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STRUCTURAL ANALYSIS OF RIGID FLANGE COUPLING BY FINITE ELEMENT METHOD

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ABSTRACT

A coupling is a device which is used to connect two shafts for power transmission. A shaft coupling consist a rigid or flexible joint. Rigid joint holds both the shaft with perfectly alignment whereas flexible joint allows angular displacement between the shaft axis. This project shows the structural analysis of flange coupling using ANSYS workbench 16.0. Grey cast Iron and Structural steel is used as flange coupling material. The main objective of this paper is to verify the safe design of flange coupling to transmit power of 37.5 kW by comparing theoretical and analytical result both. CATIA V5R20 software is used to create the model of flange coupling.

KEYWORDS: Flange Coupling, Shear stress, Grey cast iron, ANSYS 16.0, Catia V5R20

I. INTRODUCTION

A power transmission shaft is generally provided with standard length of 8m. Longer shafts are not convenient in use and transportation. Therefore shaft coupling is used to connect two separate shafts. It also reduces the bending and vibration produced is the shaft system. It also reduces the transmission of shock loads from one shaft to another shaft.

Shaft couplings can be broadly classify into two groups-

1) RIGID COUPLING: When two shafts are aligned perfectly, it is known as rigid coupling. It does not permit any misalignment to the shaft axis. Types of rigid coupling are-

a) Sleeve or muff coupling
b) Split muff or clamp coupling
c) Flange coupling

2) FLEXIBLE COUPLING: - When a coupling system provides lateral and angular misalignment to the shafts, it is known as flexible coupling. It permits certain degree of displacement to the shaft axis. Types of flexible coupling are-

a) Bushed pin type coupling
b) Universal coupling
c) Oldham coupling

FLANGE COUPLING: - Flange coupling is generally used for heavy load application. It consists of two separate flanges mounted on each end of the shaft. Out of which one flange has extended or projected face and other flange has a corresponding recess. It allows bringing the shafts perfectly co-axial. The flanges are joined by nuts and bolts. Number of bolts depends upon the power transmitted and diameter of shafts used. There are some types of flange coupling are-

a) Unprotected flange coupling
b) Protected flange coupling
c) Marine type flange coupling

LITERATURE REVIEW

Chandra Sekhar Katta, Kamana Srinivasa Rao (1) this paper shows that the structural analysis of flange coupling subjected to static load. An overview of shaft coupling and application of different composite materials can be obtained from this paper. Result comparison shows that grey cast iron is better than composite material (Aluminum, silicon, carbide) for flange material. . Solid works and ANSYS software is used for modeling and analysis work respectively.

Maram Venkata Sunil Reddy, C.Raghunatha Reddy (2) this paper shows that the metallographic analysis, hardness measurement and fracture analysis of a universal joint. Spectroscopic analysis has also carried out by

finite element method. Four different materials has been compared through ANSYS software which shows that grey cast iron is a preferable material than stainless steel, cast iron and chilled cast iron.
Mr. S.B. Jaiswal, Prof. M.D. Pasarkar (3) in this paper author has worked on high water transmission coupling. He suggested that flange is a critical part of coupling always requires attention during operation. Author recommends alloy steel material for flange to be weld for better weld ability through its analysis work. ANSYS workbench 11.0 had used for analysis work.
Vinodh Kumar S, Sampath V and Bhaskar P (7) this paper deals with optimization of design of automobile drive shaft (propeller shaft) assembly by using the composite materials. For this purpose material such as E-glass/Epoxy and Carbon Epoxy is used. Composite material results in less weight, high strength, high strength to weight ratio, and large stiffness. Therefore use of composite material is increasing in engineering application.
Prof. Salunkhe R.T., Mr. Patil N.T., (8) this paper shows the analysis of propeller shaft made of medium carbon steel using ANSYS software. Propeller shaft is designed to transmit torque of 15000 Nm at 30 rpm in a pump motor of sugar industry named as PSP Pump Pvt. LTD. Prpopeller shaft coupling includes many parts such as solid shaft, hollow sh aft, splines universal coupling, flanges and required no. of bolts and nuts. This project includes 2D, 3D design in CATIA and Finite element analysis using ANSYS software 13.0.

II. MATERIALS AND METHODS

Material is taken structural steel for shaft, key and bolt while grey cast iron as flange material.

S.N	PROPERTIES	STRUCTURL STEEL	GREY CAST IRON
1	DENSITY	7.85E-06 (kg/mm^3)	7.2E-06 (kg/mm^3)
2	YOUNG MODULUS	2E+05 (MPa)	1.1E+05 (MPa)
3	POISSON RATIO	0.3	0.28
4	TENSILE YIELD STRENGTH	250 (MPa)	0 (MPa)
5	COMPRESSIVE YIELD STRENGTH	250 (MPa)	0 (MPa)
6	ULTIMATE TENSILE STRENGTH	460 (MPa)	240 (MPa)
7	ULTIMATE COMPRESSIVE STRENGTH	0 (MPa)	820 (MPa)
8	FACTOR OF SAFETY	2.5	2.5

Mechanical coupling have a principal use in the connection of rotating shafts for the transfer of rotary motion and torque. As with all mechanical devices, a coupling must match its intended purpose and application parameter. Following parameters are used for this current study- [4]
Power transmitted by input shaft = 37.5 kW
Speed of input shaft = 180rpm
Service factor for the application = 1.5
Calculated parameters taken from book are -
Diameter of shafts, d = 60 mm
Outside diameter of hub, d_h = 2d = 120 mm
Length of the hub, l_h = 1.5d = 90 mm
Pitch circle diameter of the bolts, D = 3d = 180 mm
Thickness of flanges, t = 0.5d = 30 mm
Thickness of protecting rim, t_1 = 0.25d = 15 mm
Diameter of spigot and recess, d_r = 1.5d = 90 mm
Outside diameter of flange, D_0 = 4d+2t_1 = 270 mm
Calculation of allowable stresses for different parts-
Allowable Shear Stress for shaft, key, and bolt
$\tau_{as} = \tau_{ys} / FOS = 0.5\sigma_{yt} / FOS = 0.5 \times 250 / 2.5 = 50$ MPa
Allowable Shear Stress for flange,
$\tau_{ac} = \tau_{uc} / FOS = 0.5\sigma_{ut} / FOS = 0.5 \times 240 / 2.5 = 48$ MPa

MODELLING

In present work, models of different parts of flange coupling are prepared in CATIA V5R20 software. CATIA is one of the important CAD/CAE/CAM software. It provides various unique tools like simulation, structure design, healing assistant, composite design etc to the designer so that they can cross the boundaries of innovation in their respective fields.

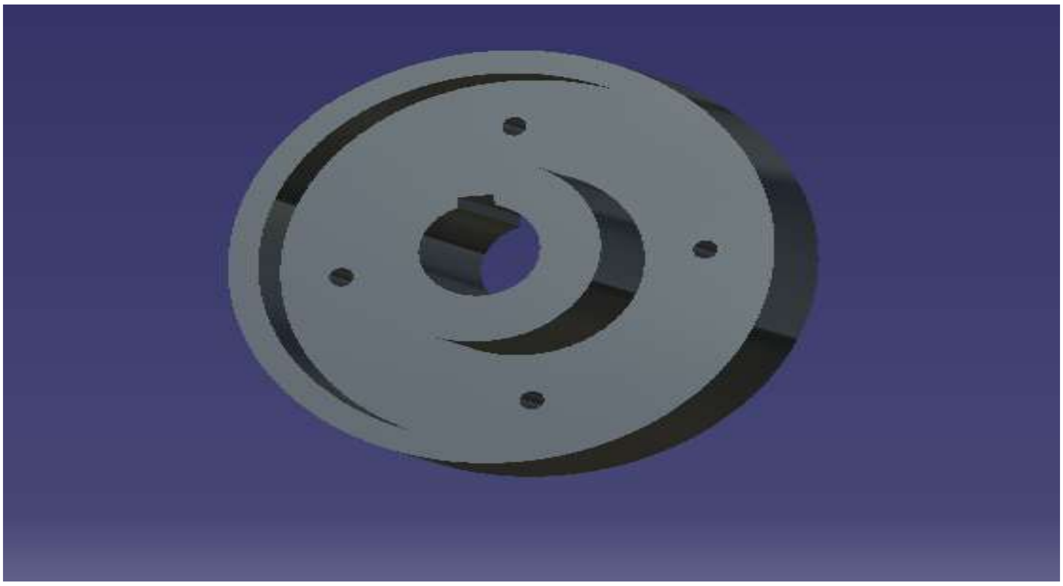

Fig 1 Right Flange with spigot

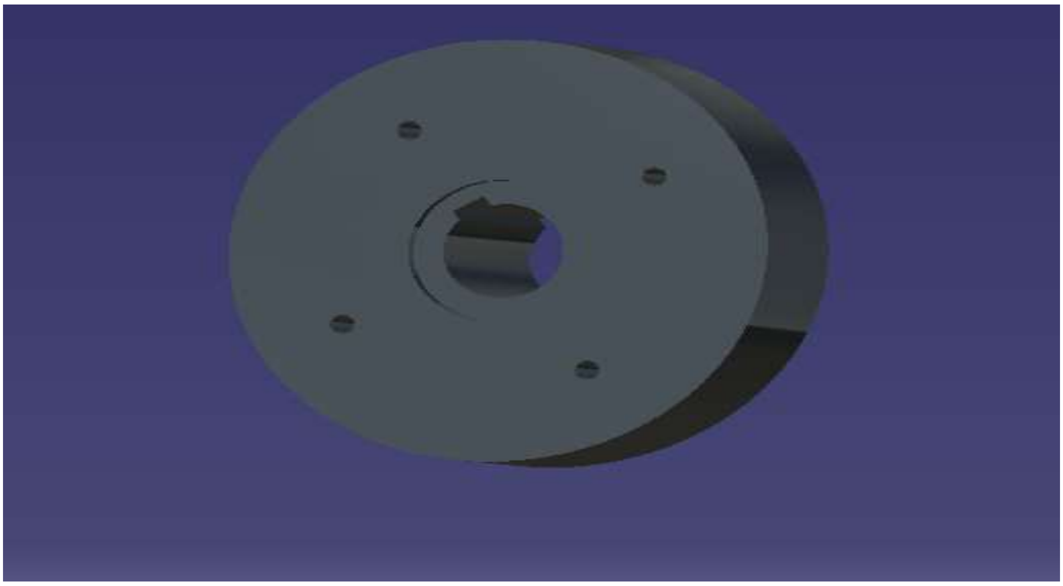

Fig 2 Left Flange with recesses

ANALYSIS

ANSYS is leading software for analysis work developed by ANSYS Inc. Some of its important analysis is structural, thermal, CFD, CFX, hydrodynamic response, turbo machinery fluid flow, magneto static etc. ANSYS workbench 16.0 has been used for the analysis work in this study.

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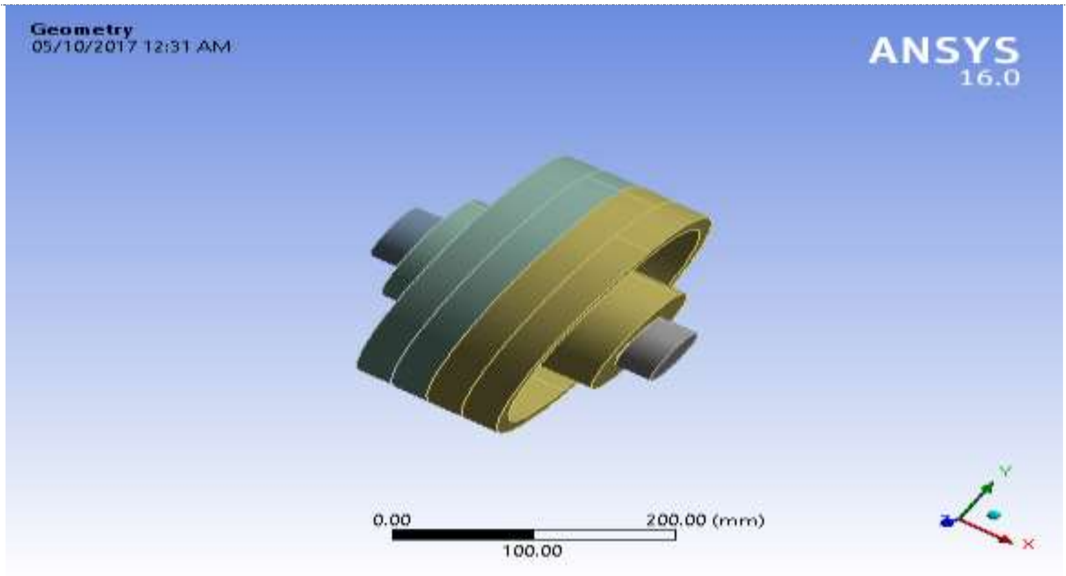

Fig 3 Solid Model imported in ANSYS 16.0

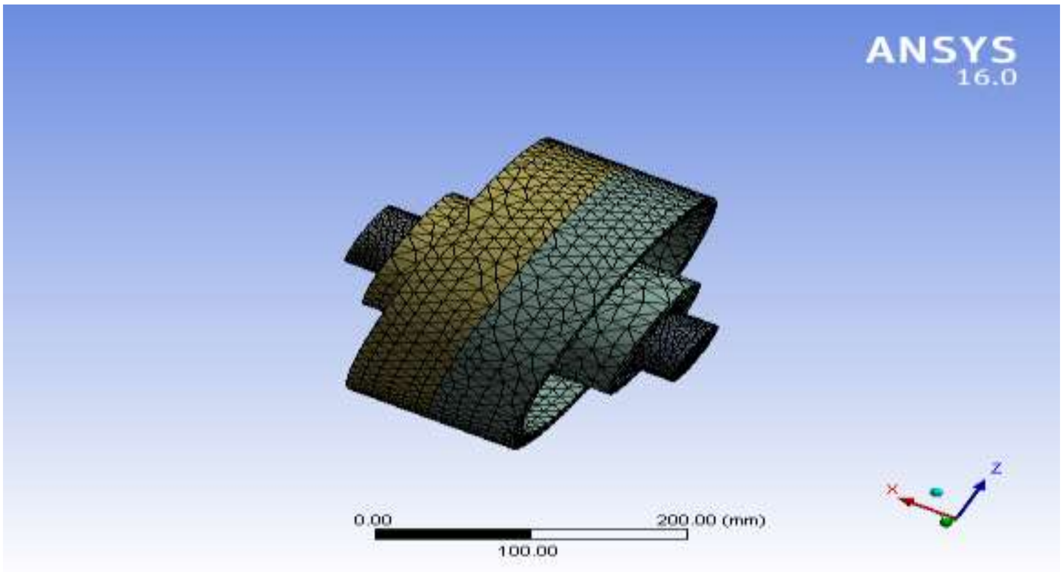

Fig 4 Mesh Model of Flange Coupling

BOUNDARY CONDITION

Here in this research structural analysis is performed to find out the suitable design for given flange coupling model. Present coupling model is designed to transmit the power of 37.5 kW and/or 2984.155 Nm torque at 180 rpm. Following are the boundary condition used for this analysis-

1.	Torque	2984.155 Nm
2.	Speed of shaft	180 rpm
3.	Cylindrical support	At both shaft ends
4.	NODES	104471
5.	ELEMENTS	46644

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III. RESULTS AND DISCUSSION

Figure 5 to 8 shows the Maximum shear stree obtained for different parts of protected rigid flange coupling through ANSYS software 16.0

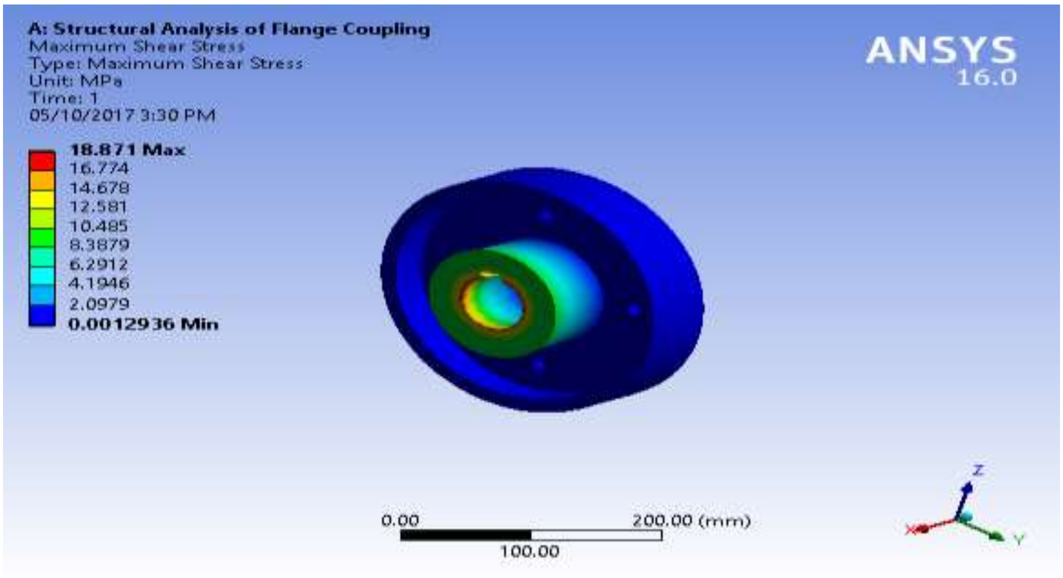

Fig 5 Max. Shear Stress for flange

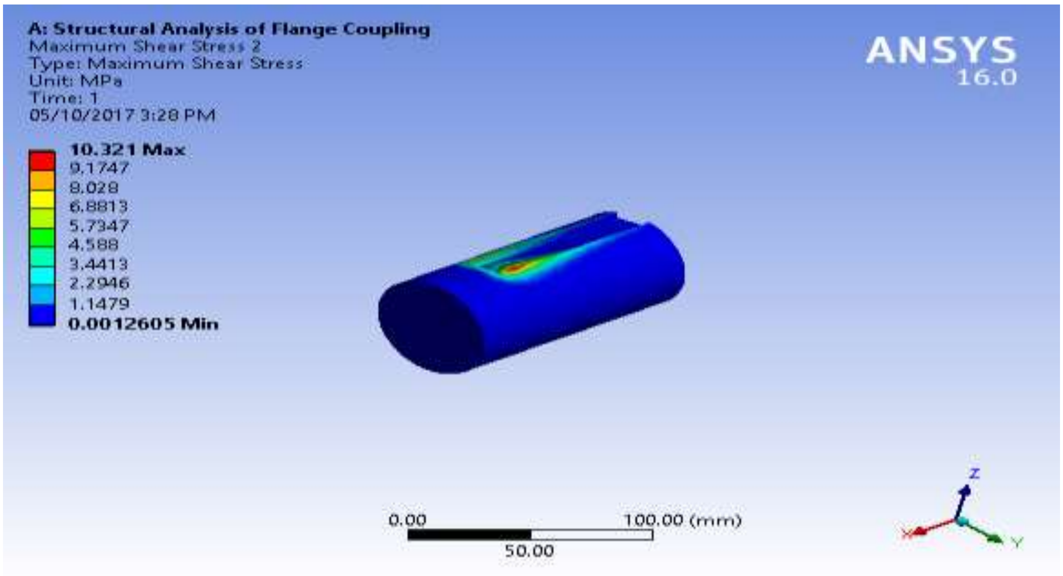

Fig 6 Max. Shear Stress for shaft

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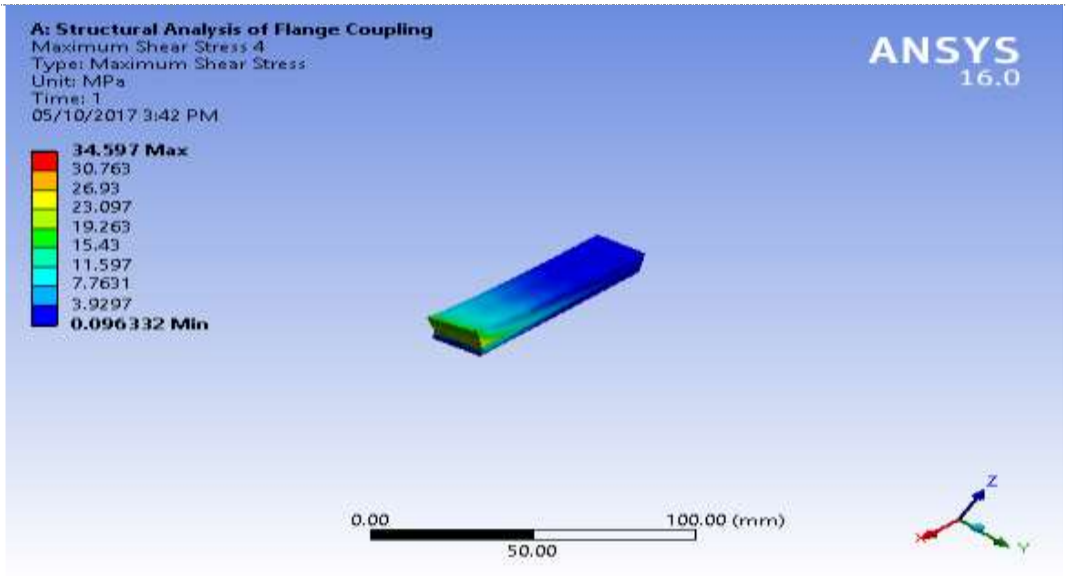

Fig 7 Max. Shear Stress for key

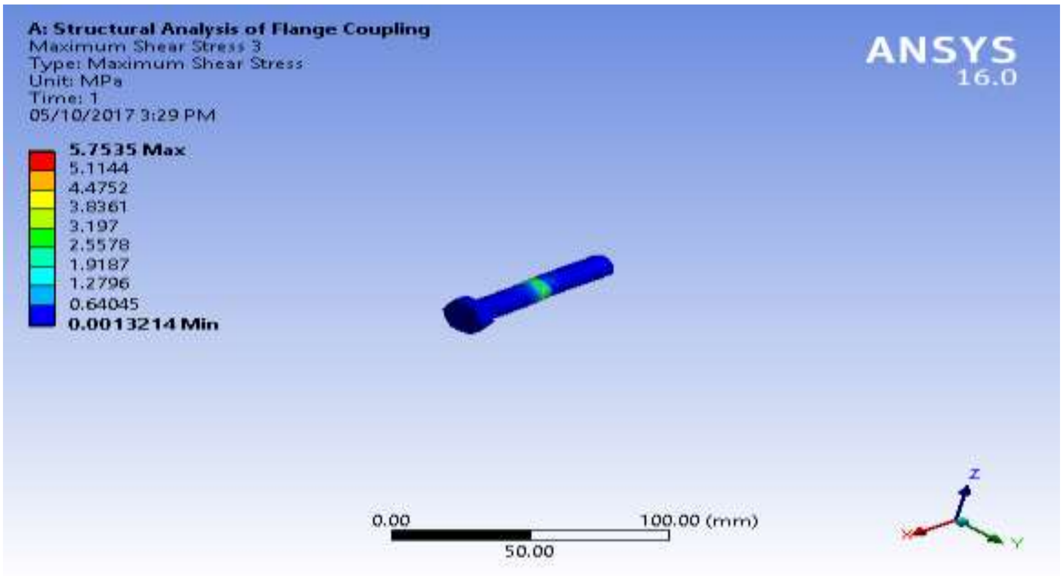

Fig 8 Max. Shear Stress for bolt

Comparison of results between theoretical and analytical solution for different parts of coupling is given below-

S.N.	COMPONENT	Theoretical Solution	Analytical Solution
1.	Allowable Shear stress in shaft	5o MPa	10.32 (MPa)
2.	Allowable Shear stress in key		34.59 (MPa)
3.	Allowable Shear stress in bolt		5.753 (MPa)
4.	Allowable Shear stress in flange	48 MPa	18.87 (MPa)

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IV. CONCLUSION

Results obtained from the ANSYS software are compared with theoretical solution of the problem. From the above table it is seen that various stress induced in different parts of the flange coupling are less than the theoretical value. Therefore, in this work, design of flange coupling is in safe mode. Stress in bolt will be modified later.

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