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DESIGN, DEVELOPMENT AND ANALYSIS OF COUPLING AND BEARING FOR THREE PHASE INDUCTION MOTOR

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ABSTRACT
Coupling and bearing are the very important components, in which coupling is used to connect two shafts while bearing is used to provide support to the rotating elements. In this paper the rigid flange coupling is designed to connect the shaft of three phase induction motor with the shaft of centrifugal pump. The shaft of motor and pump are supported by deep grove ball bearing. The analysis part of coupling and bearing is done using Ansys workbench. The static and vibrational analysis is carried out. The objective behind this paper is to develop the design of coupling and select a standard bearing which will give an increased life hour. This paper also includes the effect of the stresses and deformation in bearing when the bearing ball is made hollow.
KEYWORDS: Coupling, bearing, design of coupling, selection of bearing, Ansys workbench, static and vibrational analysis, hollow bearing balls, stresses and deformation.

Introduction:

An electromechanical device converts electrical energy into a mechanical energy. An electric motor is the best example of an electromechanical device. Three phase induction motor working on A.C. does not require any starting device or we can say that they are self starting motor. Induction motors are workhorse of the industry due to its wide range of applications. They are generally exposed to harsh industrial conditions which on prolonged exposure induce various defects in the motor. Studies have reported that majority of these defects in induction motors are caused due to damage in rolling bearings which share approximately 40% in total faults. The ball bearing defects may occur in its outer race, inner race, cage and balls. These damages also impose heavy repairing, maintenance and replacement charges. Therefore it is important to monitor, analyze and diagnose incipient bearing faults of the induction motor for its better operation.

Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. Rigid alignment must be maintained between shafts of motor and pump thus a rigid flange coupling is used to connect these shafts. These couplings are very common in the power transmission industry and are made up of two separate flanged halves that are bolted together. The halves are keyed to the shaft with tapered keys to ensure proper alignment and a tight fit. A rigid flange coupling is often employed in situations where a strong coupling is required, but little axial distance is available.

LITERATURE REVIEW

V.N. Patel, N. Tandon, R.K. Pandey [1] Theoretical and experimental vibrations of dynamically loaded deep grove ball bearing having local circular shape defects on either race are reported in this paper. In the proposed mathematical model the shaft, housing, raceways and ball masses are incorporated. Comparison and discussion is carried out of the experimental results of vibration in bearing housings. The additional displacement of the ball changes from zero to maximum when a ball approaches to the inner race defect, while it reaches to zero from its maximum value when ball reaches from the centre of the defect to the other end of the defect.

V.N. Patel, N. Tandon, R.K. Pandey [2] Focused on a dynamic model is reported herein for the study of vibrations of deep groove ball bearing having the single and multiple defects on the surface of the inner and the outer race. The mass of housing, shaft, races and balls are considered in the dynamic model. Characteristics defects frequencies and its harmonic are broadly investigated using both theoretical and experimental results are observed.

V.N. Patel, N. Tandon, R.K. Pandey [3] in this paper the experiments has been carried out using a test rig for capturing the vibration signals of test bearing. The external vibration has been imparted to the housing of the test bearing through electromechanical shaker. In envelope analysis the centre frequency has been selected using the spectral kurtosis for the **filters** length of 32 and 64 for different bandwidths. Through this study, it has been revisited and confirmed that the defect detection in envelope analysis mainly depends on the selection of centre frequency and bandwidth. The spectra of selected centre frequency with several bandwidths have been studied and compared for identification of defective frequency.

Sarabjeet Singh, Carl. Howard [4] this paper is focused on a review of literature concerned with the vibration modeling of rolling element bearings that have localized and extended defects. An overview is provided of contact fatigue, which initiates subsurface and surface fatigue, and subsequently leads to reducing the useful life of rolling element bearings. To investigate the effects on the vibration characteristics of defective rolling element bearings, a full parametric study could be conducted that could include a matrix of parameters, which can be varied. These parameters may include load (both radial and axial) on a bearing, rotational speed, clearance within a bearing, and various defect types. The types of bearing defects may range from line, to area, to extended area having different profiles of surface roughness, which can be made similar to operational defects observed in real-world applications.

C. Durvasulu Reddy, G.V. Nagamani [5] Compression coupling consists of a compressible steel sleeve which fits on to the end of shaft to be coupled. They had considered the compression coupling, deformation and stress developed in it due to force applied on it, due to rotation of shaft. In this project they have given parametric programming for structural analysis of compression coupling in Ansys, using this parametric program all couplings of similar type can be analyzed just by changing the parameter in original program.

V.G. Vijaya [6] this project deals with stress analysis of rigid flange coupling subjected to torsion using Ansys. The author concludes that, the stress obtained from Ansys software is slightly less than the theoretical calculations. The shear stress and crushing results obtained from Ansys was compared with theoretical calculations. The results obtained from Ansys matches theoretical calculations Hence the design was considered to be safe.

Shaha Rohit D, [7] Studied the rolling bearing, with outer ring fixed, is a multi body mechanical system with rolling elements that transmit motion and load from the inner raceway to the outer raceway. Modern trend of Dynamic analysis is useful in early prediction. Dynamic analysis has become a very powerful tool for the betterment of the actual performance of the system. The methodology for prediction and validation of dynamic characteristics of bearing rotor system vibration is studied. The proposed simulation method is used to determine the vibration signal response for various shaft speeds and loading condition, which is compared with experimental result. It is found simulated vibration pattern has similar characteristic compare to experimental results. The deviation in amplitude of acceleration is may be due to variation of mesh density in the region near to defect and also deviation in frequency occurs due to uncontrolled parameters during experimentation.

Xu Li-xin, Yang Yu-hu, Li Yong-gang, [8] this paper analyzed of the bearing joint has been modeled by introducing a nonlinear constraint force system, which takes into account the contact stiffness interaction between the rolling elements and the raceways. The proposed model has been applied in the dynamic simulations of a planar slider–crank mechanism with a deep groove ball bearing joint. A general methodology for dynamic modeling and simulation of planar multimode systems containing the deep groove ball bearings with clearance was presented and discussed throughout this work. The bearing joint used is modeled by introducing a nonlinear constraint force system, which takes into account the contact stiffness interaction between the rolling elements and the raceways.

Attel Manjunath, D V Girish [9] analyzed the performance of polymer ball bearings made with Polyacetal (POM) material. Ball bearings are widely used in industry from home appliances to aerospace industry. Proper functioning of these machine elements is extremely important in order to prevent catastrophic damages. It is therefore, important to monitor the condition of the bearings and to know the severity of the defects before they cause serious catastrophic damages. Hence, the study of vibrations generated by these defects plays an important role in quality inspection as well as for condition monitoring of the ball bearing machine element. This paper describes the vibration analysis technique to detect the defects in the ball bearing. The Fast Fourier Transform (FFT) detected the frequencies of damage present during the vibration analysis of a ball bearing.

Viramgama Parth D [10] focused on increased usage and the increased sophistication mechanical design came to necessity to predict their endurance capability. In this project an effort has been put to analyze the ball bearing using finite element analysis the stress level or displacement behavior of ball bearing. The main target is to find the most influencing parameters for radial stiffness of the bearing under an axial load. The life of bearing we get is in the multiple. So we can conclude that our bearing is safe against the radial and axial load which is applied at static and dynamic condition.

RESEARCH GAP:

After the literature review it was found that the static analysis of coupling using Ansys workbench was carried out but the study and effect of vibration on coupling was not found. In case of ball bearings the vibrational analysis was carried out theoretically while there was no review carried out using Ansys workbench. Also none of these studies provide a picture of the effect on bearing when the bearing ball is made hollow.

PROBLEM DEFINITION

The research gap shows us that there is an need to carry out static and vibrational study of coupling and bearing for three phase induction motor with the development and analysis on Ansys workbench as well as it is needed to find the effects on stresses and deformation when the bearing ball is made hollow.

METHODOLOGY:

Design of Coupling
⇩
Selection of Bearing
⇩
Modeling of Coupling and Bearing in Ansys
⇩
Analysis Using Ansys
⇩
Results and Conclusion

- Design of coupling:-

A coupling is needed to design for connecting a shaft of a three phase induction motor with the shaft of pump. The power of motor used is 100 KW and speed is 720 RPM. The coupling material to be used is Stainless Steel.

Table 1 : Dimensions of coupling:

Dimension	Formule	Value (IN MM)
Outside Diameter Of Hub	2d	120
Length Of Hub	1.5d	90
PCD Of Bolts	3d	180
Thickness Of Flanges	0.5d	30
Thickness Of Protecting Rim (t)	0.25d	15
Diameter Of Spigot And Recess	1.5d	90
Outside Diameter Of Flange	4d+2t	270

Properties of Stainless Steel (From Ansys Workbench)

Properties of Outline Row 4: Stainless Steel

	A	B	C
1	Property	Value	Unit
2	Density	7750	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	1.7E-05	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
7	Derive from	Young...	
8	Young's Modulus	1.93E+05	MPa
9	Poisson's Ratio	0.31	
10	Bulk Modulus	1.693E+11	Pa
11	Shear Modulus	7.3664E+10	Pa
12	Tensile Yield Strength	207	MPa
13	Compressive Yield Strength	207	MPa
14	Tensile Ultimate Strength	586	MPa
15	Compressive Ultimate Strength	0	Pa

- Selection of bearing: -

A bearing is to be selected to support the pump shaft and motor shaft, which will sustain for more than 70000 hours. The bearing required is of 60mm bore diameter with radial load of 4000N acting on it. The material to be used for bearing is titanium alloy. Calculated dynamic load carrying capacity= 570000 .The ball bearings available for the shaft diameter of 60mm i.e. inner race of 60mm with dynamic load carrying capacity above the calculated load carrying capacity are:

Table 2: Dimension Of Bearings

Outer Race	Ball Diameter	Width
130	25	31
150	35	35

From the two bearings the second bearing is selected for safer design.

Properties of titanium alloy (From Ansys Workbench)

Properties of Outline Row 7: Titanium Alloy

	A	B	C
1	Property	Value	Unit
2	Density	4620	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	9.4E-06	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
7	Derive from	Young...	
8	Young's Modulus	96000	MPa
9	Poisson's Ratio	0.36	
10	Bulk Modulus	1.1429E+11	Pa
11	Shear Modulus	3.5294E+10	Pa
12	Tensile Yield Strength	930	MPa
13	Compressive Yield Strength	930	MPa
14	Tensile Ultimate Strength	1070	MPa
15	Compressive Ultimate Strength	0	MPa

- Modeling of coupling and bearing:-

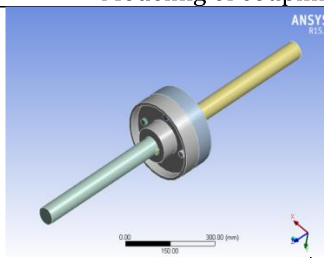


Fig 1: Coupling

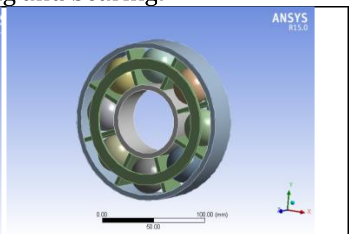


Fig 2: Bearing

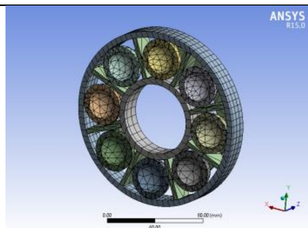


Fig 3: Bearing with hollow ball

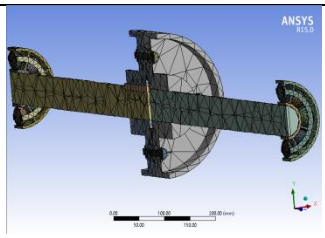
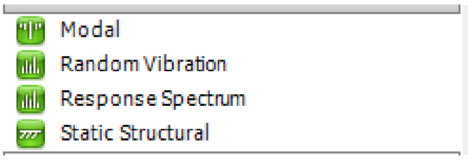


Fig 4: Coupling and bearing assembly

- Analysis using Ansys:-

The static and vibrational analysis of all the components are carried out in Ansys using following tools:-



RESULT

Table 3: Results of Bearing

Analysis:	Equivalent Stress Allowable Value: Less Than 550	Shear Stress Allowable Value: Less Than 300
Static Structural	505.7	207.4
Response Spectrum	143.5	61.3
Random Vibration	158.9	50.4

Table 4: Results of Bearing with Hollow Balls

Analysis:	Equivalent Stress Allowable Value: Less Than 550	Shear Stress Allowable Value: Less Than 300
Static structural	385.2	201.3
Response Spectrum	93.5	32.9
Random Vibration	129.5	63.3

Table 5: Results of Coupling

Analysis:	Equivalent Stress Allowable Value: Less Than 175	Shear Stress Allowable Value: Less Than 100
Static Structural	102.5	26.1
Response Spectrum	72.0	10.8
Random Vibration	105.7	13.9

Table 6: Results of Coupling And Bearing Assembly

Analysis:	**Equivalent Stress** Allowable Value: Less Than 175	**Shear Stress** Allowable Value: Less Than 100
Static Structural	130.2	66.3
Response Spectrum	99.9	28.6
Random Vibration	167.5	43.4

CONCLUSION

The calculated equivalent stress and shear stress values are within the allowable stresses. Therefore the design is considered to be safe but the results obtained by Ansys software cannot be considered as valid unless the experimental results are equal to the results obtained by Ansys software.

By the comparison of stresses induced in bearing with solid ball and bearing with hollow ball we can say that by the use of bearing with hollow balls the equivalent stresses induced will be reduced by 25 % and shear stresses induced will be reduced by 12 %. Therefore we can conclude that bearing with hollow balls are more economical than bearing with solid balls.

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