Design of Machine Elements

Ball Bearing

Mayank Raj | B21ME038
Mota Ram | B21ME039
Ayaz Khan | B21ME014

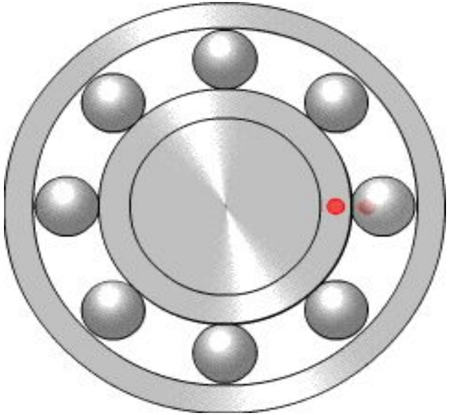
Introduction

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. It is used for relative motion between the contact surfaces of the members, while carrying the load.

PARTS

Principally, it has four major components:

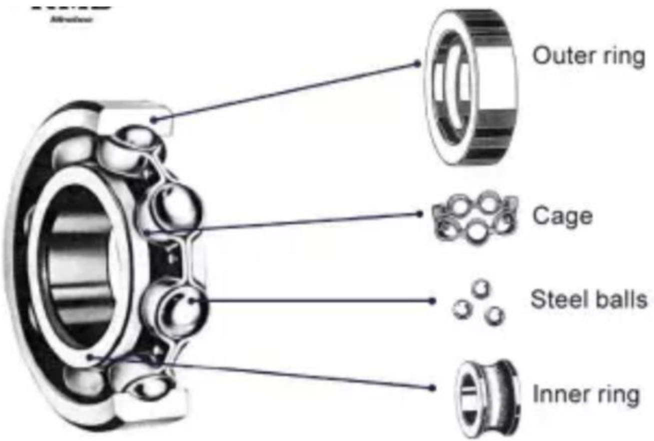
- **Outer ring**: This fits tightly inside the outer structure which is generally not moving e.g. Pump/Motor Casing
- **Inner ring:** This ring fits tightly on the shaft and rotates with it.
- **Balls:** These are the components which fill the gap between inner and outer ring and provide 'point contact' which we talked about to facilitate relative motion between inner and outer ring.
- **Cage:** This is a metal or ceramic structure which holds all the balls fixed at their relative positions while allowing them to rotate freely



https://en.wikipedia.org/wiki/File:BallBearing.gif

WORKING

From the construction, working of bearing can be understood easily. Inner ring fits on a shaft, outer ring fits inside the stationary component through which the shaft passes. As the shaft rotates, along with the inner ring, balls start spinning inside the cage. And a relative motion between inner ring and outer ring is established with minimal contact area.



Material Selection

OBJECTIVES

- Ball bearings need to withstand significant loads and friction without deforming. High hardness helps prevent wear and extend the bearing's lifespan.
- Withstand high friction, and less abrasive wear.
- Able to withstand high temperatures and heat.
- Should have well anti wear properties.
- Bearings often operate under cyclic loading conditions. Materials with good fatigue resistance can endure repeated stress cycles without failure.

General Material Performance Required For Ball Bearing

- High Hardness
- High strength
- Wear resistant and corrosion resistant
- Heat Resistance
- Fracture Toughness

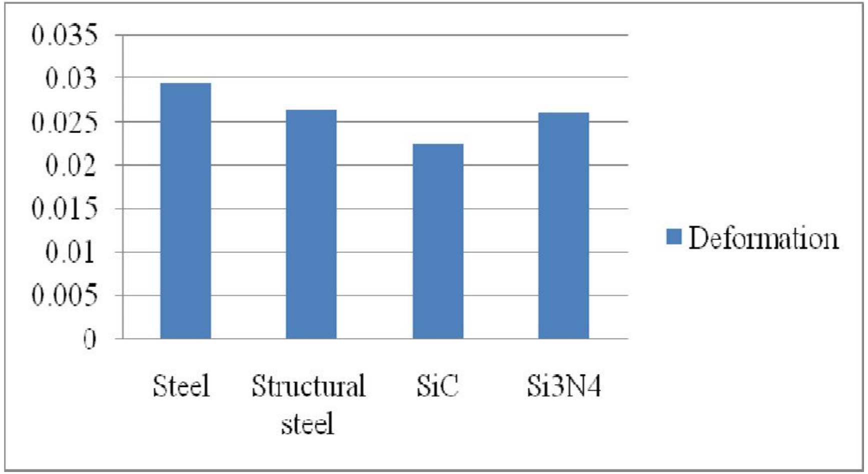
Screening

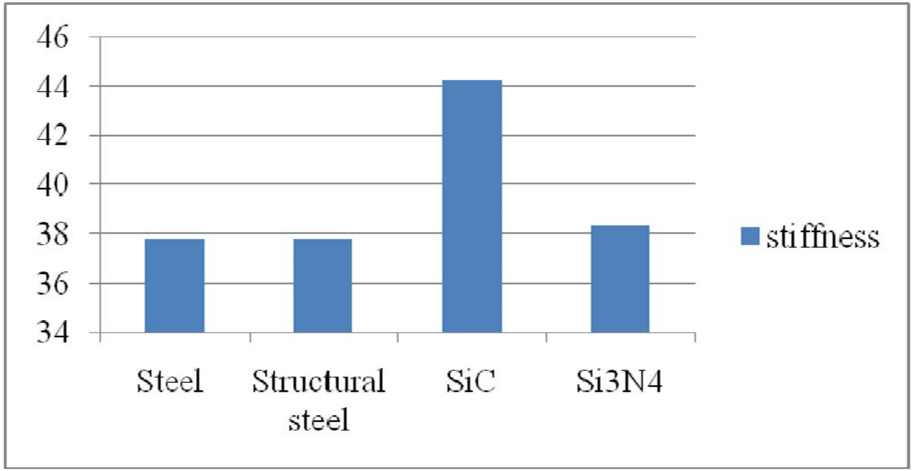
Based on the properties, potential candidate materials for ball bearing are :

- Steel
- Structural Steel
- Si3N4
- Sic

Material Selection

Analysis is carried out under static structural module of ANSYS workbench The Equivalent (Von-Misses) Stress, Maximum Principal Stress, Equivalent Elastic Strain, Maximum Shear Stress and Total Deformation are calculated using ANSYS. Bearing steel, Structural Steel, Si3N4 and SiC are used as the ball bearing material for analysis and its mechanical properties are provided as the input to the ANSYS.

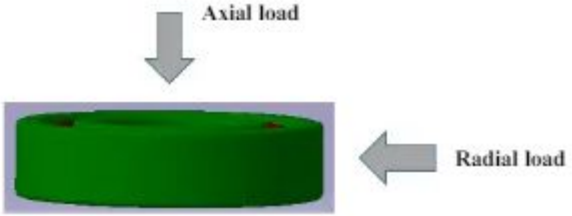


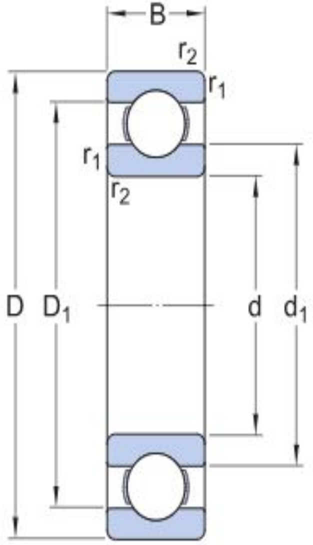


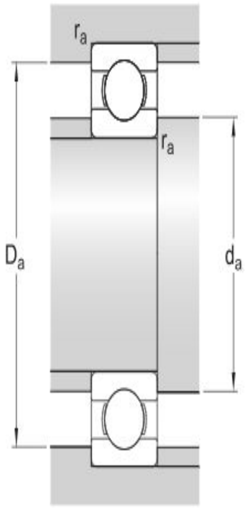
It is concluded that the Deformation and Elastic Strain induced in the Sic is less than the steel, structural steel and Si3N4 and the Stiffness of SiC is maximum among all.

Hence **SiC** is selected for ball bearing.

Calculation of the parameters of Single Row Deep Groove Ball Bearing







d Bore diameter
D Outside diameter
B Width
d1 Shoulder diameter
D1 Shoulder diameter
r1,2 Chamfer dimension
da Diameter of shaft abutment
Da Diameter of housing abutment
ra Radius of shaft or housing fillet

DATA BOOK FOR BALL BEARING SELECTION

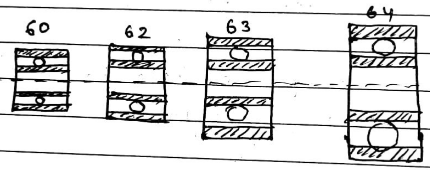
EQUIVALENT BEARING LOAD

Type of Bearing	Series (SKF)		$\frac{F_a}{F_r} \leq e$ X	$\frac{F_a}{F_r} \leq e$ Y	$\frac{F_a}{F_r} > e$ X	$\frac{F_a}{F_r} > e$ Y	e
Deep groove ball bearing	Series EL, R 160, 60, 62, 63 64, EE, RLS, RMS	$\frac{F_a}{C_o}$ =0.025	1	0	0.56	2	0.22
		=0.04				1.8	0.24
		=0.07				1.6	0.27
		=0.13				1.4	0.31
		=0.25				1.2	0.37
		=0.5				1.0	0.44

3. Calculate Co from Series 60 - 64 and then tryal and error method find X,Y.

We have differrent sieries like 60, 62, 63 & 64

E.g.,



60 extra Light
62 light
63 medium
64 heavy.

Series 64 DEEP GROOVE BALL BEARINGS

(Nomenclature same as other series)

All dimensions in mm

No.	d	D_1 min	D	D_2 max	B	r	r_1	Basic capacity, kgf Static C_o	Dynamic C	Max speed rpm
6403	17	26	62	53	17	2	1	1280	1800	10000
6404	20	29	72	63	19	,,	,,	1660	2400	8000
6405	25	36	80	69	21	2.5	1.5	2000	2825	7100
6406	30	41	90	79	23	,,	,,	2400	3350	6300
6407	35	46	100	89	25	,,	,,	3250	4300	5600
6408	40	53	110	97	27	3	2	3800	5000	5000
6409	45	58	120	107	29	,,	,,	4650	5850	4500
6410	50	64	130	116	31	3.5	,,	5300	7000	4000
6411	55	69	140	126	33	,,	,,	6400	7850	4000
6412	60	74	150	136	35	,,	,,	7100	8450	3600
6413	65	79	160	146	37	,,	,,	8000	9150	3200
6414	70	86	180	164	42	4	2.5	9100	10000	2800
6415	75	91	190	174	45	,,	,,	10160	12000	2800
6416	80	96	200	184	48	,,	,,	12800	13000	2500
6417	85	105	210	190	52	5	3	13800	13800	2500
6418	90	110	225	205	54	,,	,,	16600	15200	2200

Single Row deep groove Ball Bearing

we are Radial Force = $F_r = 8\,KN$

Axial Force / Thrust Force = $F_a = 3\,kN$.

Speed of shaft, $N = 1200$ rpm

Rating Life, $L_h = 20{,}000$ hrs

Diameter of shaft $d = 75$ mm

To Select a bearing, we have to find the value of Dynamic load capacity or dynamic load rating "C".

Rating Life $L = 60 \times N \times L_h$ revolution

$$\left[C = \left(\frac{L}{10^6} \right)^{1/K} \cdot F \right]$$ where $K = 3$ for ball bearing

where F = Equivalent Load

$$\boxed{F = X \cdot V \cdot F_r + Y \cdot F_a}$$

X = radial load factor $\xrightarrow{\text{depends on}}$ F_a / C_o

Y = Axial load factor $\Rightarrow$ F_a / F_r

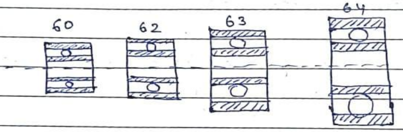
And since low. smaller ring is rotating in this case $V = \underline{1}$ = Rotational factor

To find 'C_o' which is Basic Static capacity, we assume a series.

Assumptions will be trail & error basis

We have different sieries like 60, 62, 63 & 64

E.g.,



60 extra Light
62 light
63 medium
64 heavy.

I. Start with 60 series.

Since $d = 75$ mm.

from data book, bearing is 6215

then

$C_o = 41385$ N

then

$$\frac{F_a}{C_o} = \frac{3000}{41385} = 0.07, \quad \frac{F_a}{F_r} = \frac{3000}{8000} = 0.37.$$

From data book.

$$\frac{F_a}{C_o} = 0.07 \longrightarrow e = 0.27.$$

$$\frac{F_a}{F_r} = 0.37 > e\,(0.27) \Rightarrow X = 0.56, \; Y = 1.6$$

$\therefore \quad F = XV \cdot F_r + YF_a$

$= 0.56 \times 1 \times 8000 + 1.6 \times 3000$

$F = 9280 \ N$

$L = 60 \times N \times L_h$

$= 60 \times 1200 \times 20{,}000$

$= 1440 \times 10^6$ revolutions.

$$C = \left(\frac{L}{10^6}\right)^{1/k} \times F.$$

$$= \left(\frac{1440 \times 10^6}{10^6}\right)^{1/3} \times 9280$$

$C = 104793.77 \ N.$

From databook, 6215, $C = 50{,}600 \ N$ So, 6215 Not.

II. Choose 64 series.

6415 ball bearing.

$C_o =$ ~~77,200~~ 101600 (databook).

$\frac{F_a}{C_o} = 0.02$, $\frac{F_a}{F_r} = \frac{3000}{8000} = 0.37.$

$\frac{F_a}{C_o} = 0.04 \rightarrow e = 0.22$ (data book)

$\frac{F_a}{F_r} = 0.37 > e \ (0.22) \Rightarrow X = 0.56$, $Y =$ ~~1.8~~ 2

$F = XV \cdot F_r + YF_a$

$= 0.56 \times 1 \times 8000 + 2 \times 3000$

$F = 10480 \ N.$

$$C = \left(\frac{1440 \times 10^6}{10^6}\right)^{1/3} \times 10480$$

$\left[C = 118344.69 \ N.\right]$

From data Book

6415, $C = 1{,}20{,}000$

So bearing 6415 will be suitable for this application.

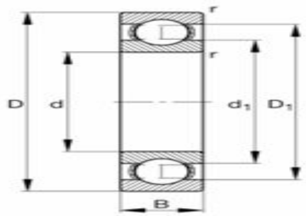
FAG

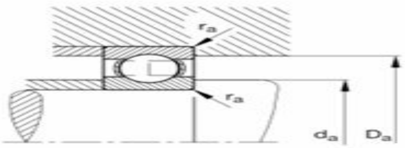
6415-M

Deep groove ball bearing

Deep groove ball bearing 64..-M, single row, solid brass cage

Technical information





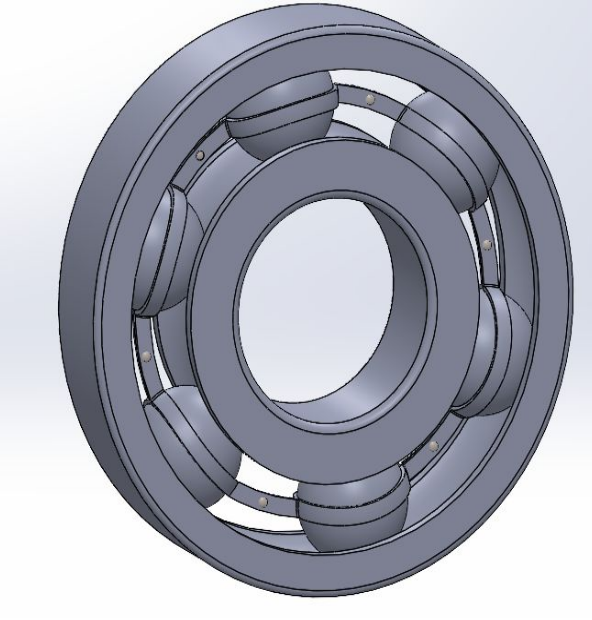
Main Dimensions & Performance Data		
d	75 mm	Bore diameter
D	190 mm	Outside diameter
B	45 mm	Width
C_r	141,000 N	Basic dynamic load rating, radial
C_{0r}	97,000 N	Basic static load rating, radial
C_{ur}	6,000 N	Fatigue load limit, radial
n_G	6,600 1/min	Limiting speed
$n_{ϑr}$	5,600 1/min	Reference speed
≈m	7 kg	Weight

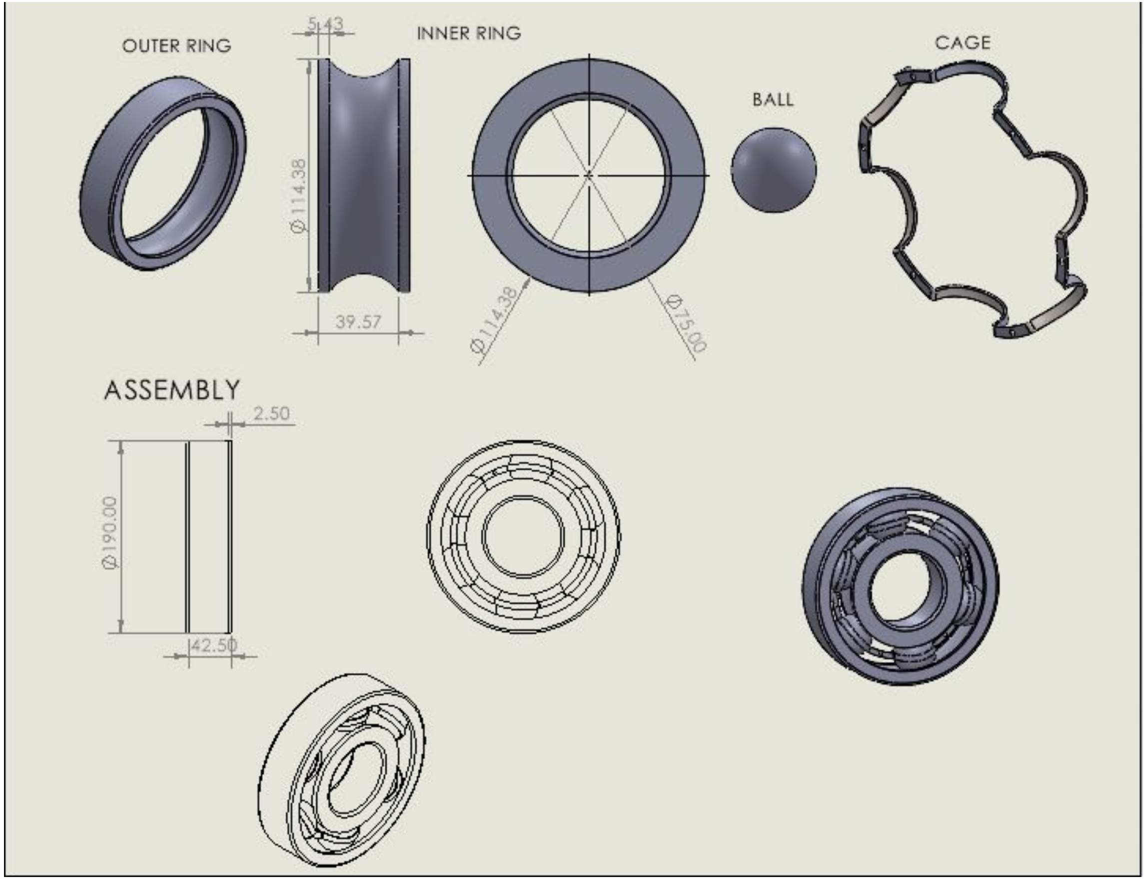
Mounting dimensions		
$d_{a\ min}$	91 mm	Minimum diameter shaft shoulder
$D_{a\ max}$	174 mm	Maximum diameter of housing shoulder
$r_{a\ max}$	2.5 mm	Maximum fillet radius

Dimensions		
r_{min}	3 mm	Minimum chamfer dimension
D_1	151.58 mm	Shoulder diameter outer ring
d_1	114.38 mm	Shoulder diameter inner ring

Temperature range		
T_{min}	-30 °C	Operating temperature min.
T_{max}	150 °C	Operating temperature max.

Calculation factors		
f_0	13.3	Calculation factor



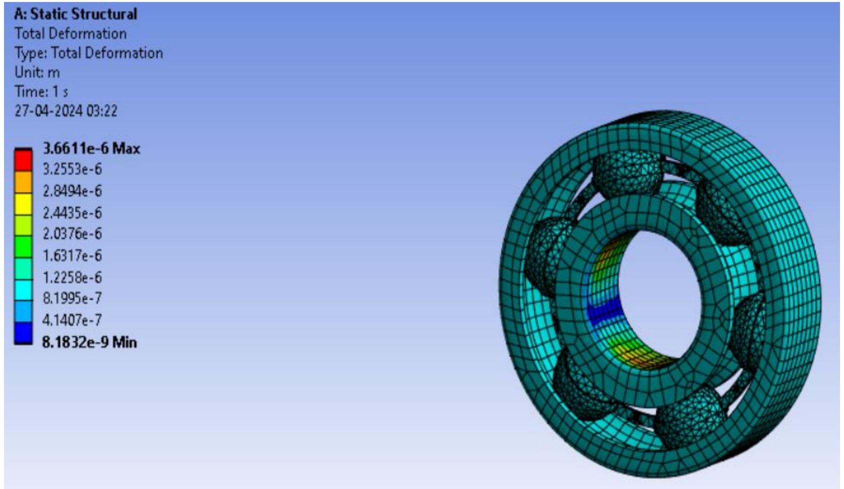


OUTER RING
5.43
INNER RING
CAGE
BALL
Ø114.38
39.57
Ø114.38
Ø75.00
ASSEMBLY
2.50
Ø190.00
42.50

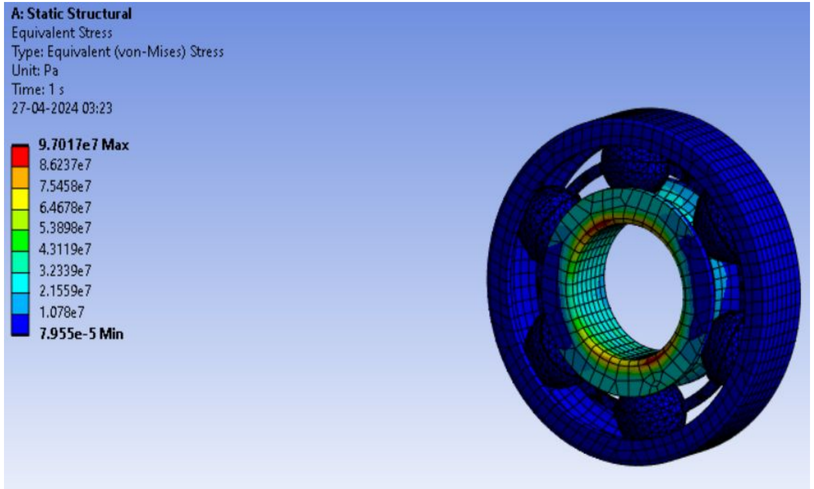
Results and Discussion

Static Analysis

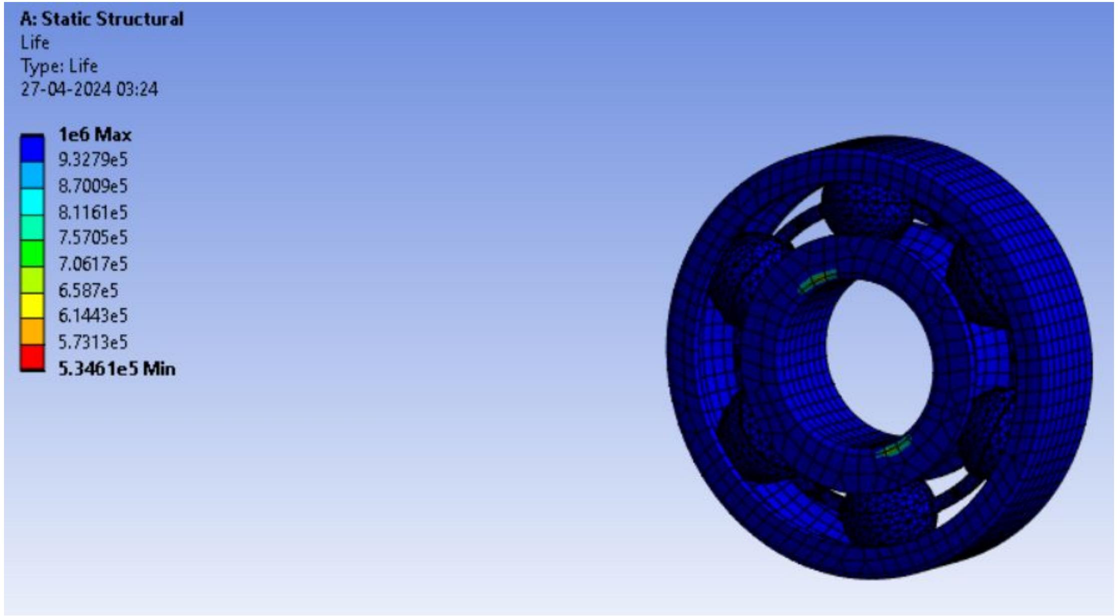
1. Total Deformation



2. Equivalent (von-Mises) stress

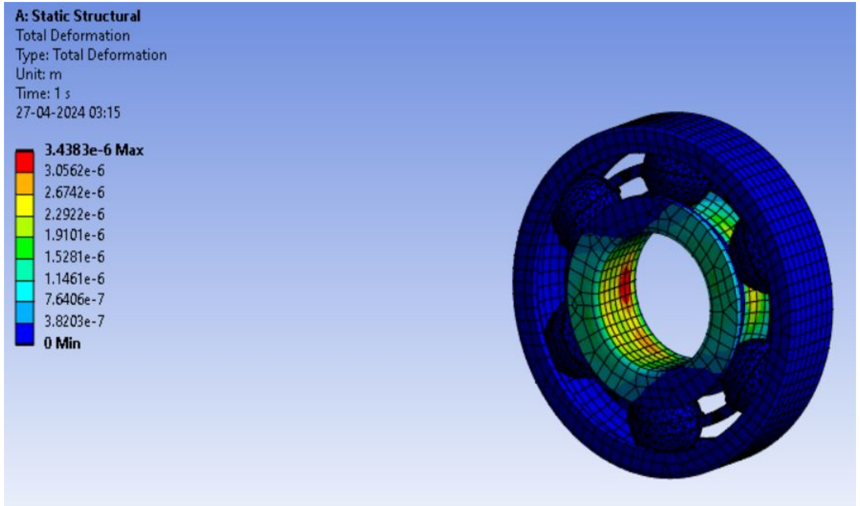


3. Fatigue life of bearing:-

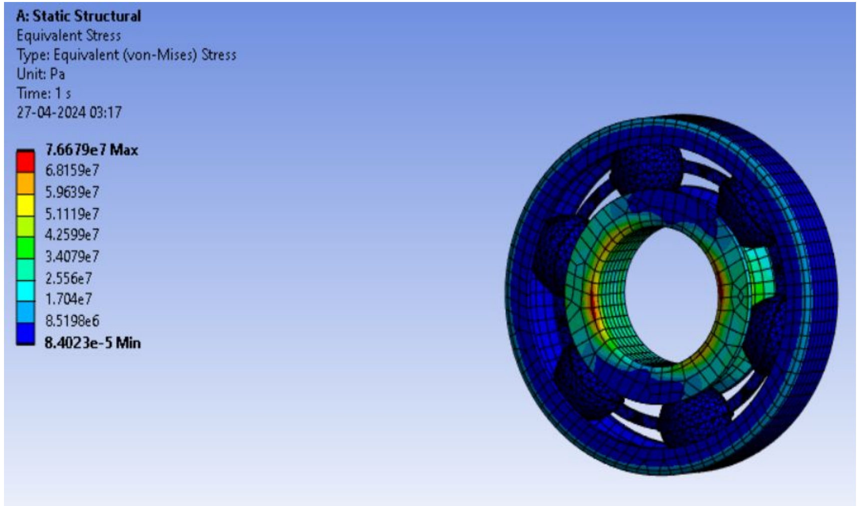


Dynamic Analysis

1. Total Deformation



2. Equivalent (von-Mises) stress:-



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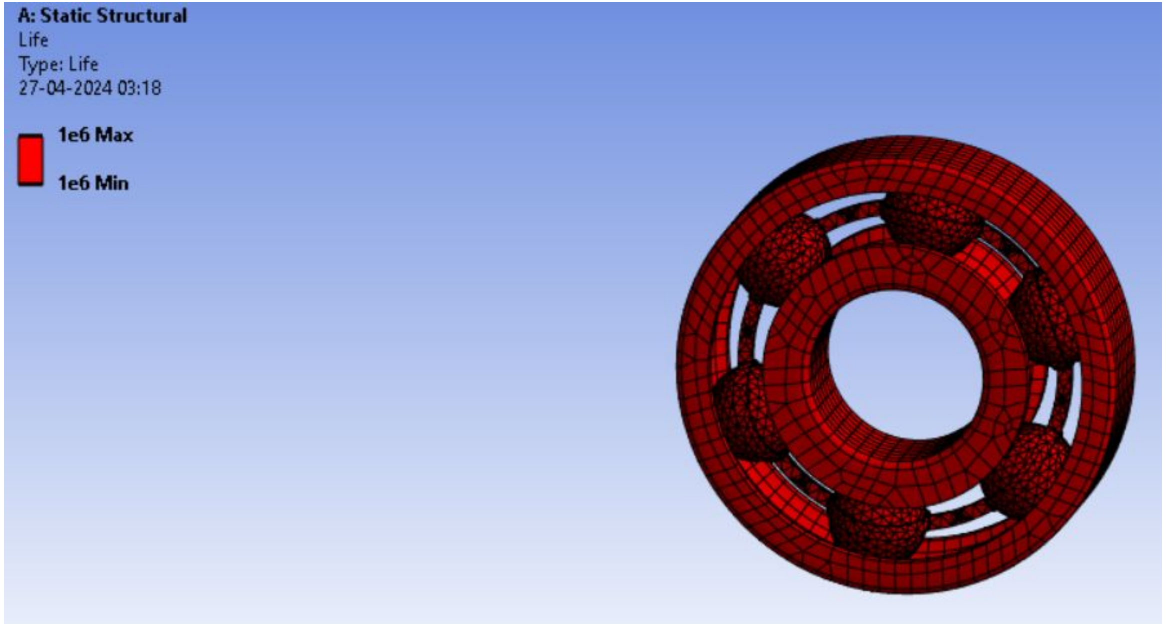

CONCLUSION

We can conclude that the deformation of this bearing in static condition is 0.036 mm and the maximum stress generated in static condition is 97 Mpa. While the deformation of this bearing in dynamic condition is around 0.034 mm and maximum stress generated is 76 Mpa. The life of bearing we get is in the multiple of 10^6. So we can conclude that our bearing is safe against the radial and axial load which is applied at static and dynamic condition.

Failure in Disc Brake

Misalignment: Improper alignment of the shaft and bearing can result in uneven load distribution, leading to excessive stress on certain areas of the bearing and eventual failure.

Overloading: Exceeding the bearing's load capacity can cause deformation of the bearing components, leading to fatigue failure or plastic deformation.

Poor Installation: Incorrect installation procedures, such as improper fitting, tight fits, or using damaged tools, can introduce stress concentrations and compromise the bearing's integrity.

Fatigue: Continuous cyclic loading can lead to metal fatigue over time, causing cracks to develop in the bearing raceways or rolling elements.

Thank You