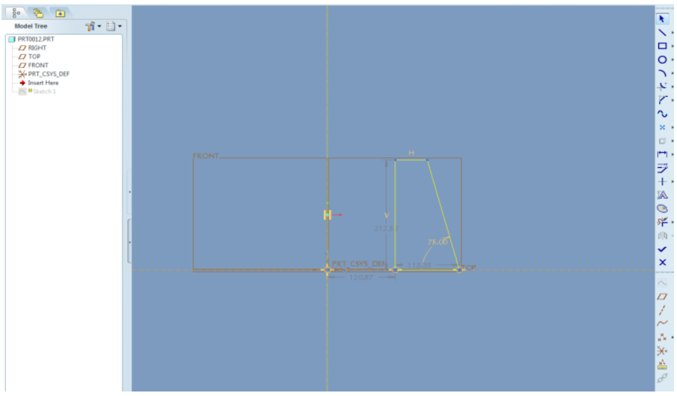
Maintenance

Many bearings require periodic maintenance to prevent premature failure, although some such as fluid or magnetic bearings may require little maintenance. Most bearings in high cycle operations need periodic lubrication and cleaning, and may require adjustment to minimize the effects of wear.

Modelling Of Tapered Roller Bearing

3d Model

Sketch



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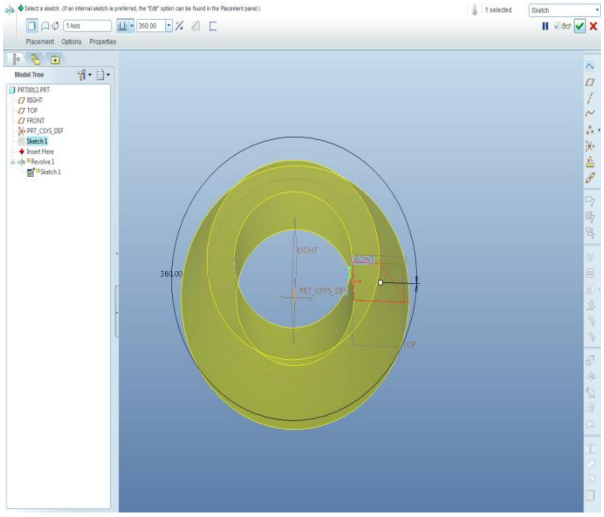
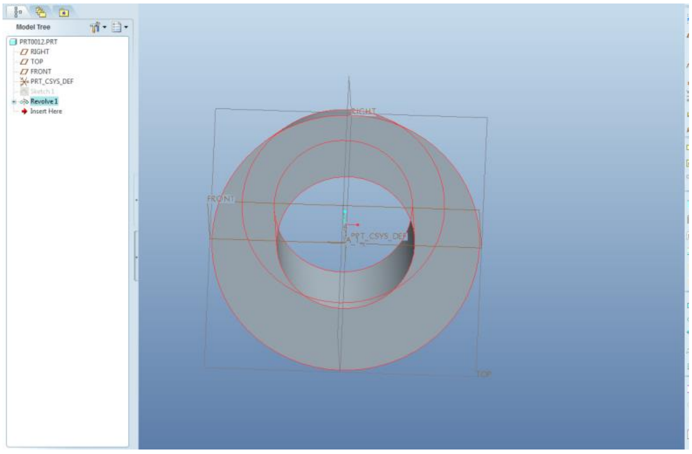
Revolve

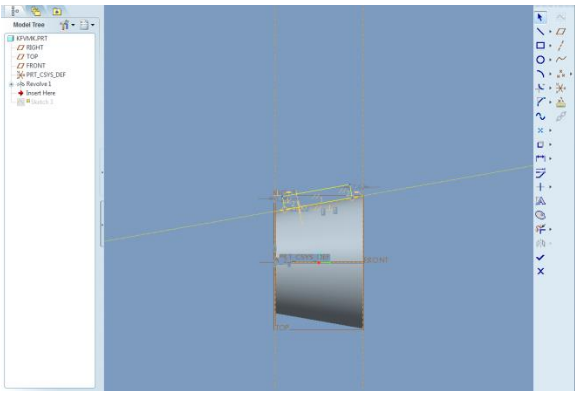


Solid part

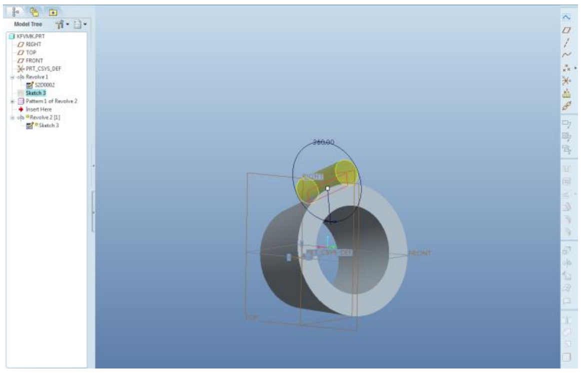


ROLLERS

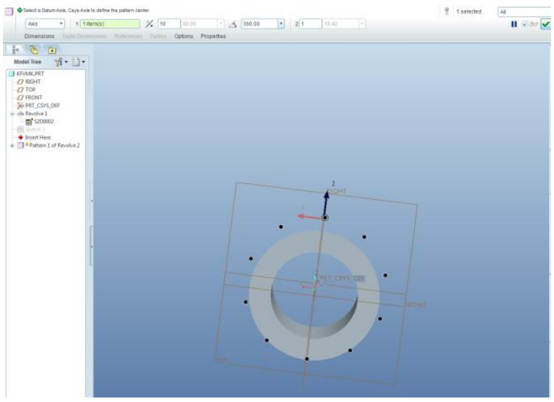
Sketch



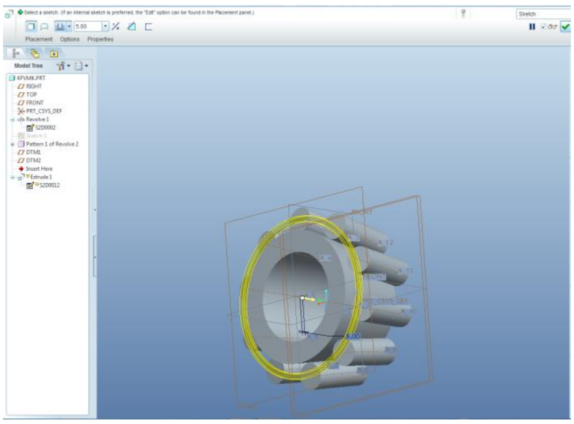
Revolve



Pattern



Extrude



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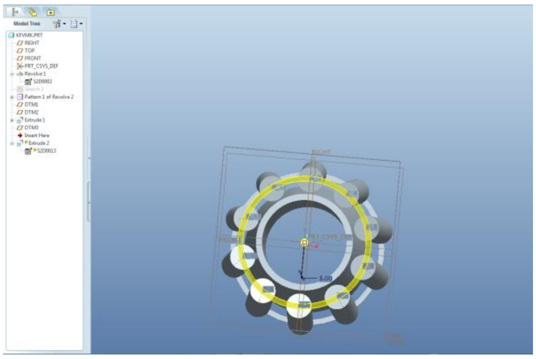
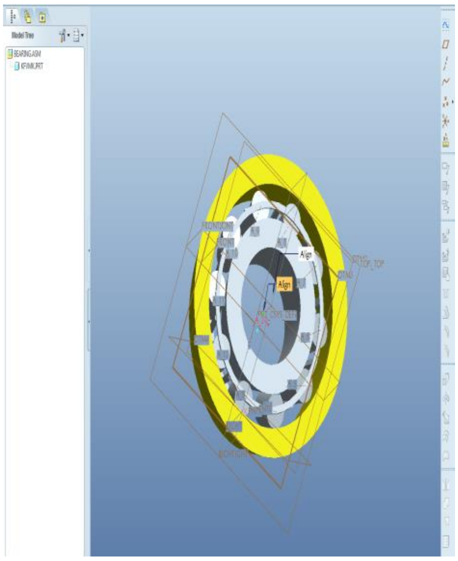
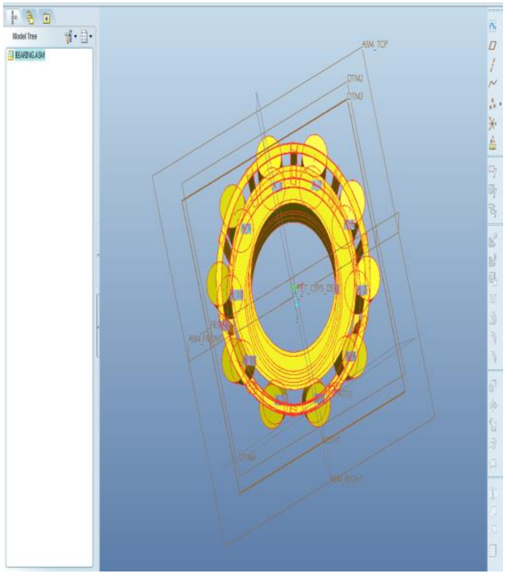


ASSEMBLY

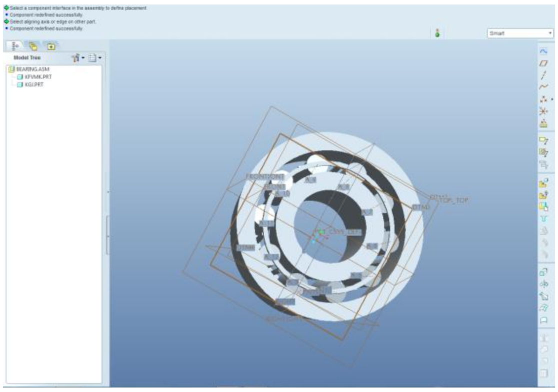
FIRST PART

SECOND PART





ASSEMBLY PART



ANALYSIS OF TAPERED ROLLER BEARING

STRUCTURAL ANALYSIS

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

MATERIAL - STEEL

Save Pro-E Model as .iges format

→→Ansys → Workbench→ Select analysis system → static structural → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

→→ select mesh on work bench → right click →edit

Double click on geometry → select MSBR → edit material →

Material properties of steel

Density : 7750kg/m^3

Young's modulus : 200000Mpa

Poisson's Ratio : 0.29

Select mesh on left side part tree → right click → generate mesh →

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Select static structural right click → insert → select pressure and displacement →

Select displacement → select required area → click on apply → put X,Y,Z component zero →

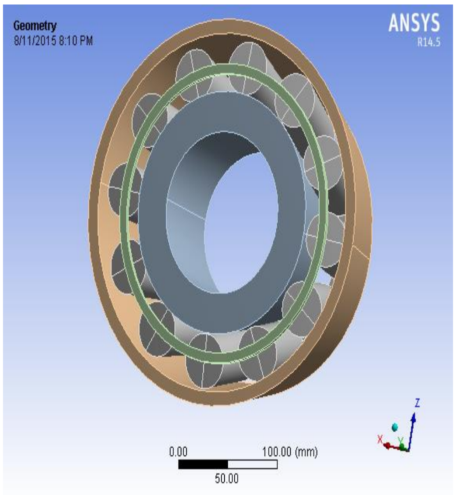
Select rotational velocity → select required axis → enter rotational velocity value 58.64306 radians/sec →

Select solution right click → solve →

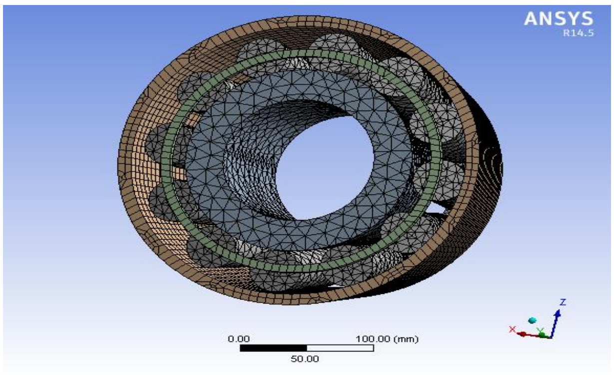
Solution right click → insert → deformation → total → Solution right click → insert → strain → equivalent (von-misses) →

Solution right click → insert → stress → equivalent (von-mises) →

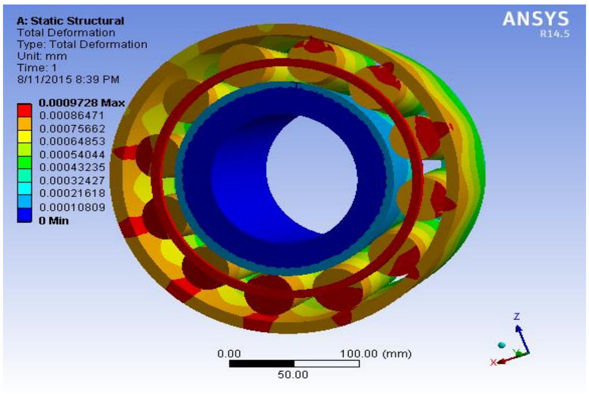
Right click on deformation → evaluate all result



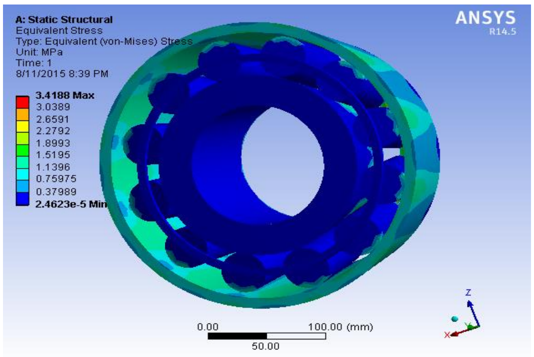
Meshing



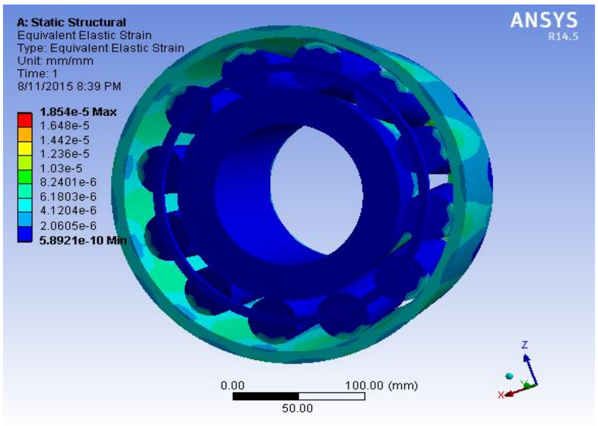
Total deformation



Von-misses stress



Von-misses strain

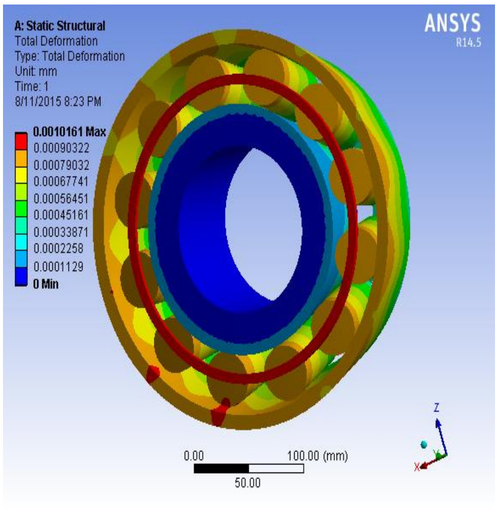


MATERIAL – ALLUMINIUM 6061

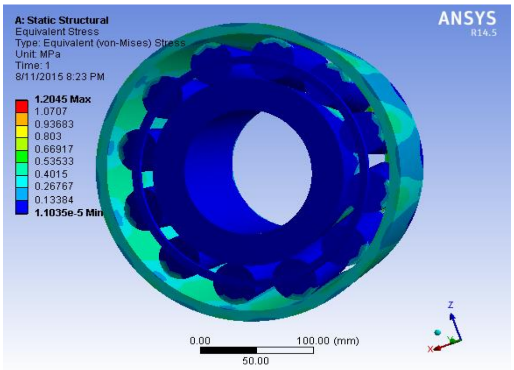
Material properties of Alluminium

Density	:	2700kg/m^3
Young's modulus	:	68900Mpa
Poisson's ratio	:	0.33

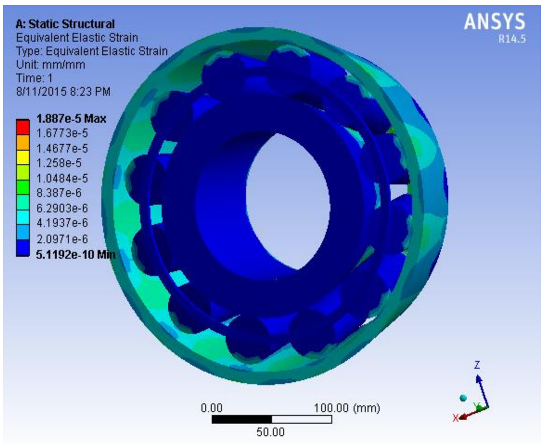
Total deformation



Von-misses stress



Von-misses strain



MATERIAL – BRASS

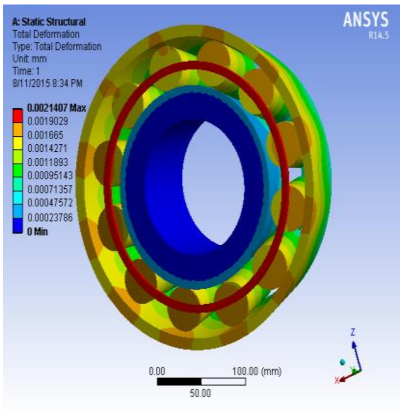
Material properties

Density : $8860 kg/m^3$

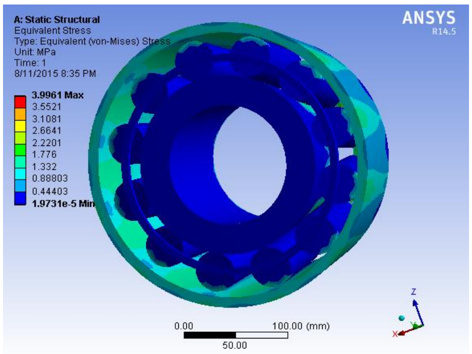
Young's modulus : 117000Mpa

Poisson's ratio : 0.375

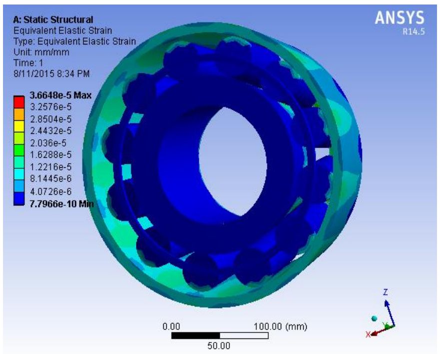
Total deformation



Von-misses stress



Von-misses strain



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MATERIAL – HIGH CHROMIUM STEEL

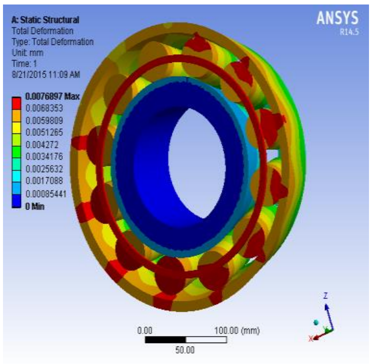
Material properties:

Density : 7860kg/m^3

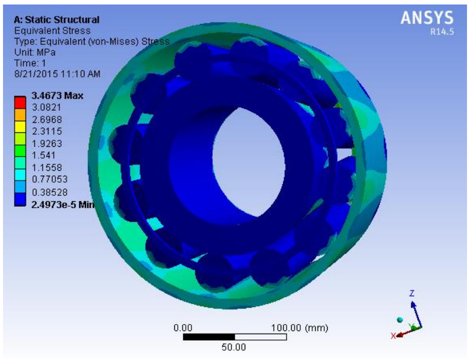
Young's modulus : 25600Mpa

Poisson's ratio : 0.29

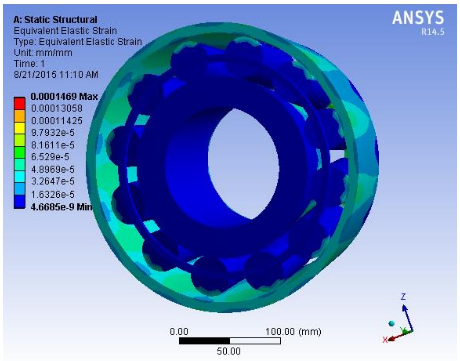
Total deformation



Von-misses stress



Von-misses strain



MATERIAL – BABBIT

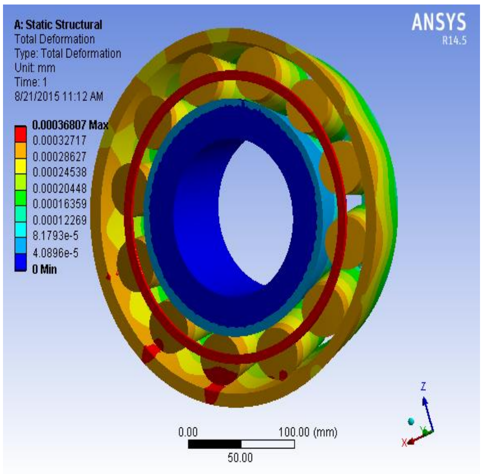
Material properties

Density : 7460kg/m^3

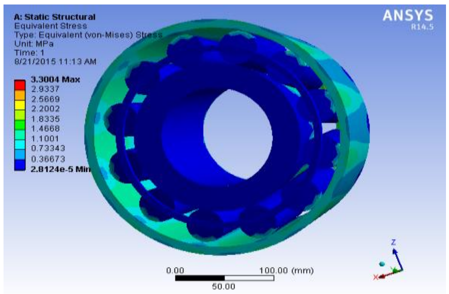
Young's modulus : 520000Mpa

Poisson's Ratio : 0.3

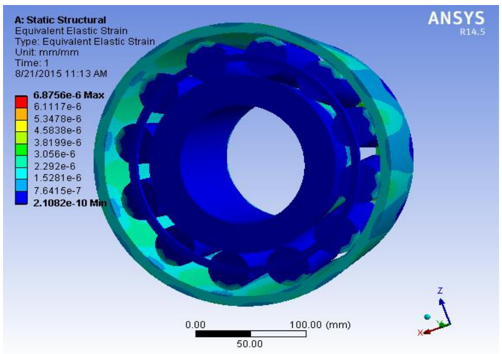
Total deformation



Von-misses stress



Von-misses strain



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VIBRATION ANALYSIS

Vibration analysis is used to detect early precursors to machine failure, allowing machinery to be repaired or replaced before an expensive failure occurs.

MATERIAL – STEEL

Save Pro-E Model as .iges format

→→Ansys → Workbench→ Select analysis system → modal → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

→→ select mesh on work bench → right click →edit

Double click on geometry → select MSBR → edit material

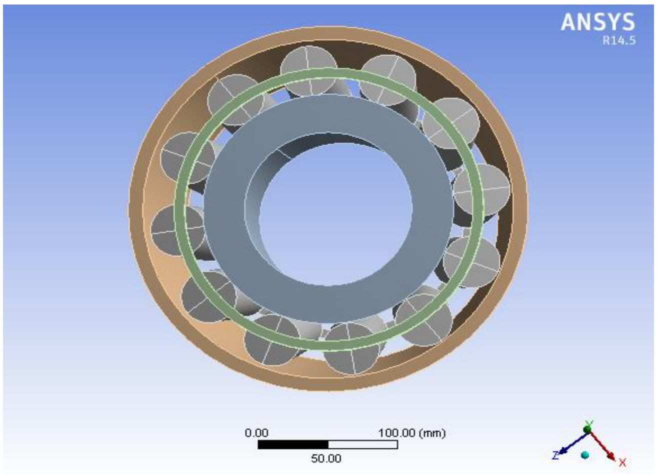
Select mesh on left side part tree → right click → generate mesh →

→→ modal(a5) → right click → insert → fixed support → select the areas → apply

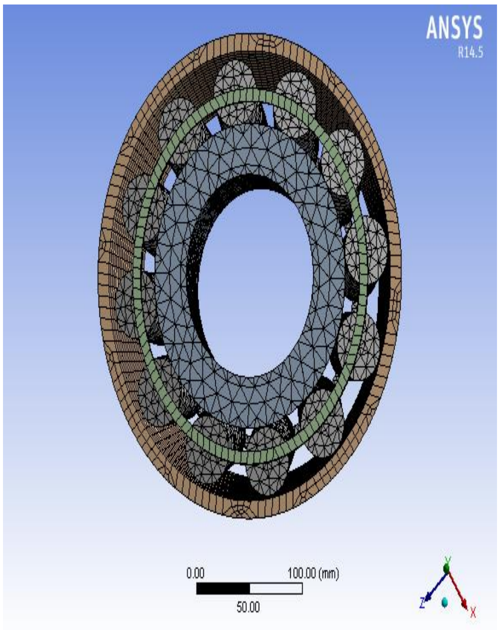
→→ Analysis setting → max. modal to find → enter no of modes

→→ Graphs → right click → select all → right click → create model shape result

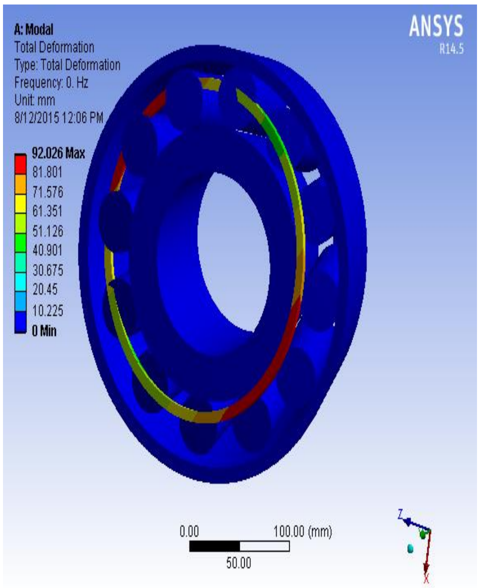
→→ Solution → right click →→ evaluate result



Meshing



TOTAL DEFORMATION 1
TOTAL DEFORMATION 2



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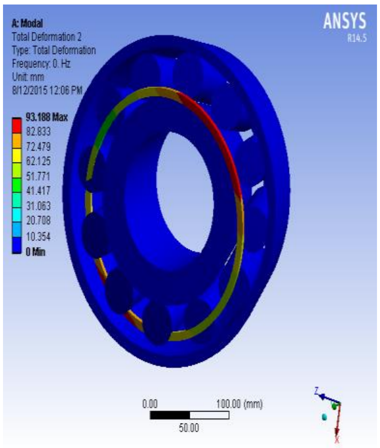
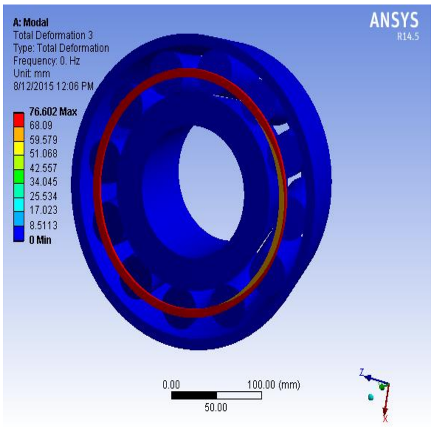
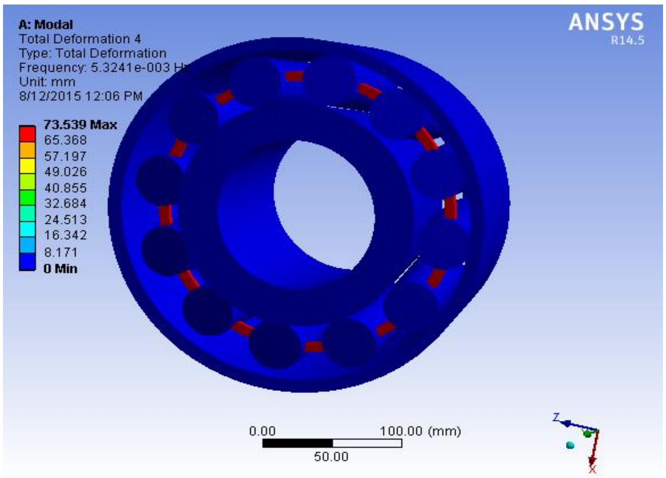


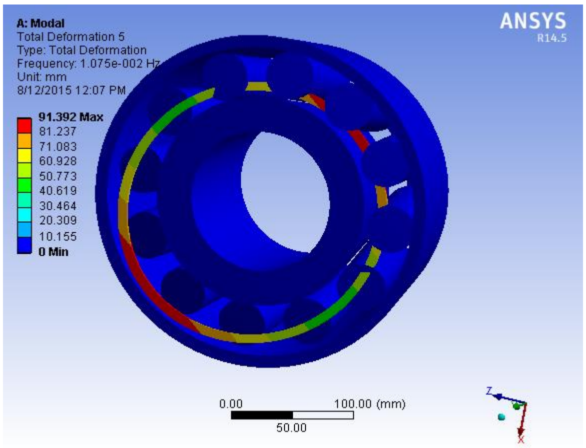
TOTAL DEFORMATION 3



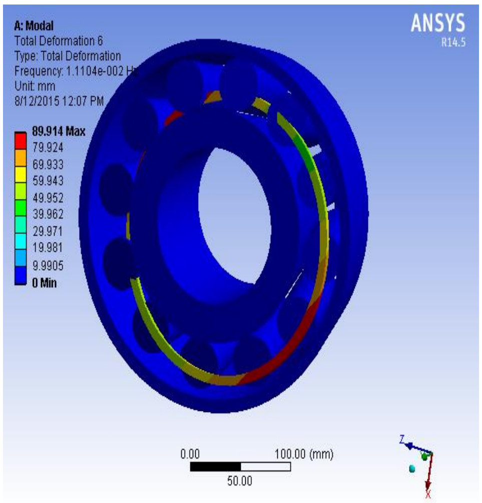
Total deformation 4



Total deformation 5



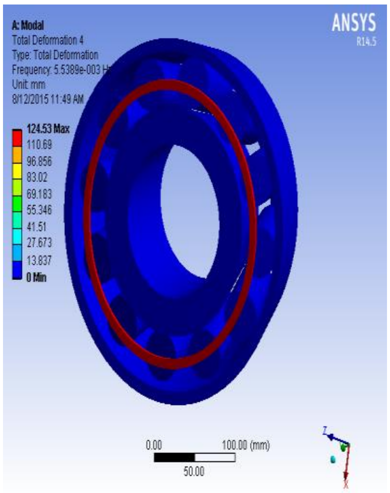
Total deformation 6



MATERIAL – ALUMINIUM 6061

Total deformation 4

Total deformation 5



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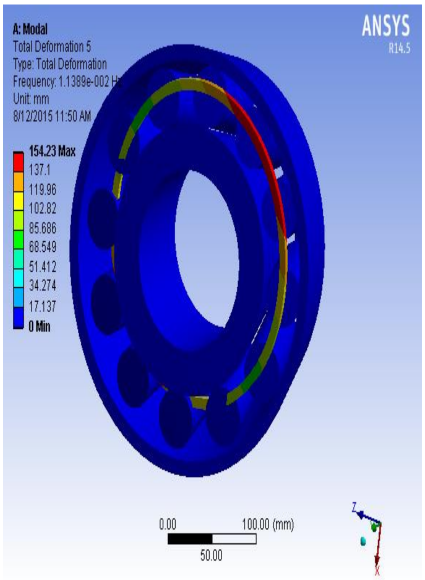
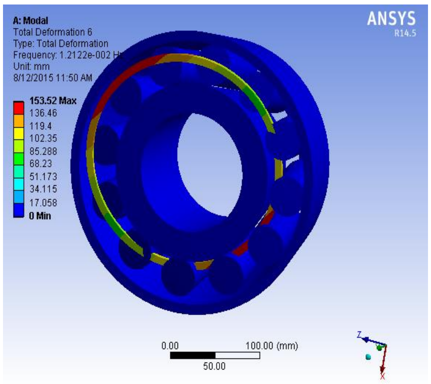
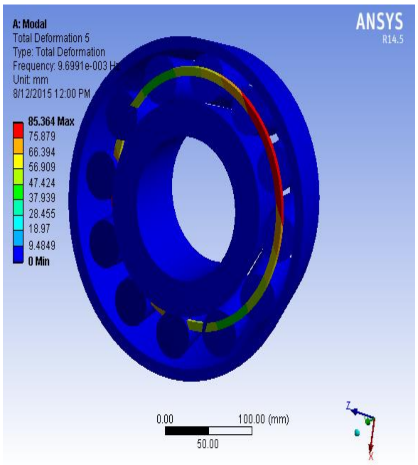


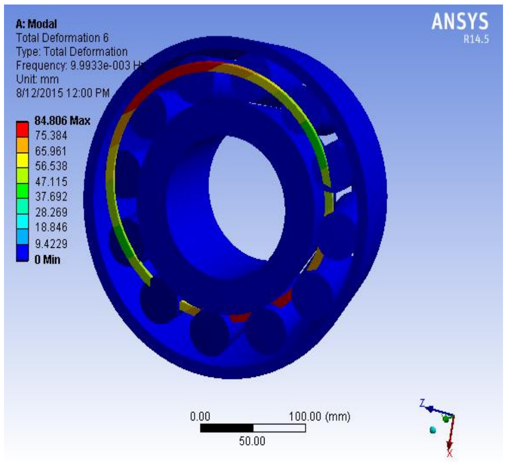
Total deformation 6



Total deformation 5

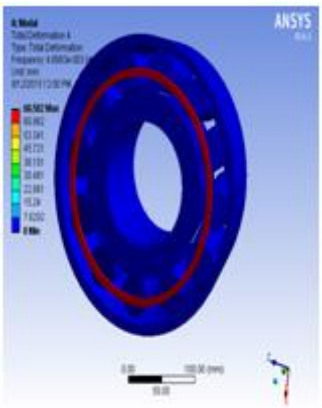


Total deformation 6



MATERIAL – BRASS

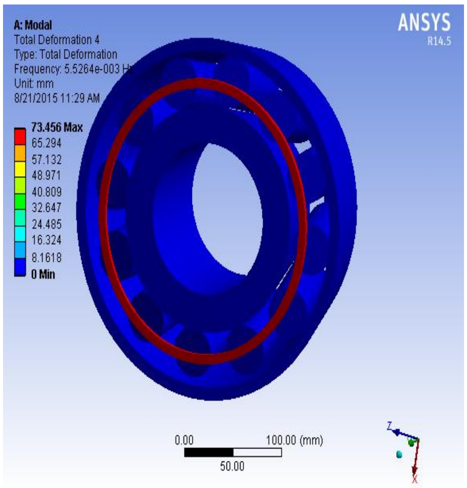
Total deformation 4



MATERIAL – HIGH CHROMIUM STEEL

Total deformation 4

Total deformation 5



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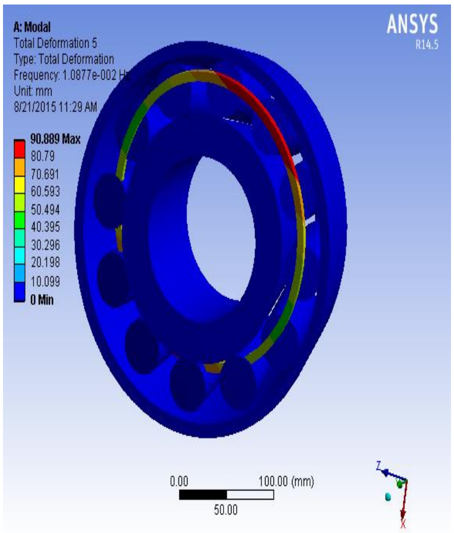
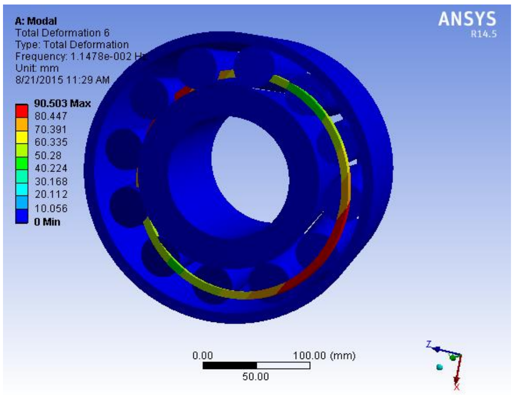


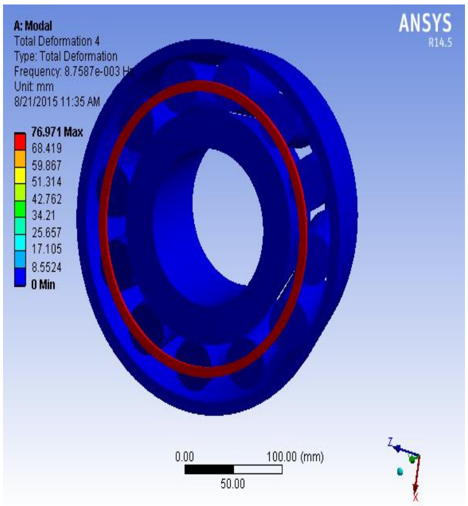
Total deformation 6

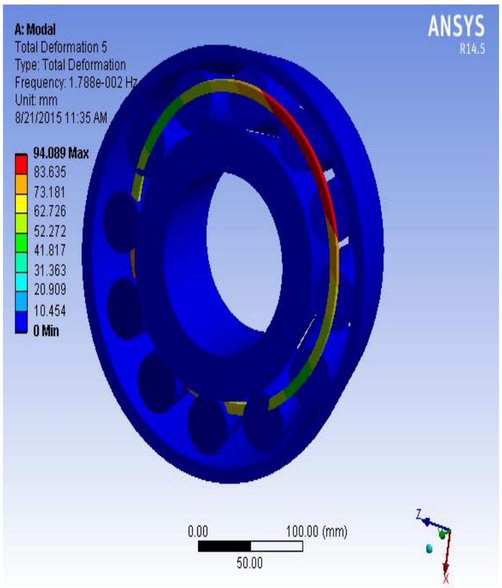


MATERIAL – BABBIT

Total deformation 4

Total deformation 5





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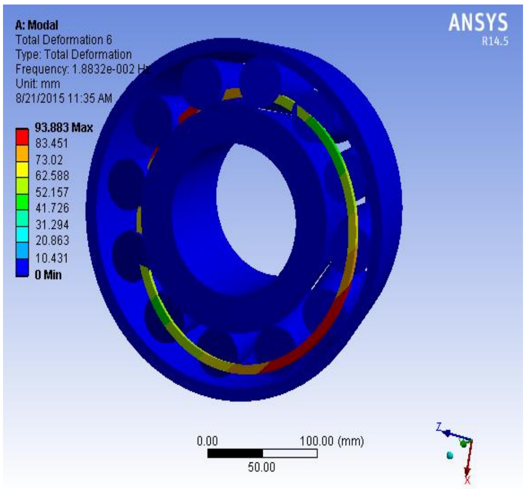

CFD ANALYSIS

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software

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is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

FLUID - OIL

Save Pro-E Model as .iges format

→→Ansys → Workbench→ Select analysis system → Fluid Flow (Fluent) → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

→→ select mesh on work bench → right click →edit

Select mesh on left side part tree → right click → generate mesh →

Specifying boundaries for inlet and outlet

Select edge → right click → create named section → enter name → outlet

Select edge → right click → create named section → enter name → inlet

File →export → fluent →input file(mesh) → enter required name → save.

→→ ansys → fluid dynamics → fluent → select 2D or 3D → select working directory → ok

→→file → read → mesh → select file → ok.

General →Pressure based

Model → energy equation → on

Model → Viscous → Edit

Materials → new → create or edit → specify Fluid material → steam

Boundary conditions → Inlet 1→ Edit

velocity :12.7912 m/s

Thermal → Temperature : 541 K

Solution → Solution Initialization→ Hybrid Initialization →done

Run calculations → No of iterations =20 → calculate → calculation complete

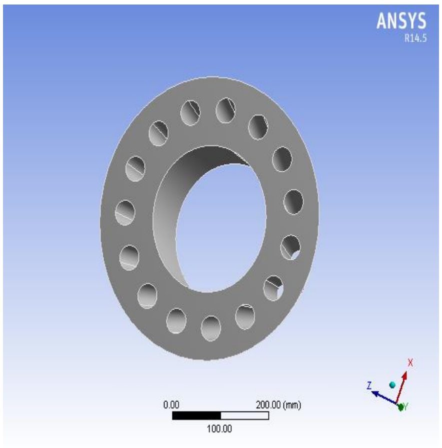
→ **Results** → **graphics and animations** → **contours** → **setup**

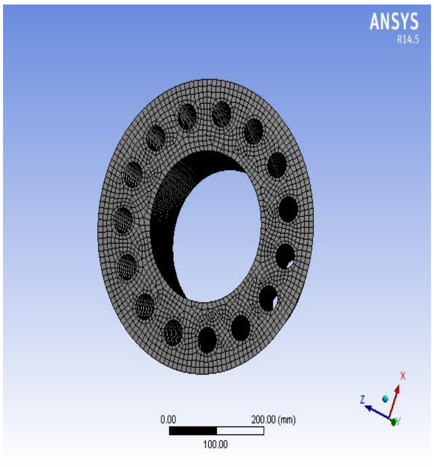
Mass flow rate

"Flux Report"

Mass Flow Rate	(kg/s)
inlet	1308.7986
interior-____msbr	45651.313
outlet	-1308.8195
wall-____msbr	0
Net	-0.020874023

Sketch Meshing





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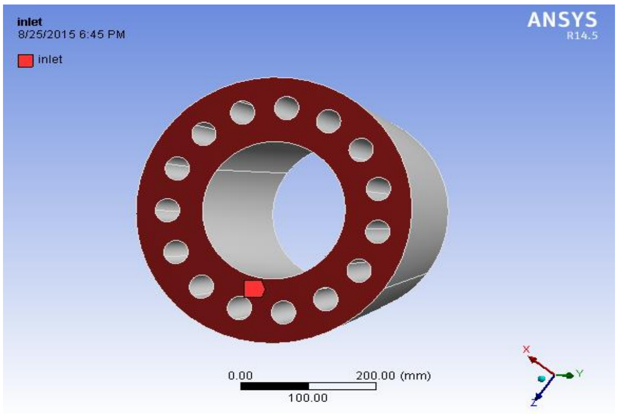
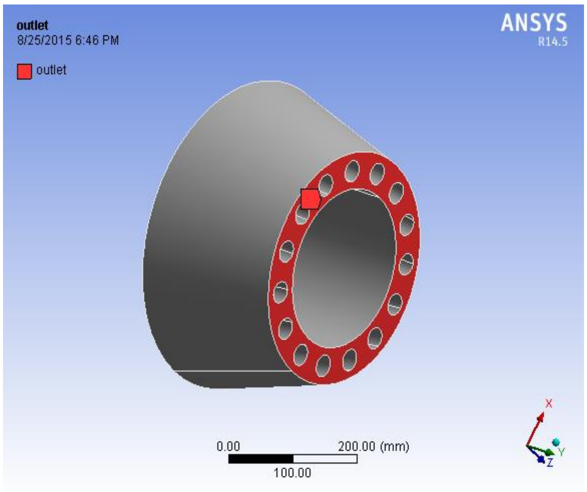
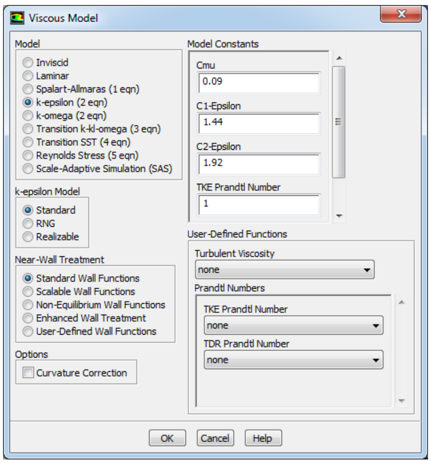
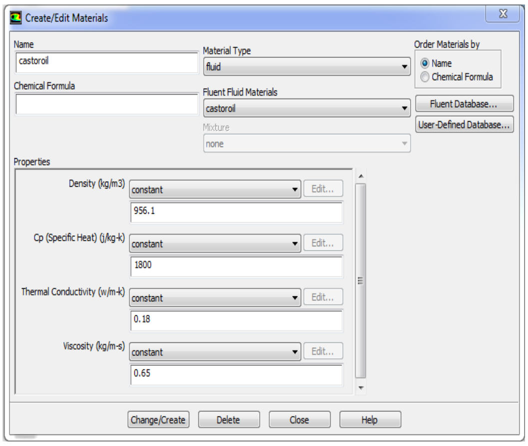
Inlet



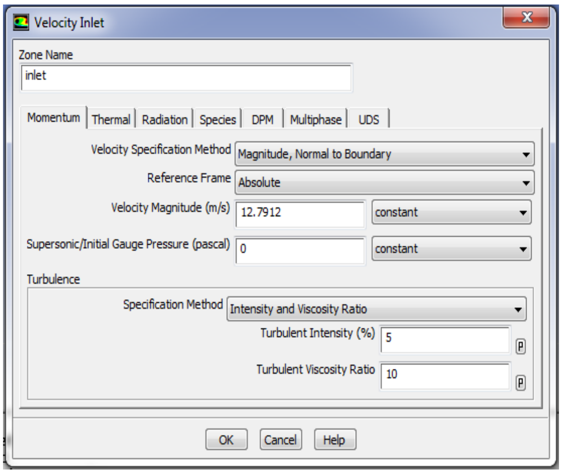
Outlet



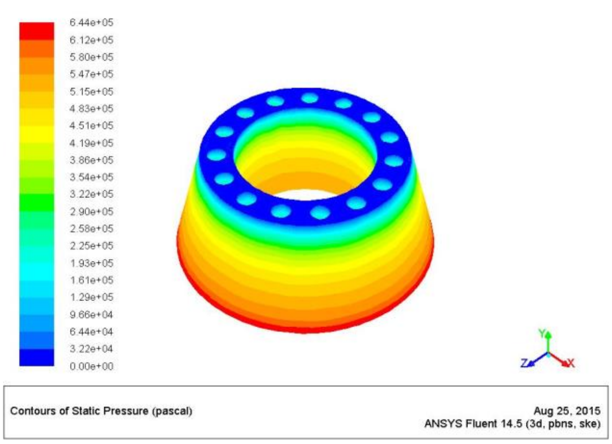




Velocity inlet



Static Pressure



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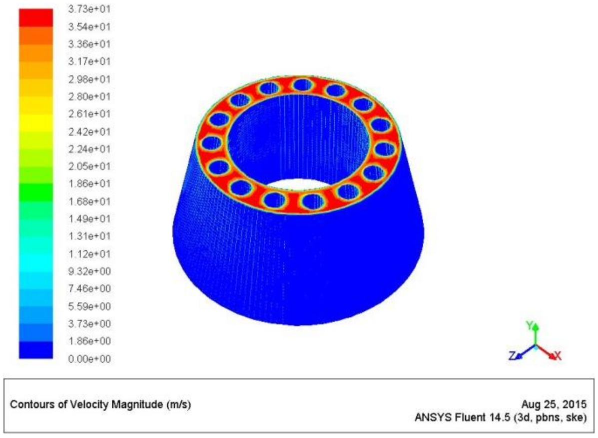
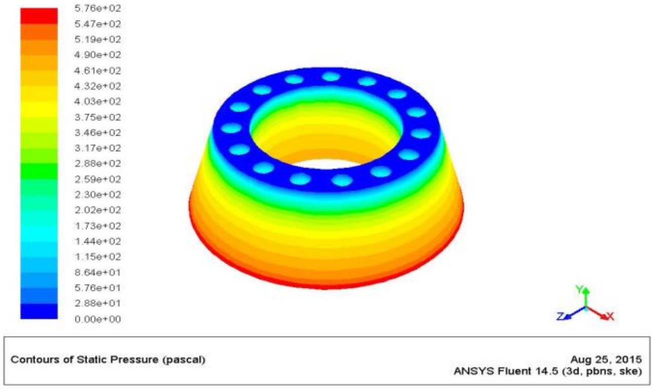
Velocity

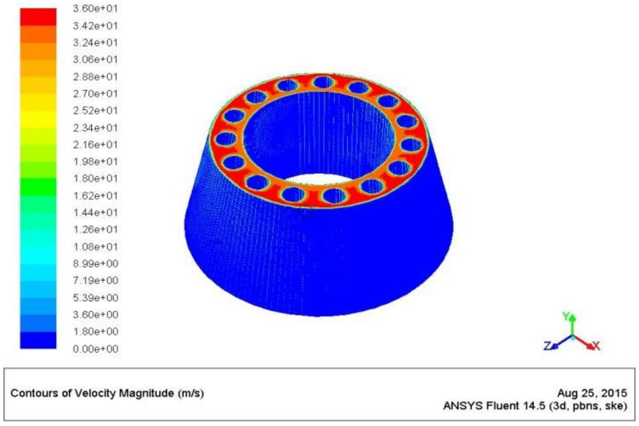


LUBRICANT – GREASE

Static Pressure



Velocity



Mass flow rate

"Flux Report"

Mass Flow Rate (kg/s)

-------------------------------- --------------------

inlet 1.3004485
interior-____msbr 45.357277
outlet -1.3004791
wall-____msbr 0

---------------- --------------------

Net -3.0517578e-05

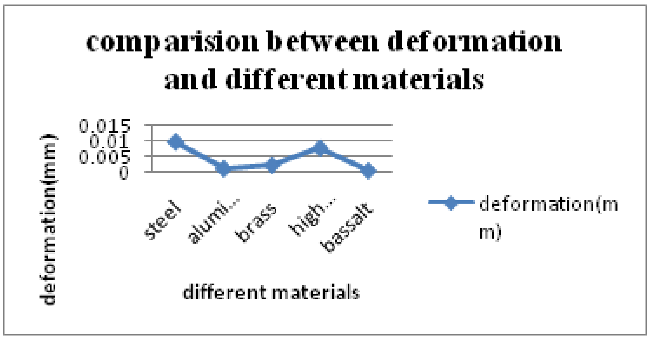
RESULT TABLES

Structural analysis

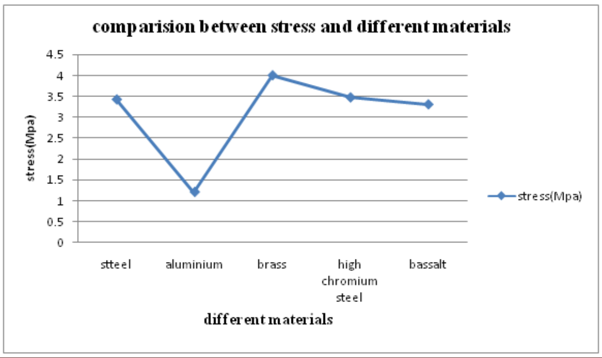
	Steel	Aluminum	Brass	High chromium Steel	Babbit
Deformation (mm)	0.009728	0.0010161	0.0021407	0.0076897	0.00036807
Strain	1.854e-5	1.887e-5	3.6648e-5	0.0001469	6.8756e-6
Stress (N/mm^2)	3.4188	1.2045	3.9961	3.4673	3.3004

GRAPHS

DOF



Strain



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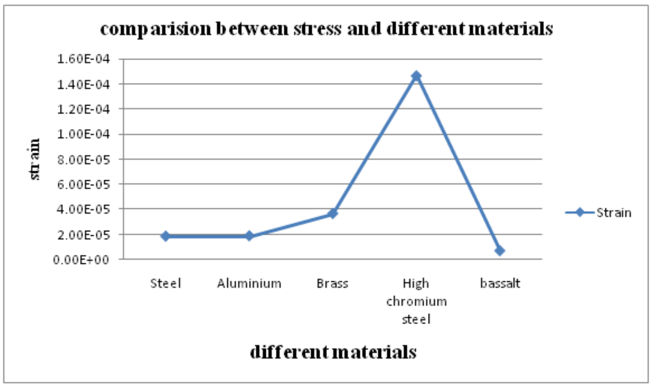
Stress

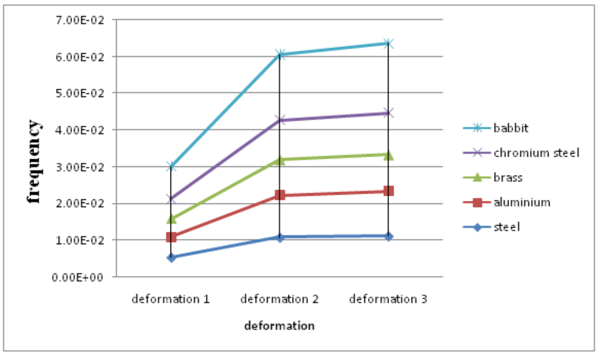


Vibrational analysis

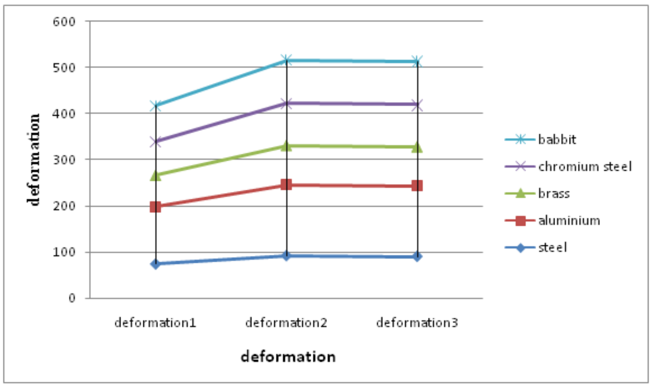
		Steel	Aluminum	Brass	High chromium Steel	Babbitt
Mode 1	Frequency (Hz)	0	0	0	0	0
	Deformation (mm)	90.026	155.83	85.51	90.577	93.664
Mode 2	Frequency (Hz)	0	0	0	0	0
	Deformation (mm)	93.188	155.54	85.165	91.211	93.664
Mode 3	Frequency (Hz)	0	0	0	0	0
	Deformation (mm)	76.602	127.23	70.021	74.459	77.214
Mode 4	Frequency (Hz)	$5.3241e^{-3}$	$5.5389e^{-3}$	$4.8993e^{-3}$	$5.5264e^{-3}$	$8.7587e^{-3}$
	Deformation (mm)	73.539	124.53	68.582	73.456	76.971
Mode 5	Frequency (Hz)	$1.075e^{-2}$	$1.1389e^{-2}$	$9.6991e^{-3}$	$1.0877e^{-2}$	$1.788e^{-2}$
	Deformation (mm)	91.392	154.23	85.364	90.889	94.089
Mode 6	Frequency (Hz)	$1.1104e^{-2}$	$1.2122e^{-2}$	$9.9933e^{-3}$	$1.1478e^{-2}$	$1.8832e^{-2}$
	Deformation (mm)	89.914	153.52	84.806	90.503	93.883

GRAPHS

Frequency



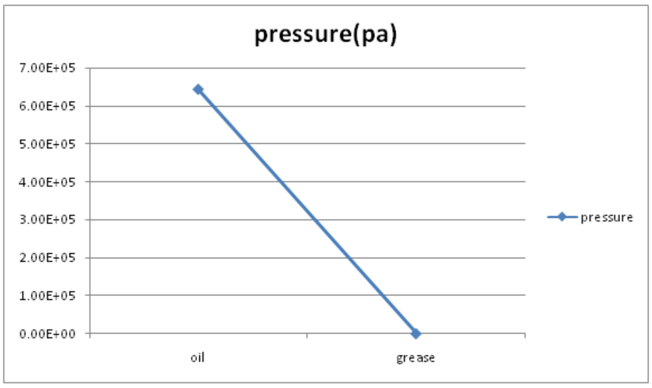
Deformation



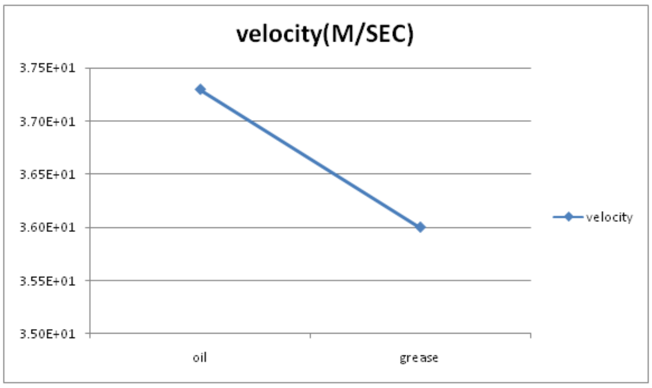
CFD ANALYSIS

Lubrication	Pressure (Pa)	Velocity (m/s)	Mass flow rate (Kg/s)
Oil	6.44e+05	3.73e+01	0.020874023
Grease	5.76e+02	3.60e+01	3.0517578e-05

Pressure



Velocity



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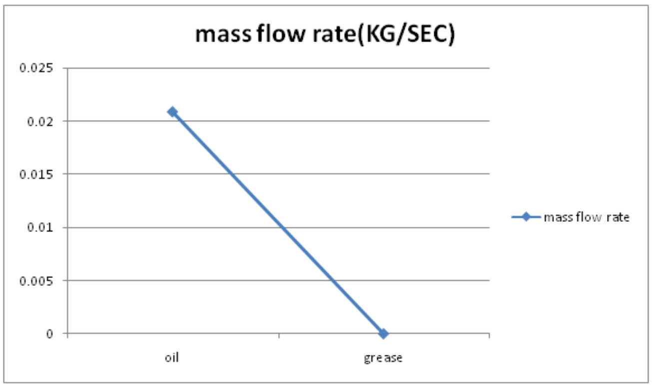
Mass flow rate



CONCLUSION

The most used material for tapered roller bearing is High Chromium Steel. In this project structural and vibration analysis is done to compare Steel, Aluminum, Brass, High chromium Steel, Babbit. CFD analysis is done on the bearing to evaluate the pressure and temperature by changing the lubricants. The lubricants considered are fluid lubricants Oil, Grease lubricants.

By observing the structural analysis results, the stress value is less for aluminum than other materials. By observing the vibration analysis results, the frequencies are less for Brass material so vibrations are less when Brass is used and also deformations are less. So it can be concluded that using Brass is better since the stress is less than its allowable strength but the main disadvantage of its weight due to more density.

By observing the CFD analysis results, the pressure is less when grease is used but the mass flow rate is less when compared with that of oil. When the pressure is decreased, the stresses due to the fluid pressure reduces on the bearing and the outlet velocity of fluid is almost similar to oil. So using grease is better.

FUTURE SCOPE

In the present thesis, the stresses on the bearing are evaluated by applying only the angular velocity of the bearing. In the future, the stresses due to hydrodynamic pressures, that is pressures developed due to fluid flow can also be analyzed using FSI (Fluid Structure Interaction) technique which will be used for further improvement of using different fluids other than those used in the present thesis.

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