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Research Article

Fracture Examination of a Tube-well Water Pump Deep Groove Ball Bearing for Life Improvement using Finite Element Analysis

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Abstract

Tube wells are used for watering the crops. Pump is fitted at the deep side of the tube wells. Pumps are used for supplying the water in the field. After 6 to 8 months, failure of bearing occurs. The bearing used in the pump is deep groove ball bearing. The main cause of bearing failure is misalignment of bearing on shaft at the time of maintenance, excessive loading while operating the water pump, overheating by friction during excessive operating conditions, poor lubrication and some corrosion effects. The speed of bearing shaft is 2800 rpm, which is the maximum operating speed. This failure can be examine using the engineering analysis. Some engineering modifications will improve the life of bearing and decrease the rate of failure.

Keywords: *Ball Bearing, Pump, Tube Well, Finite Element Analysis, Materials.*

1. Introduction

Tube-well water pump is the important part of our daily life. In India, more than 75% people belong to agriculture background. But these people face problems like the failure of the deep groove ball bearing (DGBB) more often, because of the vibration caused due to the high speed of the shaft. India is an agriculture based country. Their main occupation is farming. They used tube wells for watering the crops. Pump is fitted at the deep side of the tube wells. Pumps are used for supplying the water in the field. These farmers face a problem of bearing failure within approx. 6 to 8 months. The bearing used in the pump is Deep Groove Ball Bearing. The main causes of bearing failure are misalignment of bearing on shaft at the time of maintenance, excessive loading while operating the water pump, overheating by friction during excessive operating conditions, poor lubrication and some corrosion effects. The speed of bearing shaft is 2800 rpm, which is the maximum operating speed. This failure or fracture can be examined using the engineering analysis. Some kind of engineering modifications will improve the life of deep groove ball bearing and reduce the rate of failure.

To generate a three-dimensional solid CAD model, Autodesk Inventor software is used as a design modeler. After the design modeling, the finite element model is generated using FEA software ANSYS. Then the engineering data tool is used to select various Deep Groove Ball Bearing (DGBB) materials that are Stainless Steel, Structural Steel, Steel EN42, and Steel EN45. Then geometry is imported using "STP" file conversion on ANSYS. After this the model is converted into meshed model. Then the boundary conditions are applied. The structural analysis model is used for the analysis of DGBB. The output parameter is total Deformation. The life of the bearing is calculated in the terms of total deformation. Total 7 numbers of cases are generated for analysis. Vibration analysis is done on 6 different frequency modes. Deformation is calculated on these different frequencies for all cases. Total 7 numbers of cases are also generated for analysis. For fracture analysis, SIFS1, SIFS2, SIFS3 & J-Integral is calculated.

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2. Material

The material chosen for the analysis are Stainless Steel, Structural Steel, Steel EN42, and SteelEN45. The various properties of the materials are shown in Table1.

Table 1

Engineering Data	Ball Materials			
	Stainless Steel	Structural Steel	Steel EN42	Steel EN45
Density (Kg/m3)	7750	7850	7850	7700
Young's Modulus (MPa)	193000	200000	195000	204000
Poisson's Ratio	0.31	0.3	0.27	0.29
Bulk Modulus (MPa)	169300	166700	141300	161900
Shear Modulus (MPa)	73664	76920	76770	79070

Specific Heat	480	434	480	480
Ultimate Tensile Strength (MPa)	505	510	420	621
Yield Strength (MPa)	215	250	220	350

3. Model of deep groove ball bearing

In this study, a full three-dimensional solid model of deep groove ball bearing is introduced to the ANSYS software. The three kinds of the analysis, named as structural analysis, fracture analysis and vibration analysis can be obtained by the imposition of the boundary conditions and loads on the FEA model. Model of the deep groove ball bearing is shown in figure 1.

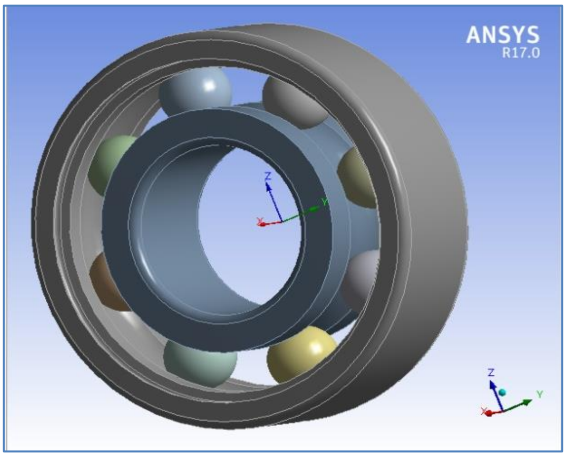

Fig.1 Model of Deep Groove Ball Bearing

4. Boundary conditions

A condition that is required to be satisfied at all or part of the boundary of a region in which a set of differential conditions has to be solved. To be useful in applications, a boundary value problem should be well posed. This means that given the input to the problem there exist a unique solution, which depends continuously on the input. The fixed supports are shown in figure 2 & rotational velocity is shown in figure 3.

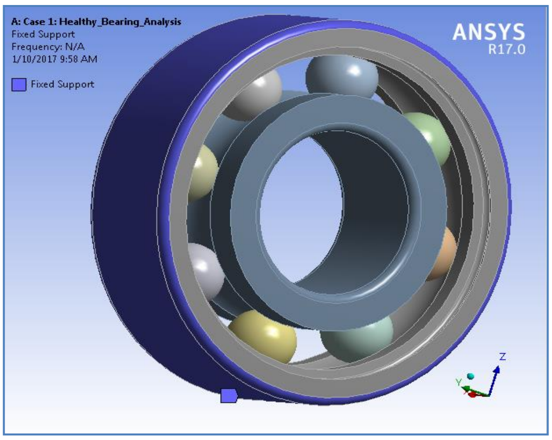

Fig.2 Fixed Supports on Outer Race of the Bearing

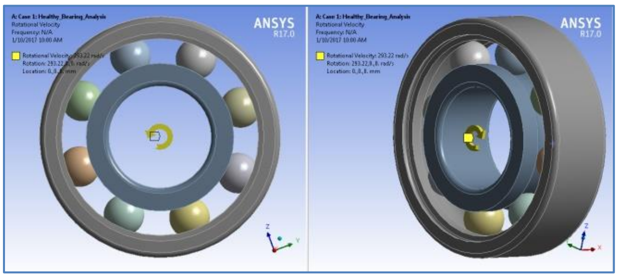

Fig.3 Rotational Velocity (2800 RPM) given to the Inner Race of the Ball Bearing

5. Structural analysis

A structural system is the combination of structural elements and their materials. It is important for a structural engineer to be able to classify a structure by either its form or its function, by recognizing the various elements composing that structure. The structural elements guiding the systemic forces through the materials are not only such as a connecting rod, a truss, a beam, or a column, but also a cable, an arch, a cavity or channel, and even an angle, a surface structure, or a frame. It is used to determine the total Deformation occurs in the bearing.

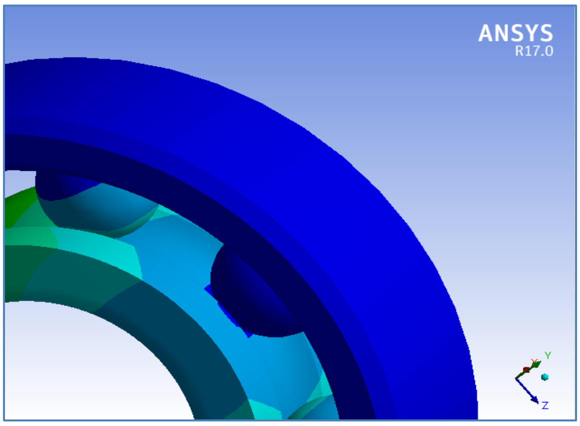

Fig.4 Total Deformation in Inner Race

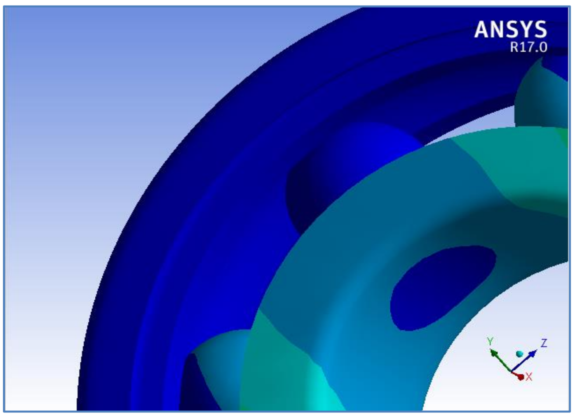

Fig.5 Total Deformation in Outer Race

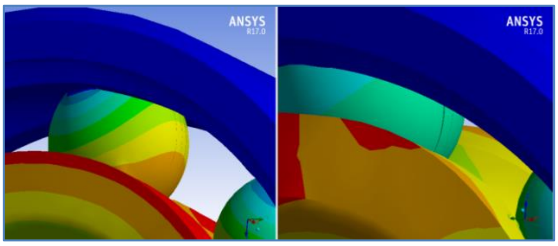

Fig.6 Total Deformation in Ball of Bearing made by Stainless Steel

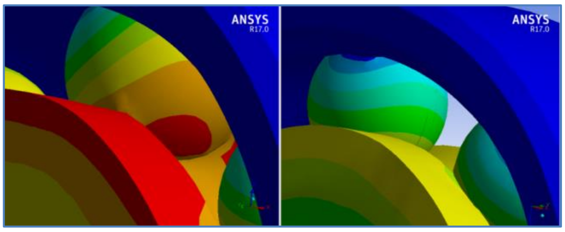

Fig.7 Total Deformation in Ball of Bearing made by Structural Steel

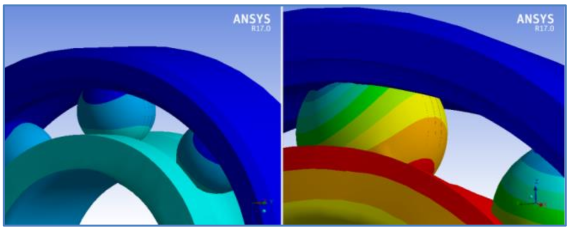

Fig.8 Total Deformation in Ball of Bearing made by Steel EN42

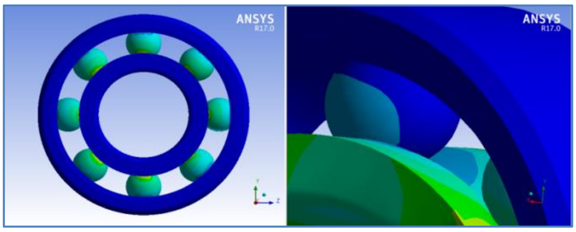

Fig.9 Total Deformation in Ball of Bearing made by Steel EN42

Table 2

Description	Total Deformation (mm)
Ball Bearing Analysis with Fracture on Inner Race	0.059
Ball Bearing Analysis with Fracture on Outer Race	0.009
Ball Bearing Analysis with Fracture on Ball made by Stainless Steel	0.925
Ball Bearing Analysis with Fracture on Ball made by Structural Steel	0.886
Ball Bearing Analysis with Fracture on Ball made by Steel EN42	0.840
Ball Bearing Analysis with Fracture on Ball made by Steel EN45	0.779

6. Vibration analysis

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The oscillations may be periodic, such as the motion of a pendulum or random, such as the movement of a tire on a gravel road.

Total Modes to find: 06
Deformation Profiles: 06

Table 3 Fracture on Inner Race

Mode No.	Ball Bearing Analysis with Fracture on Inner Race	
	Frequency (Hz)	Deformation (mm)
1	24295	193.04
2	27122	186.98
3	34454	244.93
4	34655	247.01
5	35652	196.11
6	35725	197.37

Table 4 Fracture on Outer Race

Mode No.	Ball Bearing Analysis with Fracture on Outer Race	
	Frequency (Hz)	Deformation (mm)
1	26693	187.2
2	27427	194.99
3	34764	243.06
4	34994	242.19
5	36657	193.89
6	37054	197.22

Table 5 Fracture on Ball made by Stainless Steel

Mode No.	Ball Bearing Analysis with Fracture on Ball made by Stainless Steel	
	Frequency (Hz)	Deformation (mm)
1	26369	201.65
2	26954	190.43
3	33732	264.38
4	35858	208.4
5	36014	233.89
6	37249	207.97

Table 6 Fracture on Ball made by Structural Steel

Mode No.	Ball Bearing Analysis with Fracture on Ball made by Structural Steel	
	Frequency (Hz)	Deformation (mm)
1	26,883	197.62
2	27157	186.62
3	33959	259.09
4	36227	204.23
5	36389	229.21
6	37692	203.81

Table 7 Fracture on Ball made by Steel EN42

Mode No.	Ball Bearing Analysis with Fracture on Ball made by Steel EN42	
	Frequency (Hz)	Deformation (mm)
1	26711	199.97
2	26977	187.83
3	33734	260.66
4	35929	214.13
5	36134	236.04
6	37345	207.98

Table 8 Fracture on Ball made by Steel EN45

Mode No.	Ball Bearing Analysis with Fracture on Ball made by Steel EN45	
	Frequency (Hz)	Deformation (mm)
1	27069	200.15
2	27313	187.91
3	34160	260.92
4	36421	226.13
5	36589	225.24
6	37876	207.48

Table 9 Fracture Analysis on Inner race

Object Name	SIFS (K1)	SIFS (K2)	SIFS (K3)	J-Integral (JINT)
Minimum	7.887 MPa·mm^(0.5)	-9.782 MPa·mm^(0.5)	-14.063 MPa·mm^(0.5)	7.5038e-004 mJ/mm^2
Maximum	19.199 MPa·mm^(0.5)	9.7919 MPa·mm^(0.5)	-3.4084 MPa·mm^(0.5)	2.2694e-003 mJ/mm^2

Table 10 Fracture Analysis on Outer Race

Object Name	SIFS (K1)	SIFS (K2)	SIFS (K3)	J-Integral (JINT)
Minimum	6.8576e-004 MPa·mm^(0.5)	-0.50107 MPa·mm^(0.5)	-0.37954 MPa·mm^(0.5)	5.1609e-007 mJ/mm^2
Maximum	0.29045 MPa·mm^(0.5)	0.38831 MPa·mm^(0.5)	9.2802e-003 MPa·mm^(0.5)	1.2998e-006 mJ/mm^2

Table 11 Fracture Analysis on Ball made by Stainless Steel

Object Name	SIFS (K1)	SIFS (K2)	SIFS (K3)	J-Integral (JINT)
Minimum	-12.314 MPa·mm^(0.5)	-1.8316 MPa·mm^(0.5)	1.0372 MPa·mm^(0.5)	1.0606e-004 mJ/mm^2
Maximum	-4.2198 MPa·mm^(0.5)	2.37 MPa·mm^(0.5)	9.0791 MPa·mm^(0.5)	7.1606e-004 mJ/mm^2

Table 12 Fracture Analysis on Ball made by Structural Steel

Object Name	SIFS (K1)	SIFS (K2)	SIFS (K3)	J-Integral (JINT)
Minimum	-11.772 MPa·mm^(0.5)	-1.7164 MPa·mm^(0.5)	0.97033 MPa·mm^(0.5)	9.5894e-005 mJ/mm^2
Maximum	-4.122 MPa·mm^(0.5)	2.2114 MPa·mm^(0.5)	8.8498 MPa·mm^(0.5)	6.3468e-004 mJ/mm^2

Table 13 Fracture Analysis on Ball made by Steel EN42

Object Name	SIFS (K1)	SIFS (K2)	SIFS (K3)	J-Integral (JINT)
Minimum	-11.332 MPa·mm^(0.5)	-1.7753 MPa·mm^(0.5)	0.99616 MPa·mm^(0.5)	9.106e-005 mJ/mm^2
Maximum	-3.9143 MPa·mm^(0.5)	2.1705 MPa·mm^(0.5)	9.0449 MPa·mm^(0.5)	6.1493e-004 mJ/mm^2

Table 14 Fracture Analysis on Ball made by Steel EN45

Object Name	*SIFS (K1)*	*SIFS (K2)*	*SIFS (K3)*	*J-Integral (JINT)*
Minimum	-11.633 MPa·mm^(0.5)	-1.7358 MPa·mm^(0.5)	0.97933 MPa·mm^(0.5)	9.1355e-005 mJ/mm^2
Maximum	-4.0436 MPa·mm^(0.5)	2.1967 MPa·mm^(0.5)	9.0138 MPa·mm^(0.5)	6.1165e-004 mJ/mm^2

7. Fracture Analysis

Flaws and defects in structures and components sometimes lead to disastrous results even though the stress level in a "perfect" structure may indicate a satisfactory design. The study of crack initiations and growth is a complicated topic which involves physics, chemistry, mechanics etc. The engineering field of fracture mechanics was established to develop a basic understanding of such crack propagation problems. For example, engineers usually want to know the conditions under which an existing crack will continue to grow.

8. Result analysis

The structural analysis represents the comparison of total deformation in ball of bearing made by various materials i.e. stainless steel, structural steel, steel EN42 and steel EN45

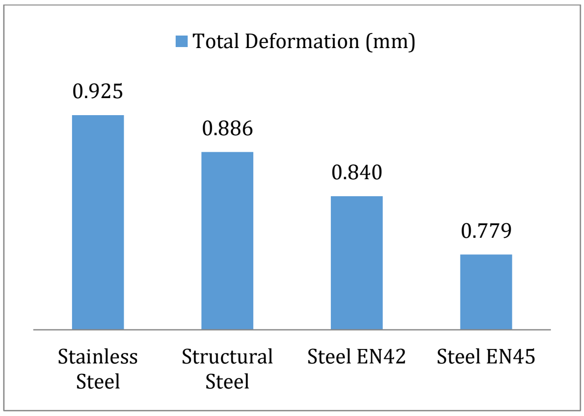

Fig. 10 Total deformations in Structural Analysis

Thus, the total deformation occur minimum, when the ball of deep groove bearing is made by Steel EN45 material.

The vibration analysis has been done on six modes which represent various deformation profiles on various frequencies. The vibration analysis shows that the minimum deformation at maximum frequency occurs in ball of Steel EN45 material.

Conclusion

1. Structural Analysis shows that minimum deformation occurs in bearing ball, when the ball is made by Steel EN45 material. It shows that Steel EN45 ball material have 15.8% less deformation as compared to the existing ball material.
2. Vibration Analysis shows that minimum deformation occurs at maximum frequency in bearing ball, when the ball is made by Steel EN45 material. It shows that Steel EN45 ball material have 9.4% less deformation as compared to the existing ball material.
3. Fracture Analysis on the basis of SIFS-K1, SIFS-K2, SIFS-K3 and J-Integral calculation represents that minimum propagation of cracks occurs in ball made by Steel EN45 material for opening, sliding and tearing modes.
4. Life of the ball is directly proportional to the deformation occurs. The structural analysis represents the reduction in deformation is 15.8 % and due to the proportional relationship, life of the ball increased by in the same ratio.
5. Thus, on the basis of these above three methodologies the Steel EN45 material gives the optimum results for the ball fracture and failure, which shows the life improvement in terms of deformation and crack propagation

References

S. Bharath Subramaniam, R. V. M. Deva Harsha, M. Vivek, V. V. V. Durga Prasad (2016.), Thermal Analysis of Ceramic Conventional Ball Bearings, *Indian Journal of Science and Technology, September*

Mr. Mahesh Kale, Mr. P. J. Sawant (Jan 2016), Review of Vibration Studies of Deep Groove Ball Bearing Considering Single and Multiple Defects in Races, *International Journal of Advanced Research in Science, Engineering and Technology.*

Mr. Shinde S. S., Dr.Dhamejani C. L. (Sept.-2015.), Ball Bearing Analysis Of Fault Simulation Using Finite Element Method - A Review, *International Journal Of Innovations In Engineering Research And Technology [Ijiert]*

M. Chandra Sekhar Reddy (Nov 2015), Thermal Stress Analysis of A Ball Bearing By Finite Element Method, *International Journal Of Advanced Research In Engineering And Technology (Ijaret.*

Vidhyasagar R. Bajaj, B.R. Borkar (January 2015), Finite Element Analysis of Integral Shaft Bearing, *International Journal of Emerging Engineering Research and Technology.*

Arvind Singh , Veerendra Kumar (July 2014), Fatigue Analysis of Deep Groove Ball Bearing Based on ANSYS: A Review, *International Journal Of Engineering Sciences & Research Technology.*

W. Ost, Patrick de baets (2004), Failure analysis of the deep groove ball bearings of an electric motor, *International journal of Engineering Failure Analysis.*

Milan Zeljković Aleksandar Živković Ljubomir Borojev (July 1998), Ball Bearings Static Behavior And Lifetime, *International Journal of Solids and Structures.*

Viramgama Parth D (May – 1998.) Analysis of Single Row Deep Groove Ball Bearing, *International Journal of Engineering Research & Technology (IJERT)*