iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** VII **Month of publication:** July 2018

DOI: http://doi.org/10.22214/ijraset.2018.7039

Analysis on Effects of Different Materials used to Manufacture Deep Groove Ball Bearing

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Abstract: Here in this work it calculated the effect of different types of material used to manufacture deep groove ball bearing. For calculating the suitability of material used for deep groove ball bearing here it calculate the value of contact stress on inner and outer ring, it also calculated the value of total deformation. For analyzing the different material here it considered four different materials that are SUJ2, ASTM 52100, JIS4104 and SUS440C. In order to check different conditions of loading on different material here it considered 2000, 4000, 6000 and 10000 N load to perform static analysis on deep groove ball bearing. For the analysis here it considered 6332 type deep groove ball bearing. During dynamic analysis different rotational speed were applied on the ball bearing and calculate the value of equivalent stress and total deformation, for different rotating conditions hear it considered four different rotational speed that is 1000, 1500, 2000 and 2500 RPM. Through analysis it is found that SUS440C material is the optimum material to manufacture deep groove ball bearing.
Keywords: Deep groove ball bearing, FEA, Static analysis, Dynamic analysis, Material, deformation

I. INTRODUCTION

A bearing is a machine element that constrains relative motion to only the desired motion, 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 are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts. Rotary 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 simplest form of bearing, the plain bearing, consists of a shaft rotating in a hole. Lubrication is often used to reduce friction. In the ball bearing and roller bearing, to prevent sliding friction, rolling elements such as rollers or balls with a circular cross-section are located between the races or journals of the bearing assembly.

A wide variety of bearing designs exists to allow the demands of the application to be correctly met for maximum efficiency, reliability, durability and performance. The performances of bearing were analyzed at both the condition that is static and dynamic to improve the quality and performance of bearing. Here in this work it has numerically analyzed the contact stresses and deformation during the static and dynamic condition of ball bearing. Here in this work four different materials were used to minimize the contact stresses and also to reduce total deformation of ball bearing. In order to perform the numerical analysis of ball bearing first it has to develop the solid model of ball bearing.

II. SOLID MODEL OF BALL BEARING

Here in this work the solid model of ball bearing were drawn on the basis of parameters that were considered during the experimental analysis of ball bearing perform by shuting li [19]. The geometric specification of ball bearing used for the numerical analysis were shown in the below table.

Table.1 Geometric parameter of ball bearing

Parameters	Value
Inner race diameter or bore diameter (d)	32 mm
Outer race diameter (D)	75 mm
Width (B)	20 mm
Ball diameter	11.11 mm
Number of ball	8

On the basis of given geometric specification solid model of ball bearing were develop. The solid model of ball bearing were shown in the below fig.

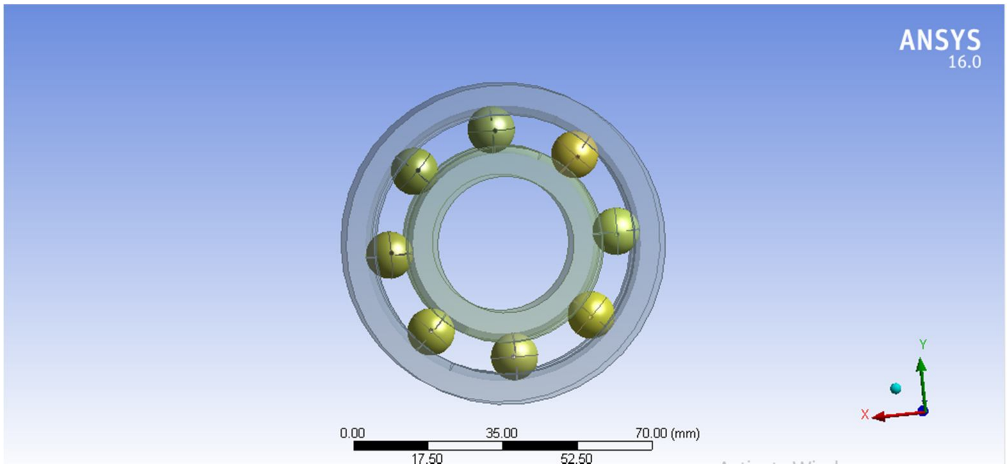

Fig.1 solid model of ball bearing used for the numerical analysis

A. Mesh

To perform the numerical analysis first it has to discretize the complete body of ball bearing in to number of nodes and elements. In order calculate the dependency of result on nodes and elements, here in this work it perform mesh of ball bearing with different number of nodes and elements and calculated the value of contact stresses. Through analysis it is found that the contact stress does not depend on the number of nodes and elements. Here in this analysis it discretizes the ball bearing in to 18894 numbers of elements which gives optimum result. The mesh of the ball bearing is shown in the below fig.

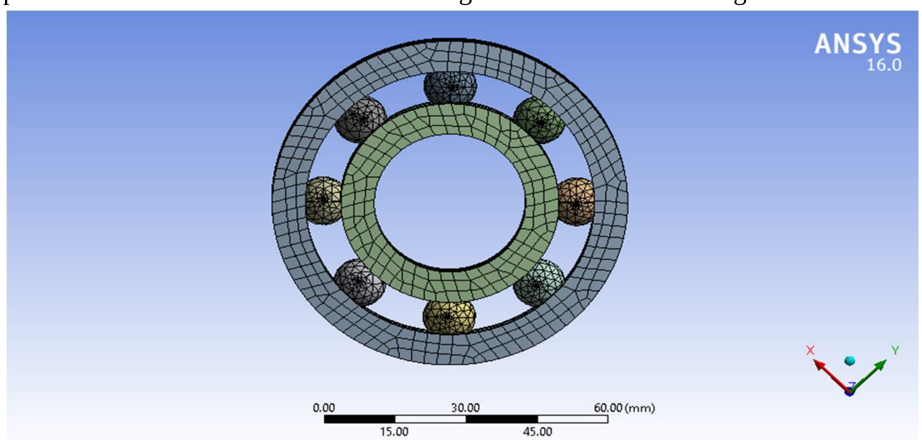

Fig.2 shows the meshing of the ball bearing

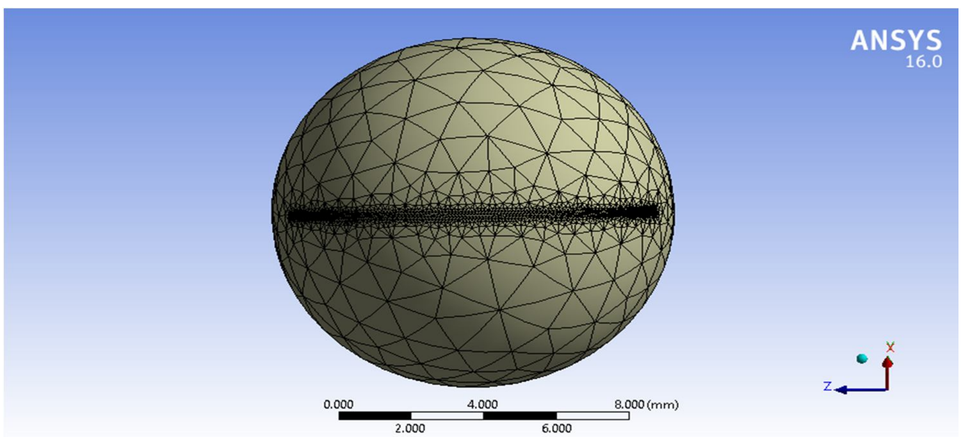

Fig.3 shows the fine meshing on balls

B. Materials

Here in this work four different materials were considered to manufacture ball bearing. The contact stress in ball bearing mainly depends on the material properties that are used for the manufacturing of bearing. So in order to reduce contact stress and deformation in ball bearing here if considered four different types of material used for manufacturing of ball bearing. The properties of four different materials used for the numerical analysis is shown in the below section. For the initial analysis here we have considered material as considered in base paper that is SUJ2 type

Table.2 Properties of SUJ2 material

Property	value
Density (kg/m^3)	7850
Young modulus (MPa)	2.1×10^5
Poisson ratio	0.3

Table.3 Properties of ASTM 52100 material

Property	value
Density (kg/m^3)	7827
Young modulus (MPa)	2.0133×10^5
Poisson ratio	0.277

Table.4 Properties of JIS4104 material

Property	value
Density (kg/m^3)	7830
Young modulus (MPa)	2.08×10^5
Poisson ratio	0.285

Table.5 Properties of SUS440C material

Property	value
Density (kg/m^3)	7680
Young modulus (MPa)	2×10^5
Poisson ratio	0.27

C. Mathematical model

In order to validate the numerical analysis here it calculated the value of contact stress analytically. Here it calculates the value of contact stress for SUS440C material at 2000 N load condition. The mathematical calculation used for finding contact stress

$$\sigma = \frac{3F}{2\pi ab}$$

Where

$$a = 1.145\, n_a\, (F.K.\gamma)^{\frac{1}{3}},\quad b = 1.145\, n_b\, (F.K.\gamma)^{\frac{1}{3}},\quad \gamma = \frac{1-{v_1}^2}{E_1} + \frac{1-{v_2}^2}{E_2},\quad K = \frac{1}{\frac{2}{R_1} - \frac{1}{R2} + \frac{1}{R3}}$$

Where F = radial load, R_1 = radius of ball, R_2 = radius of inner race groove, R_3 = radius of inner race, R_1 = 5.5562 mm, R_2 = 5.6674 mm, R_3 = 23.009 mm, K = 4.4058 mm, γ = 8.667 × 10^{-6} MPa^{-1}

$$n_a = \frac{1}{k}\left(\frac{2kE(e)}{\pi}\right)^{\frac{1}{3}}$$

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VII, July 2018- Available at www.ijraset.com

$$n_b = \left(\frac{2kE(e)}{\pi}\right)^{\frac{1}{3}}$$

a = 1.0025 mm

b= 0.5012 mm

Contact between inner ring and ball

Contact stress = 1900.35MPa

D. Boundary condition

Here in this work first it perform the static analysis of ball bearing, to perform the numerical analysis of ball bearing at static state here we have considered same boundary conditions as considered during the experimental analysis performed by shuting [19]. Here in this work for static analysis it considered outer ring of the ball bearing is in fix condition whereas 2000 N radial load is applied on the ball bearing and calculate the value of contact stresses and total deformation of ball bearing. During the dynamic analysis of ball bearing it considered four different loading conditions that is 2000, 4000, 6000 and 10000 N

III. RESULT

This work considered both that is static and dynamic numerical analysis of ball bearing to analyses the different material used for the ball bearing. It calculates the value of contact stress and deformation of ball bearing at different loads during static state numerical analysis. For analyzing the effect of different loads on contact stress and deformation during dynamic analysis it considered four different load that is 2000, 4000, 6000, 10000 N and calculate the value of contact stress and deformation for each load.

A. For Static Analysis

During static analysis it considered the same material as considered during the experimental analysis performed by shuting [19] that is SUJ2 and also considered the same boundary condition as considered during the experimental analysis.

B. Validation Of Numerical Analysis

In order to validate the numerical model of deep groove ball bearing it calculated the value of contact stresses on inner and outer ring of deep groove ball bearing for different loads the value of contact stress for different loads were shown in the below table.

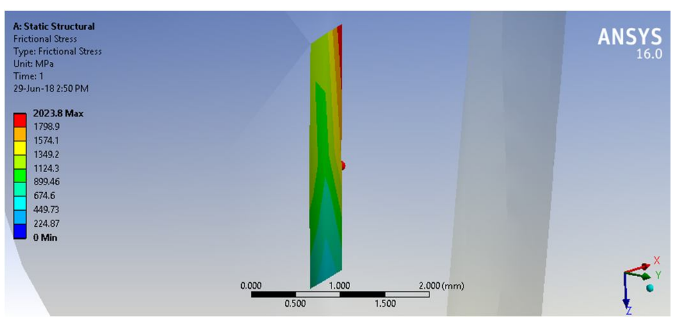

Fig.4 shows the contact stress on inner ring for 2000 N load

Table.6 Value of contact stresses in between inner ring and balls

Applied load (N)	Contact stress from base paper (MPa)	Contact stress for FEA analysis (MPa)	Error in %
2000	2000	2023.8	1.19
4000	2640	2681.7	1.57
6000	3090	3137.3	1.53
10000	3800	3846	1.21

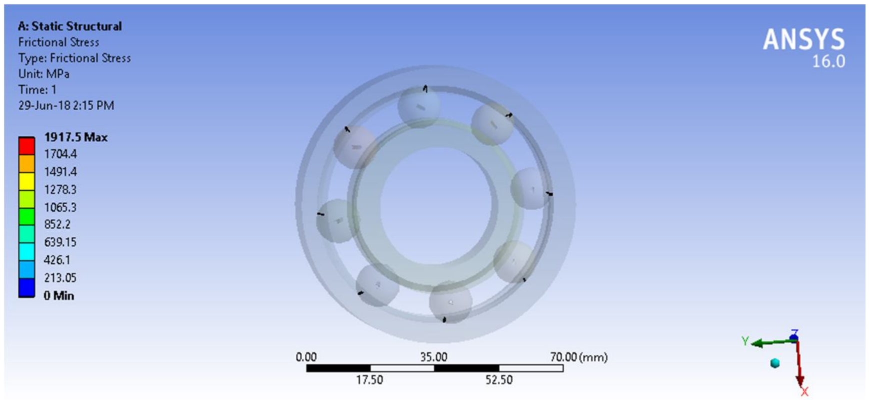

Fig.5 shows the contact stress on outer ring for 2000 N load

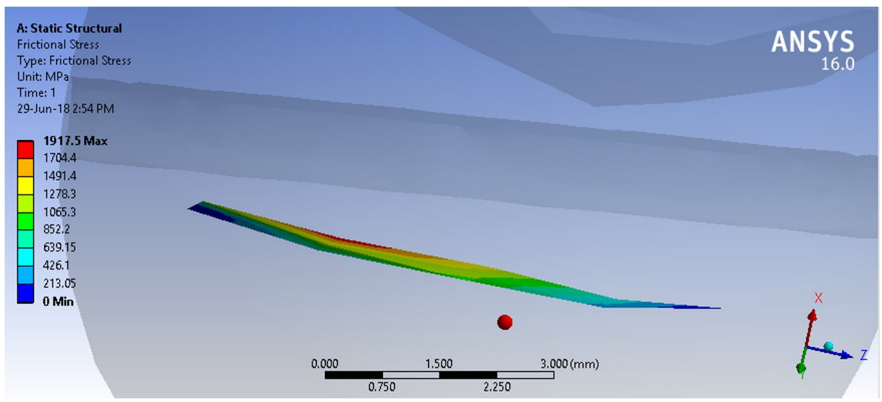

Fig.6 contact stress at contact point of ball

Table.7 Value of contact stresses in between outer ring and balls

Applied load (N)	Contact stress from base paper (MPa)	Contact stress for FEA analysis (MPa)	Error in %
2000	1900	1917.5	0.92
4000	2500	2540.8	1.6
6000	2940	2972.1	1.09
10000	3600	3643.2	1.2

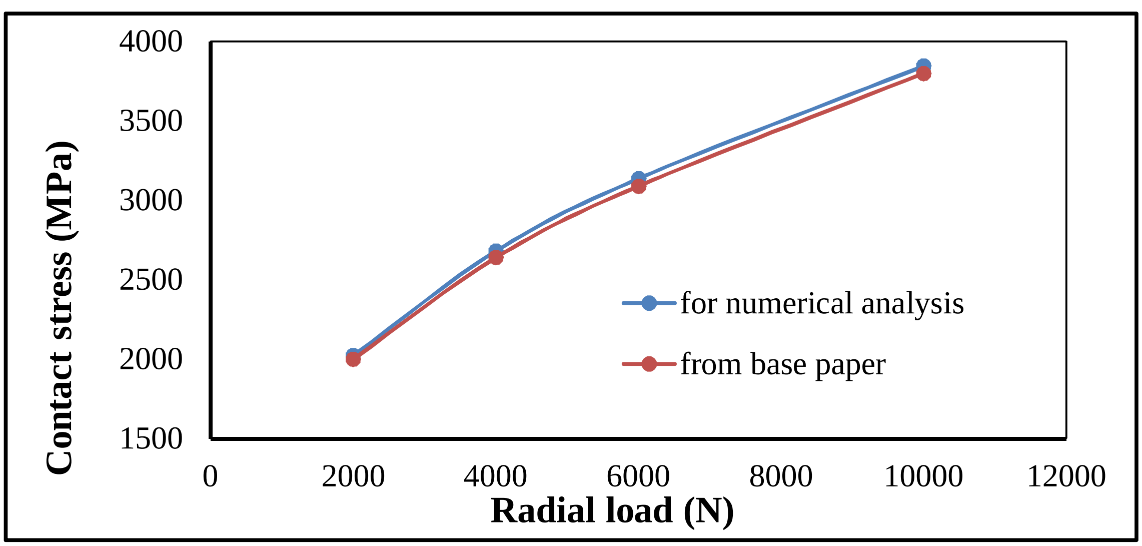

Fig.7 comparison of value of contact stresses in between inner ring and ball

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VII, July 2018- Available at www.ijraset.com

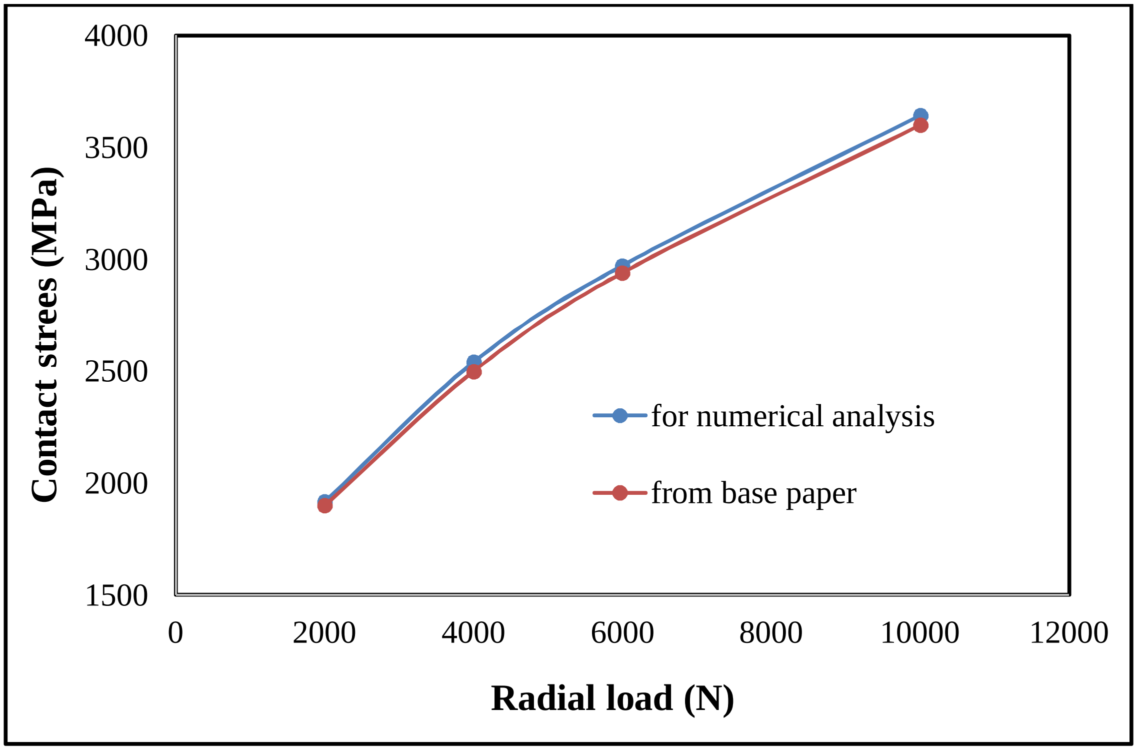

Fig.8 comparison of value of contact stresses in between outer ring and ball

From above graph it is found that the value of contact stresses at inner and outer ring is near to the value of contact stresses as given in the base paper so here we can say that the numerical analysis of deep groove ball bearing is correct. After validating the numerical analysis of deep groove ball bearing here it perform the numerical analysis on different materials used for the manufacturing of deep groove ball bearing and calculate the value of contact stresses on inner and outer ring and also calculate the value of total deformation.

C. For SUJ2 Material

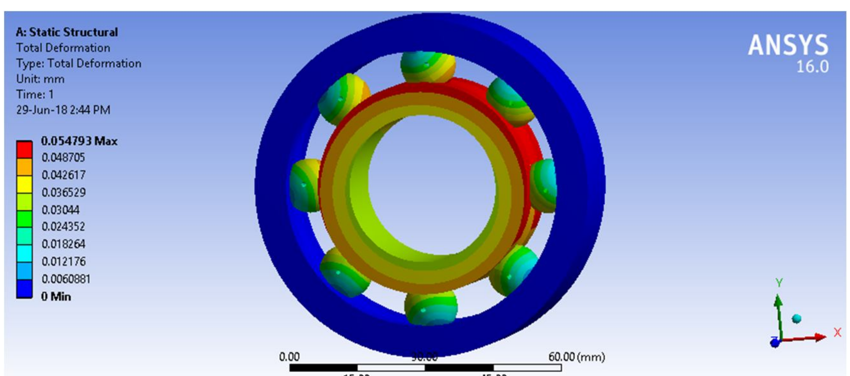

Fig.9 shows the total deformation ball bearing at 2000 N load

Table.8 Shows the value of different parameters of deep groove ball bearing of SUJ2 material

Load (N)	Contact stress on outer ring (MPa)	Contact stress on outer ring (MPa)	Total Deformation
2000	1917.5	2023.8	0.0547
4000	2540.8	2681.7	0.7260
6000	2972.1	3137.3	0.08492
10000	3643.2	3846	0.10411

D. For JIS4104 Material

Table.9 Shows the value of different parameters of deep groove ball bearing of JIS4104 material

Load (N)	Contact stress on outer ring (MPa)	Contact stress on outer ring (MPa)	Total Deformation
2000	1920.6	1991.6	0.05271
4000	2544.8	2639	0.06984
6000	2976.9	3087.3	0.08170
10000	3649.1	3784.8	0.10016

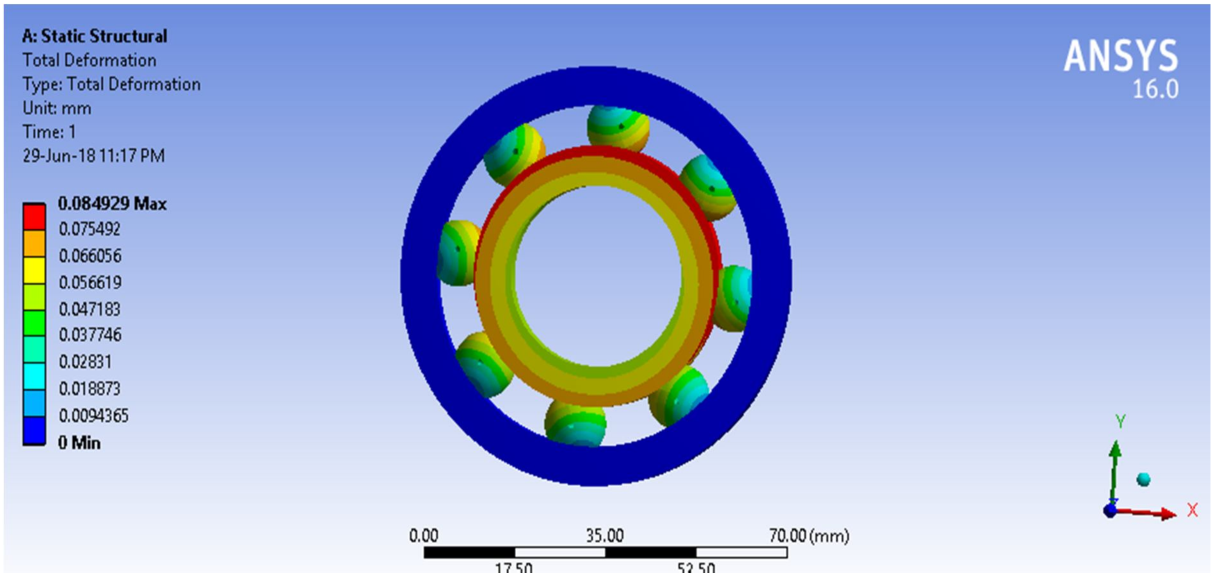

Fig.10 shows the total deformation 6000 N

E. For ASTM 52100 Material

Table.10 Shows the value of different parameters of deep groove ball bearing of ASTM 52100 material

Load (N)	Contact stress on outer ring (MPa)	Contact stress on outer ring (MPa)	Total Deformation
2000	1922.2	1975.7	0.05446
4000	2547	2618	0.07216
6000	2979.5	3062.8	0.08441
10000	3652.3	3754.6	0.10348

F. For SUS440C Material

Table.11 Shows the value of different parameters of deep groove ball bearing of SUS440C material

Load (N)	Contact stress on outer ring (MPa)	Contact stress on outer ring (MPa)	Total Deformation
2000	1923.7	1962.5	0.04983
4000	2548.9	2600.4	0.06603
6000	2981.7	3042.2	0.07724
10000	3655.1	3729.4	0.09468

G. Comparison of Different Material

Here we have compares the value of contact stresses on inner and outer ring of deep groove ball bearing and also compared the value of total deformation take place on ball bearing and find the optimum material for deep groove ball bearing.

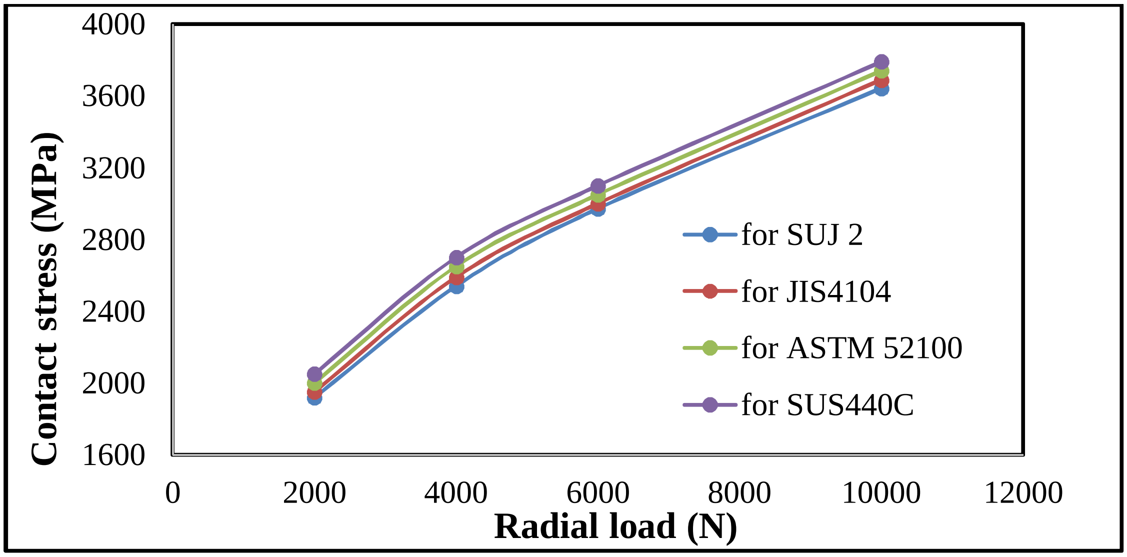

Fig.11 comparison of value of contact stress on the inner ring of deep groove ball bearing

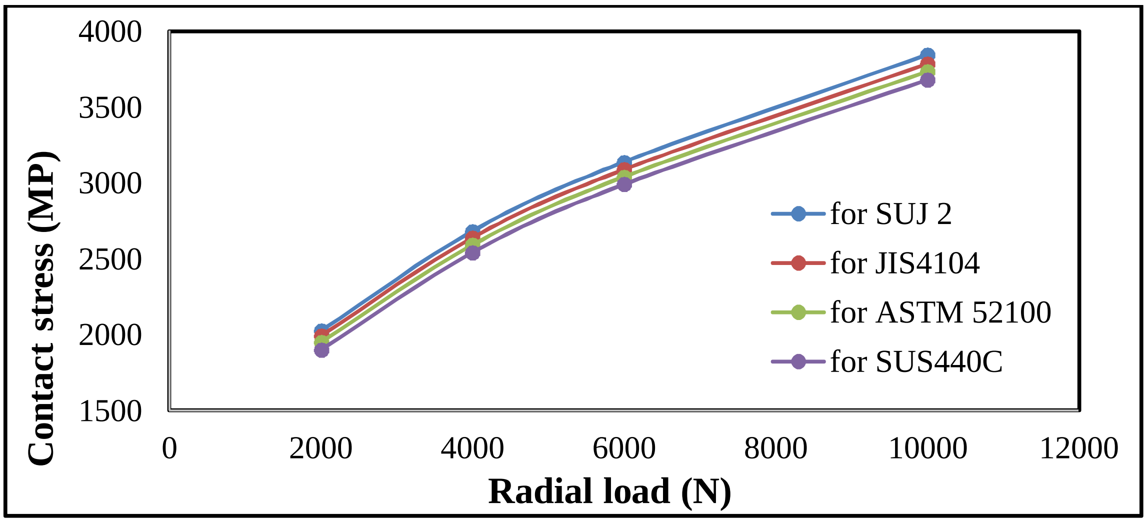

Fig.12 comparison of value of contact stress on the outer ring of deep groove ball bearing

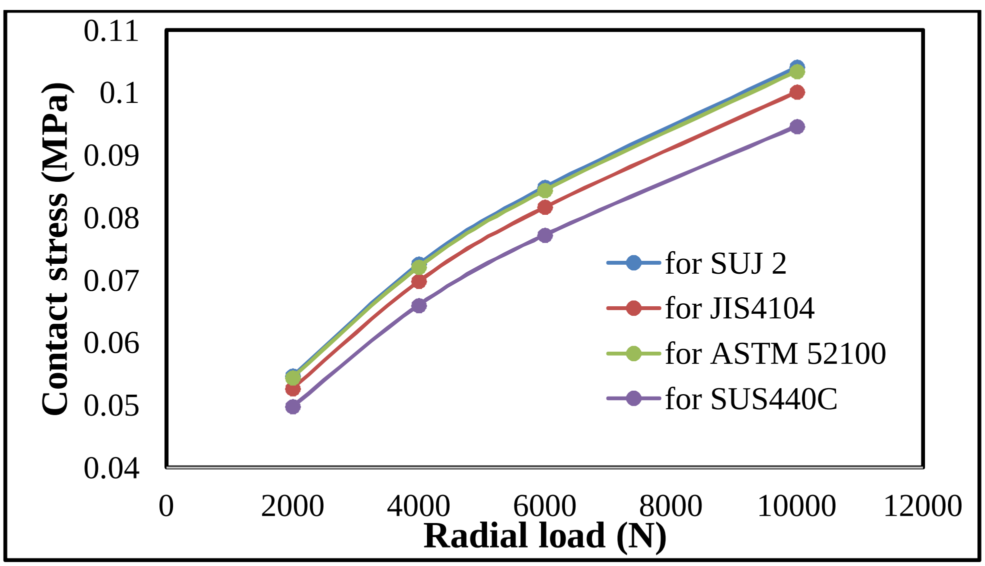

Fig.13 comparison of value of total deformation of deep groove ball bearing

From the above analysis it is found that the value of contact stresses is minimum for SUS440C material and also shows the minimum total deformation as compared to other material. From the analysis it is also found that as the value of load increases the value of contact stresses also increase.

H. For Dynamic Analysis

Here in this section it calculate the value of equivalent stress for different loading condition and also calculate the value of total deformation during dynamic analysis of deep groove ball bearing. For SUS440C material at 2000 N loading condition the value of equivalent stress is shown in the below fig.

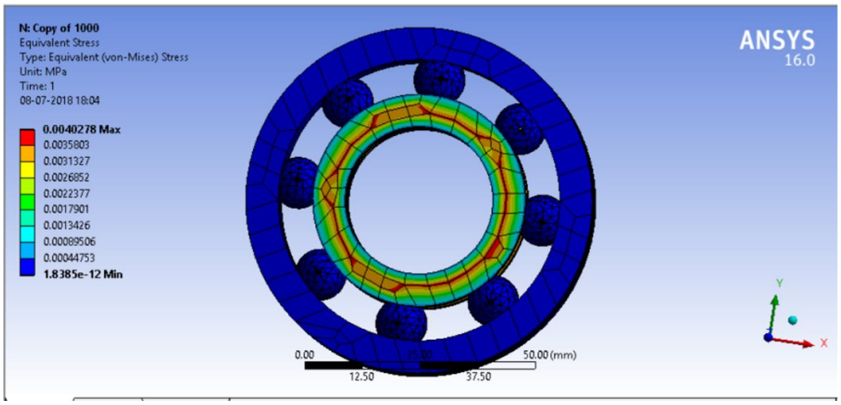

Fig. 14 value of equivalent stress for dynamic loading at 1000 rpm

Table. 12 Value of equivalent stresses for different material at different rotational speed

Rotational Speed (RPM)	Equivalent stress (MPa) for SUS440 material	Equivalent stress (MPa) for JIS4104 material	Equivalent stress (MPa) for SUJ 2 material	Equivalent stress (MPa) for ASTM 52100 material
1000	0.004	0.0071	0.0079	0.0054
1500	0.009	0.0138	00146	0.0115
2000	0.016	0.0227	0.025	0.0195
2500	0.025	0.038	0.0405	0.034

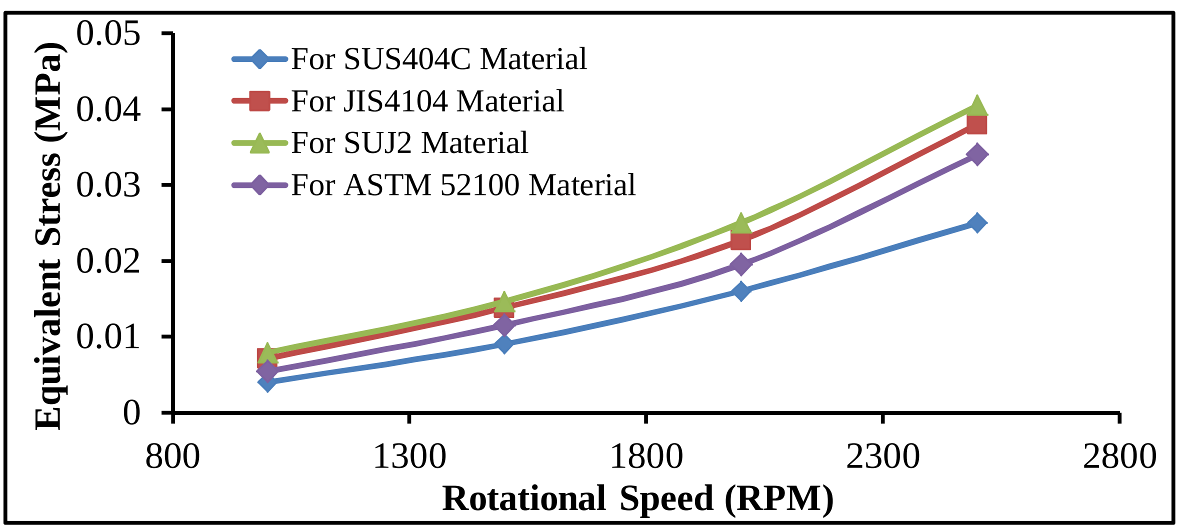

Fig.15 comparison of value of equivalent stress for different materials during Dynamic analysis

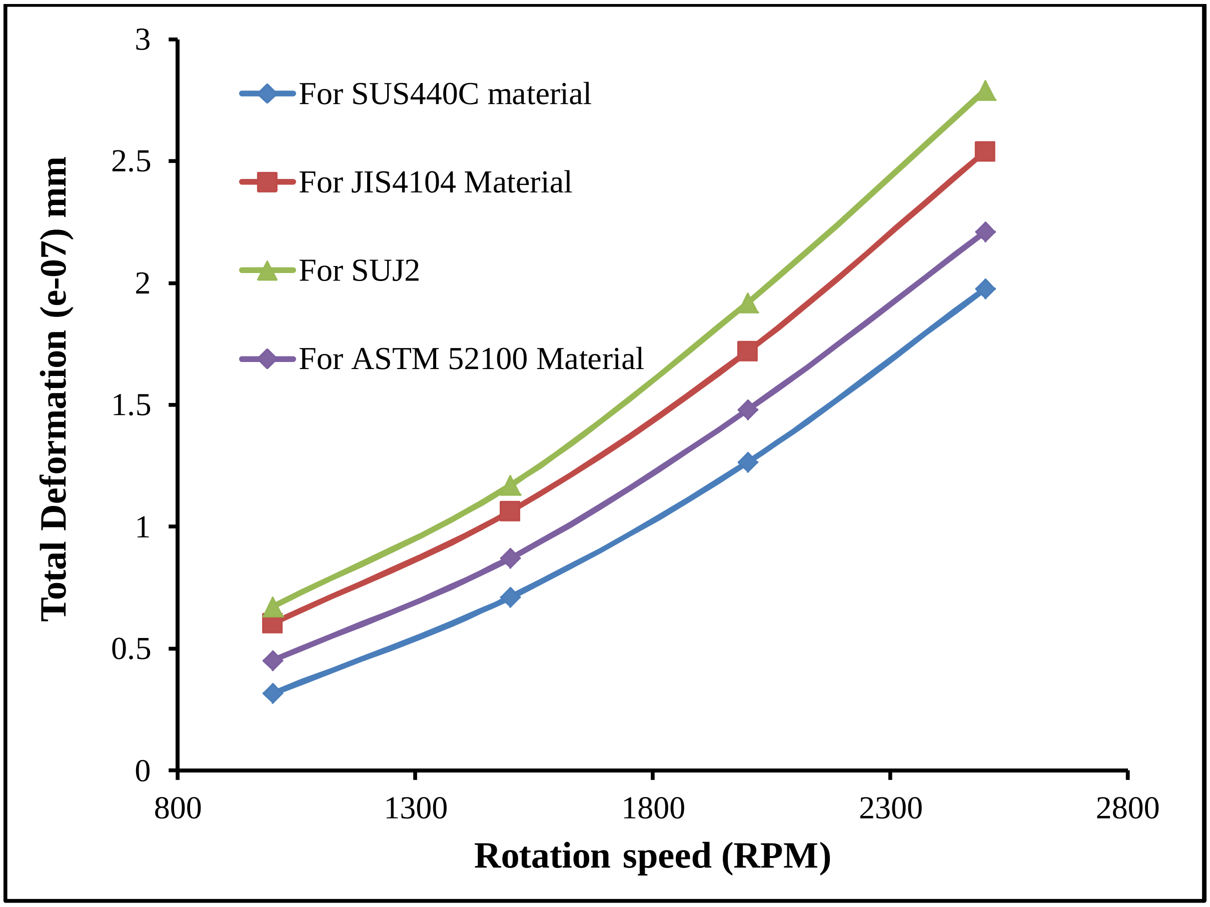

Fig. 16 comparison of value of Total Deformation for different material during dynamic condition

From the dynamic analysis it is found that the total deformation of deep groove ball bearing is minimum for SUS440C material during different running speed. Through analysis it is found that the value of equivalent stress is minimum for SUS440C material as compared to other materials.

After evaluating deep groove ball bearing for static and dynamic analysis, it is found that SUS440C material is the most compatible material to manufacture deep groove ball bearing.

IV. CONCLUSION

A. After performing the numerical analysis of deep groove ball bearing, it is found that the value of contact stresses increases with increase in load.
B. The value of contact stresses on outer ring is minimum for material SUS440C during static loading condition.
C. Through analysis it is also found that the value of total deformation is minimum for material SUS440C which shows the maximum load bearing capacity of material as compared to other materials.
D. During dynamic analysis, material SUS440C shows the less equivalent stress and minimum total deformation.
E. So here it is conclude that SUS440C material is the optimum material to manufacture deep groove ball bearing.

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