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DESIGN ANALYSIS OF RIGID FLANGE COUPLING BY USINGCAE AND CAD

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ABSTRACT

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Coupling is a passive element which helps in transmits the power unlike the active elements which produces or absorbs the power. This paper deals with rigid flange coupling. Rigid flange coupling are designed for heavy torques or industrial equipment. This project deals with shear stress analysis of rigid flange couplings subjected to torsional moment or torque by comparing the theoretical and analytical values and proceeds to find out the optimized value of grade of materials for the rigid flange Coupling (carbon steel for shaft, keys and bolts, and grey cast iron for flange) on the criteria of appropriate dimensions for the components and appropriate value of factor of safety. This has been done by making manual calculations for various grades and structural analysis with software ANSYS (FEM based).

Keywords: CATIA V5, ANSYS Workbench, Rigid Flange Coupling, Carbon Steel And Grey Cast Iron Materials.

I. INTRODUCTION

Coupling :

Coupling is a mechanical device used to connect the shafts together for the purpose of transmitting high power and torque. Generally, couplings are used for connecting the shafts unit that are manufactured separately. Such as motor and generator shafts; electric motor and centrifugal pump shafts etc. [2]

Types of coupling :

There are three types of coupling:-

1) Rigid coupling
2) Flexible coupling
3) Universal coupling

Rigid flange coupling:

These forms of couplings offer a solid association between 2 shafts, high preciseness and force, however while not placement absorption capabilities; it permits no movement between the 2 shafts and that they need lubrication in persistently. they cannot absorb vibrations, each shafts ought to be absolutely aligned to confirm an honest performance and avoid damping transmission and doable breaks within the installation.[5] Rigid Coupling is employed solely whenever the placement between instrumentation shafts is incredibly tiny or no placement is gift within the system. This type of coupling principally preferred for vertical applications like vertical pump. In those cases, rigid couplings square measure a really effective means that of connecting machine shafts. However the rigid couplings accustomed connect 2 shafts of 2 rotating instrumentation which permit transmission power and force from one machine to a different machine. That can also be used if machines that have shafts of various sizes. Rigid couplings square measure used once precise shaft alignment is needed (shafts square measure already aligned); any shaft placement can have an impact on the coupling's overall performance moreover as its life, as a end result of inflexible couplings do not have the flexibility to compensate misalignments.[2]

The rigid flange couplings have the following merits:

(i) It has high torque transmitting capacity.
(ii) It is easy to assemble and dismantle.

(iii) It has simple construction.
(iv) It is easy to design and manufacture.

Proportions of Rigid Coupling

(i) dh = outside dia of hub.

dh = 2d

(ii) lh = length of hub or effective length of key

lh = 1.5 d

(iii) D = pitch circle diameter of bolts

D = 3d

(iv) t = thickness of flanges.

t = 0.5 d

(v) t1 = thickness of protecting rim .

t1 = 0.25 d

(vi) dr = dia of spigot and recess .

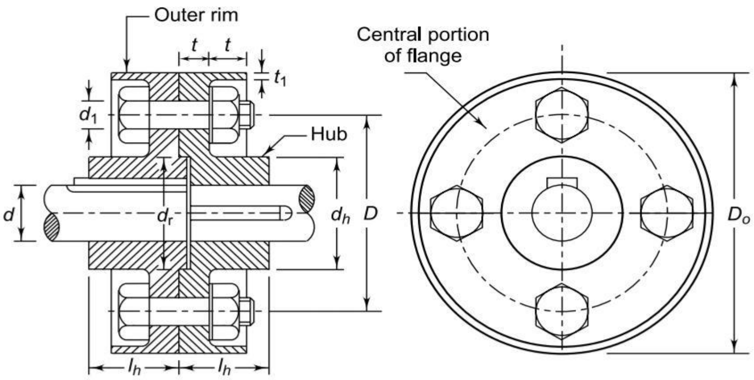

Figure 1: Sectional view of rigid flange coupling.

dr = 1.5 d

(vii) D0 = outside dia of flange.

D0 = (4d + 2t1)

II. LITERATURE REVIEW

1. Prof. K.K. Jain, Asst. Prof. Prateekyadav-August 2017-This task indicates the structural evaluation of flange coupling the use of ANSYS workbench 16.0. Grey cast Iron and Structural metal is used as flange coupling material. The major goal of this paper is to secure the design of flange coupling to transmit strength & evaluating theoretical and analytical end result both. CATIA V5R21 software program is used to create the model of flange coupling. (5)

2. Praveen Kumar Sonwane, Asst. Prof. Prateekyadav August 2017-This task suggests the structural evaluation of flange coupling through the use of ANSYS software program model 16 For this evaluation a theoretical answer is taken from "DESIGN OF MACHINE ELEMENTS through VB BHANDARI" third version web page no 366.(6)

3. Dr. Santosh 2018-The impact on modal parameters of rigid flange coupling having fixed support at the two ends is studied with the aid of various the diameter, material and power to the shaft. Analytical evaluation has been carried out referring the wellknown method of layout and vibration. (7)

4. Somvirsinghbharatbhushan may 2017-In the work design of flange coupling is made by means of the usage of CATIA V5 design software program and static structural analysis is carried out in ANSYS workbench software program and the stress and deformation used to be calculated. The Finite Element Analysis effects are considerable to improve the component design at the early creating stage. The predominant goal of the work is

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to minimize the weight of the flange coupling without affecting the overall performance so as to decrease the price of the material. (8)

5. Ankitbasnetoctober 2015-The current study of this paper is to minimize the maximum shear stress through deciding on a appropriate material for flange coupling. For this purpose, modelling of the rigid-flange coupling is carried out in SOLIDWORKS and analysed in ANSYS Workbench. (4)

6. v.g.vijayadecember2013-This assignment offers with stress evaluation of rigid flange couplings subjected to torsion using ANSYS. The concept associated to the title will be studied from 'FUNDAMENTALS OF MACHINE DESIGN by T.J.PRABHU, page no- 12.3Analytical answer will be obtained. To achieve computer answer ANSYS will be used. A comparison of outcomes acquired from two & three will be presented. (11)

III. OBJECTIVE

The main objective of this paper is to design and find out the safe grade for the various material components of the rigid flange coupling for a given standard motor to transmit 37.5KW power at 180rpm which ensures high safety and lies within the range of minimal cost. Stress analysis has been carried out using FEM. The 3D CAD Model has been prepared using CATIA V5 R21 software and the stress analysis has been done in ANSYS workbench. The manual calculations or theoretical values have been compared with the Analytical values (Numerical method –FEM). Finally the maximum shear stress values have been obtained and on the basis of these values grades for the different materials chosen.

IV. METHODOLOGY

Step 1 Design of Coupling Components: A rigid flange coupling is needed to be designed for the powertransmissionof37.5kwinastandardmotorwithRPM=180.Designtorque is 1.5 times of the rated torque

Step 2 Calculations with differentmaterial grades: Calculations have been performed by taking different grades of material.

Step 3 Construction of graphs: To compare different values of shear stress calculated of different material grade with the permissible shear stress values, different graphs has been plotted which highlights the difference between the two and exhibits in selection of the appropriate materialgrade.

Step 4 Modelling of Coupling Components using CATIAV5:3d modelling of rigid flange coupling has been done in CATIA v5 r21.

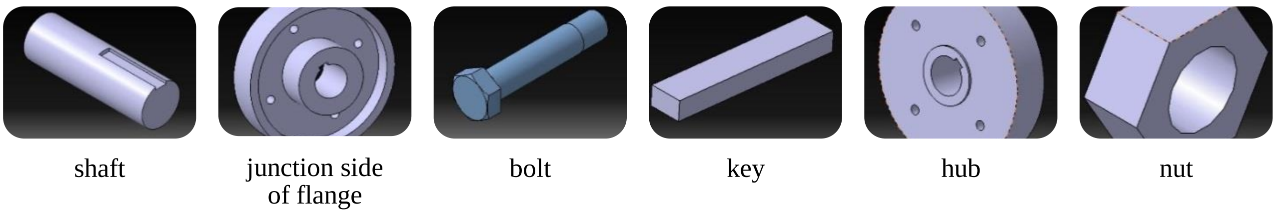

Figure 2: parts of rigid flange coupling

Step 5 Analysis using ANSYS: The static analysis of all the components are carried out in ANSYS using following tools: Static structural

Step 6 Selection of appropriate grade of material: Keeping in mind, the shear stress values, power transmitted, optimal costs, and high safety the right grade has been selected.

Step 7 Results and conclusion: Analytical values of ANSYS and theoretical values from calculations are compared to obtain the result.

V. DESIGN AND CALCULATIONS

It is required to design a rigid type of flange coupling to connect two design shafts. Considering a standard motor with Power = 37.5 kW and RPM =180. Assuming design torque to be 1.5 times the rated torque.

Step 1 Selection of material:

- The shafts are subjected to torsional shear stress. On the basis of strength, plain carbon steel is used for the shaft. The FOS for the shafts is assumed to be 2.5.

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- The keys and bolts are subjected to shear and compressive stresses. On the basis of strength criterion, plain carbon steel is selected for the keys and the bolts. It is assumed that the compressive yield strength is 150 % of the tensile yield strength. The FOS for the keys and the bolts is taken as 2.5.
- Flanges have complex shape and the easiest method to make the flanges is casting. Grey cast iron is selected as the material for the flanges from manufacturing considerations. It is assumed that ultimate shear strength is one half of the ultimate tensile strength. The FOS for the flanges is assumed as 2.5

Step 2 Permissible stresses:

(a) For shaft-Ductile material is generally used more preferably carbon steels Factor of safety (FOS) is taken 2.5 Following table depicts the values of maximum permissible shear stress values (τ_{max}) for the corresponding values of yield stress(σ_{yt}) for the grades of carbon steels taken for the experiment [9]:

Table 1. Determining the value of shear stress for shaft

Serial no.	Carbon steel grades [15]	Yield stress values (σ_{yt}) In N/mm^2	$\tau = \frac{\sigma yt}{2 * FOS}$
1	C07	196	39.2
2	C10	206	41.2
3	C15	235	47
4	C25	275	55
5	C35	304	60.8
6	C40	324	64.8
7	C45	353	70.6
8	C50	373	74.6
9	C60	412	82.4
10	C65	422	84.4

(b) For flange- Grey cast iron is generally used. Factor of safety (FOS) is taken 2.5.Following table depicts the values of maximum permissible shear stress values (τ_{max}) for the corresponding values of ultimate stresses(b_{ut}) for the grades of Grey cast iron taken for the experiment [9]:

Table 2. Determining the value of shear stress for flange

Serial no.	Grey cast iron grades [16]	Yield stress values (σ_{ut}) In N/mm^2	$\tau = \frac{\sigma ut}{2 * FOS}$
1	FG150	150	30
2	FG200	200	40
3	FG220	220	44
4	FG260	260	52
5	FG300	300	60
6	FG350	350	70
7	FG400	400	80

(c) For keys and bolts-Ductile material is generally used more preferably carbon steelsFactor of safety (FOS) is taken 2.5 Following table depicts the values of permissible shear stress (τ_{max}) and permissible compressive stress(σc)for the corresponding values of yield stress(σ_{yt}) for the grades of carbon steels taken for the experiment [9]:

Table 3. Determining the shear & compressive stresses for keys and bolts

Serial no.	Carbon steel grades [15]	Yield stress values (σ_{yt}) In N/mm²	$\tau = \frac{\sigma yt}{2 * FOS}$ In N/mm²	$\sigma c = \frac{1.5 * \sigma yt}{FOS}$ In N/mm²
1	C07	196	39.2	117.6
2	C10	206	41.2	123.6
3	C15	235	47	141
4	C25	275	55	165
5	C35	304	60.8	182.4
6	C40	324	64.8	194.4
7	C45	353	70.6	211.8
8	C50	373	74.6	223.8
9	C60	412	82.4	253.2
10	C65	422	84.4	253.2

Step 3 Diameter of shafts- Taking into consideration the service factor of 1.5, the design torque is given by,

$$T_d = \frac{60 \times 10^6 (kW)}{2\pi n} \times (1.5) \qquad [9]$$

$$= \frac{60 \times 10^6 (37.5)(1.5)}{2\pi (180)}$$

= 2984155.18 N – mm

Different values of diameter are calculated by taking different values of τ of different values of carbon steel using the formula below:

$$\tau = \frac{16T_d}{\pi d^3} \qquad [9]$$

Considering the maximum permissible stress value and nominal costs, the material for shaft has been chosen C35 for which diameter of shaft is 64 mm. Diameter of shaft chosen for the design of coupling is “d”= 64mm

Step: 4 Dimensions of flange-

Table 4. Design specification of coupling

Part specification	Dimensions in mm.
Hub diameter (d_h) =2d = 2(64)	128
Hub length (l_h)= 1.5d=1.5(64)	96
Bolt circle diameter (D) = 3d=3(64)	192
Flange thickness (t)=0.5d	32
Web thickness(t_1)=0.25d	16
Diameter of spigot and recess (d_r) =1.5d	96
Outside diameter of flange (D_o) =(4d+2t_1)	288

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The thickness of recess is assumed as 5 mm. The hub is treated as a hollow shaft subjected to torsional moment.

$$J = \frac{\pi(d_h^4 - d^4)}{32}$$

$$J = \frac{\pi(128^4 - 64^4)}{2} [17]$$

$$= 24706489.94 \text{ mm}^4$$

$$r = \frac{d_h}{2}$$

$$r = \frac{128}{2}$$

$$=64 \text{ mm}$$

Torsional shear stress in the hub is given by (τ_{hub}) :

$$\tau = \frac{T_d * r}{J}$$

$$= \frac{2985155.18 * 64}{24706489.94}$$

$$= 7.73 \text{ N/mm}^2$$

The shear stress in the flange at the junction of the hub is determined by (τ_{junc}):

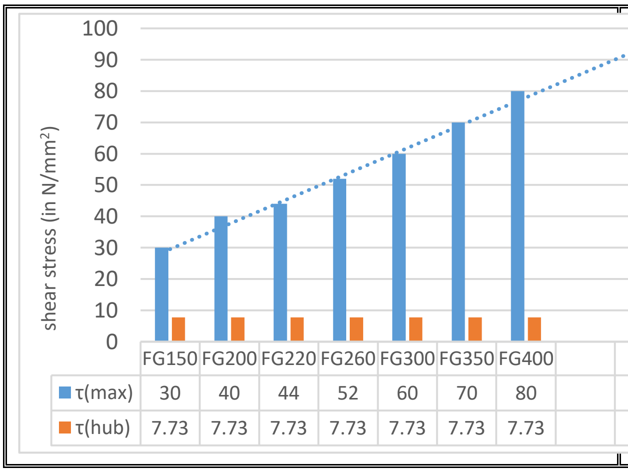
$$\tau_{junc} = \frac{2T_d * r}{\pi d_h^2 * t} [17]$$

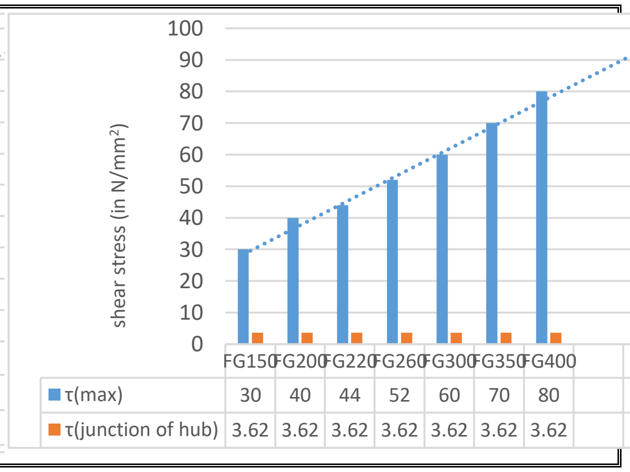
$$= \frac{2 * 2984155.18}{\pi * 128^2 * 32} [17]$$

$$=3.62 \text{ N/mm}^2$$

VI. GRAPHS FOR COMPARISION

Comparison of values of stresses for different grades of grey cast iron and carbon steel with the corresponding values of normal shear stress for the various coupling components





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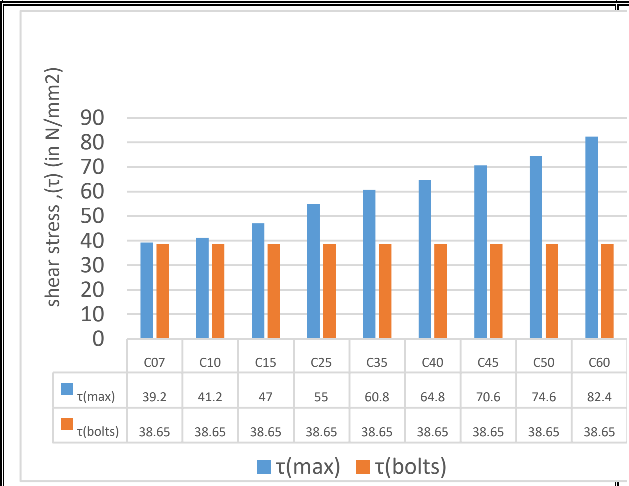
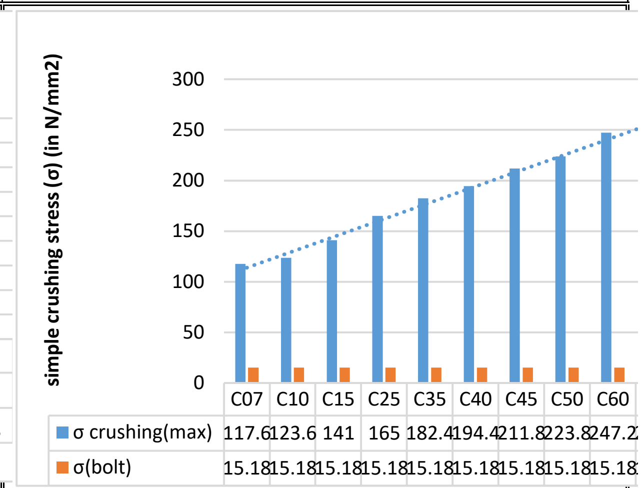
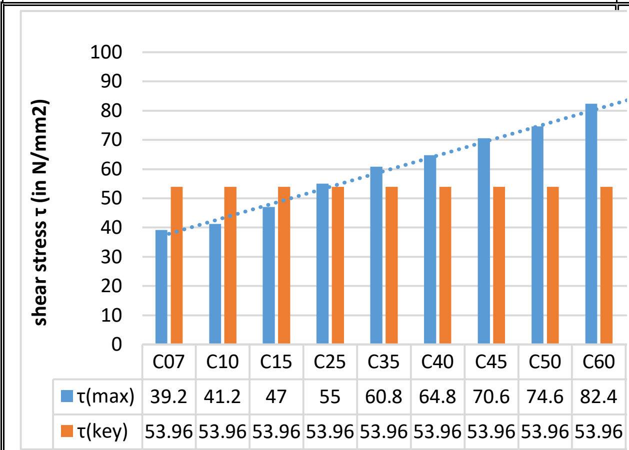
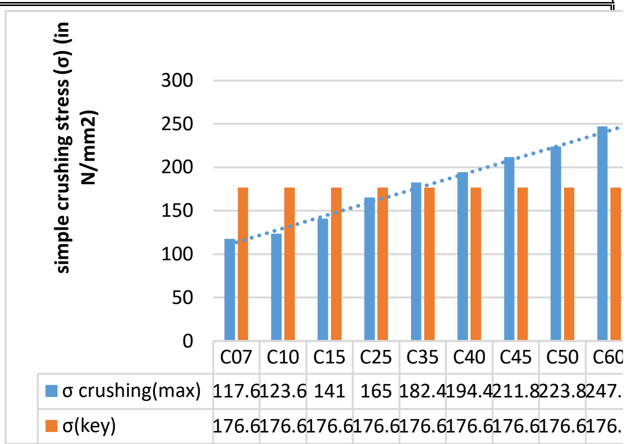
maximum shear stress ,τ(max) with torsional shear stress for hub, τ(hub)	maximum shear stress ,τ(max) with shear stress in the flange at the junction of the hub, τ(junc)





maximum shear stress ,τ(max) with shear stress in the bolts, τ_{bolt}	crushing stress ,σc(max) with simple crushing stress in the bolts, σbolt





maximum shear stress ,τ(max) for different grades of plain carbon steels with shear stress in the keys, τkey	maximum crushing stress ,σc(max) simple crushing stress in the keys, σkey

Figure 3: Graphs for comparision

VII. CAD & CAE

CAD: Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD package is employed to extend the productivity of the designer, improve the standard of style, improve communications through documentation, and to form a info for producing. Designs created through CAD package are useful in protective merchandise and inventions once utilized in patent applications. CAD output is commonly within the kind of electronic files for print, machining, or alternative producing operations. The term CAD (for computer aided design and drafting) is also used.

CAE: Computer-aided engineering refers to the utilization of code to simulate the results of various conditions on the planning of a product or structure victimisation simulated hundreds and constraints. CAE tools area unit usually accustomed analyze and optimize the styles created inside CAD code. Major classes of CAE tools embrace finite part analysis (FEA), machine fluid dynamics (CFD) and multi-disciplinary style optimisation (MDO). These tools area unit accustomed perform style iterations victimisation virtual prototypes (sometimes referred to as "digital twins") before building physical prototypes. This protects corporations vital time and cash in development whereas usually yielding higher quality styles that meet multi-disciplinary and multi-functional necessities. pc assisted engineering primarily uses pc assisted style (CAD) code, that area unit generally referred to as CAE tools. CAE tools area unit being employed, for instance, to analyse the hardiness and performance of elements and assemblies. The term encompasses simulation, validation, and optimization of product and producing tools within the future, CAE systems are going to be major suppliers of data to assist support style groups in higher cognitive process. Computer-aided engineering is employed in several fields like automotive, aviation, space, and construction industries.

VIII. DESIGNING AND DRAFTING OF RIGID FLANGE COUPLING IN CATIAV5 R21

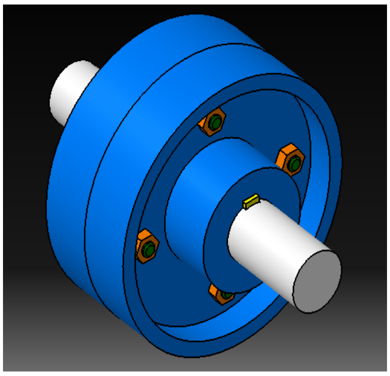


Fig a: Rigid Flange Coupling

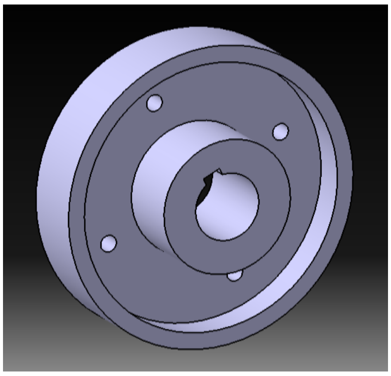


Fig b: Flange

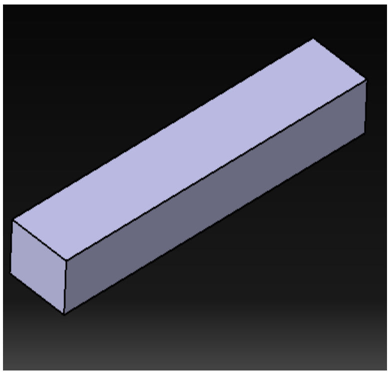


Fig c: Key

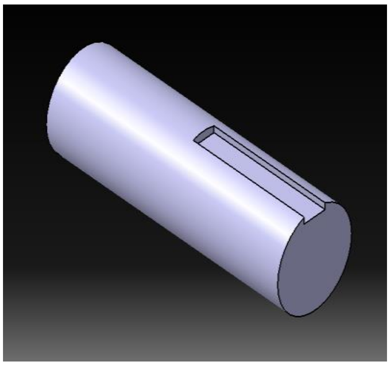


Fig d: Shaft

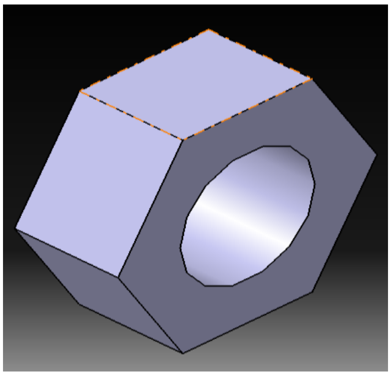


Fig e: Nut

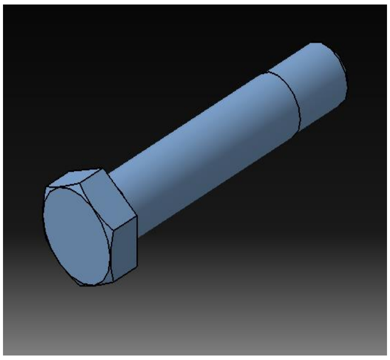


Fig f: Bolt

Figure 4: Various components of the rigid flange coupling have been designed in CATIAV5 sofware

IX. DRAFTED FIGURES OF THE RIGID FLANGE COUPLING

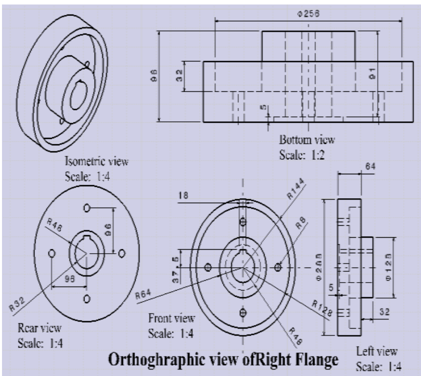


Fig a: Right Flange

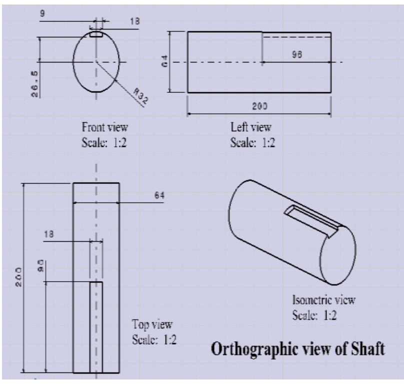


Fig b: Shaft

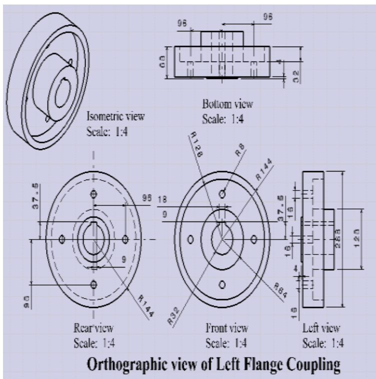


Fig c: Left Flange

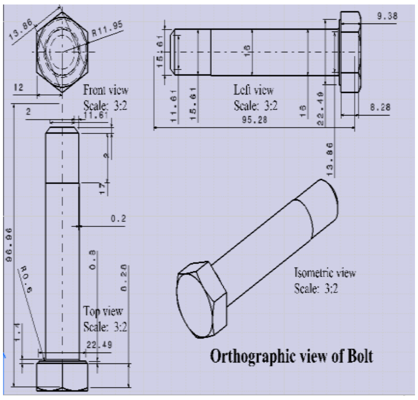


Fig d: Bolt

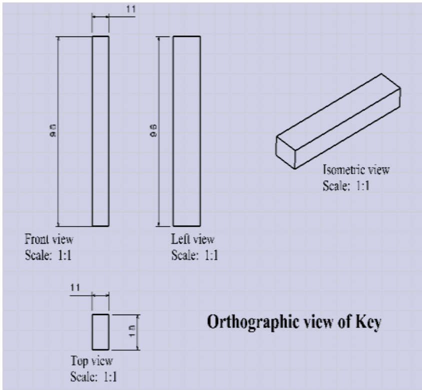


Fig e: Key

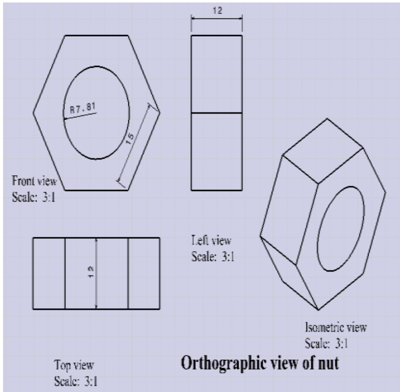


Fig f: Nut

Figure 5: Drafted figures for various parts of coupling

X. ANALYSIS OF RIGID FLANGE COUPLING IN ANSYS 18.10 (FEM BASIS)

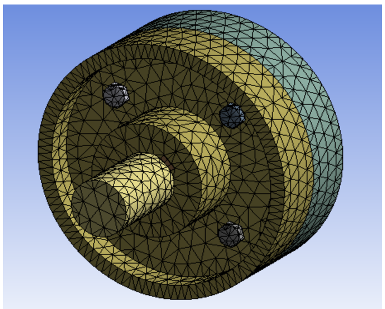


Fig a: Fine Meshing Of Coupling

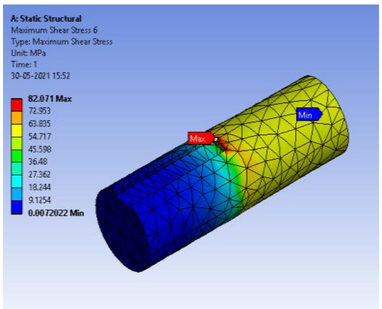


Fig b: Max Shear Stress In Shaft

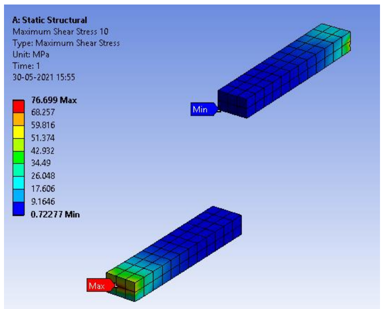


Fig c: Max Shear Stress In Key

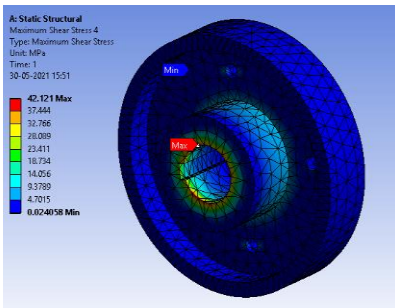


Fig d: Max Shear Stress In Right Flange

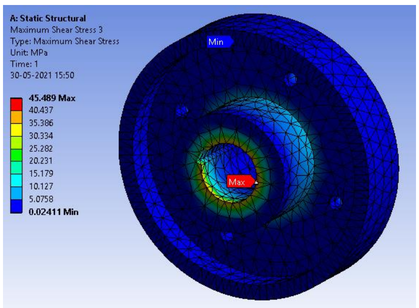


Fig e: Max Shear Stress In Left Flange

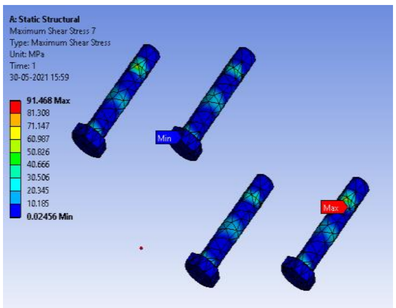


Fig f: Max Shear Stress In Bolt

Figure 6: Figures shows the maximum shear stress obtained for different parts of protected rigid flange coupling through ANSYS software 18.1

XI. SELECTING GRADES FOR COUPLING MATERIALS

After the manual stress analysis coupling is subjected to the fem analysis in ANSYS18.1 The table below shows the maximum shear stress values for each component on a rigid flange coupling under working condition. The analytical values are obtained using ANSYS workbench. Stress comparison between theoretical and analytical values for obtaining the max shear stress and on the basis of max stress generated in the parts, the grades are chosen to strengthen the coupling.

Table 5. Selection of grades

parts	materials	Selection of grades	Permissible shear stresses FOS=2.5	Theoretical solution(in N/mm^2)	Analytical solution (N/mm^2)	Max shear stress generated in parts
shaft	Carbon steel	C60	(412/2.5)*.5=82.5	60.8	82	82
flange	Grey cast iron	Fg260	(260/2.5)*.5=52	7.73	45.489	45.5
bolt	Carbon steel	C60	(412/2.5)*.5=82.5	38.65	91.468	91.5
key	Carbon steel	C60	(412/2.5)*.5=82.5	53.96	76.699	77

Table 6. Selected grades

Parts	Materials	Grades
Shaft	Carbon Steel	C60
Key	Carbon Steel	C60
Bolt	Carbon Steel	C60
Flange	Grey Cast Iron	FG260

XII. BOUNDARY CONDITIONS

This 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 at 180 rpm. Following are the boundary condition used for this analysis-

Table 7. Boundary conditions

Moment applied	2984155 N-mm
Support	One end is fixed
Nodes	42295
Elements	22565

XIII. RESULTS AND CONCLUSION

The table below shows the maximum shear stress values for each component on a rigid flange coupling under working condition. The analytical values are obtained using ANSYS Workbench

Table 8. Max stresses generated in parts.

Materials for different parts of coupling	Theoretical solution (in N/mm^2) (manually calculated values)	Analytical solution (N/mm^2)(computationally calculated values)	Maximum stress generated in parts
Carbon steel (ductile material) for shaft c60	60.8	82	82
Grey cast iron (brittle material) for flange fg200	7.73	45.489	45.5
Carbon steel (ductile material for bolt c60	38.65	91.468	91.5

Carbon steel (ductile material for key c60	53.96	76.699	77

Results obtained from the ANSYS software are compared with theoretical solution of the task. From the above table it is seen that various stresses induced in different parts of the flange coupling are more than the theoretical value. Therefore, in this work, design of flange coupling is safe for the given torque and the required power output if c60 for ductile and fg260 for brittle are chosen. The optimized grade for each component has been selected.

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