Failure analysis and cost analysis of C.I. Flange Coupling

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***Abstract*— A Coupling is a device which transmits power between two shafts rotating at designed speed. It is the important part of any power transmission system and may continue long time if design and cost analysis is maintained properly and the product can be chosen by the users. The present study of this paper is to reduce the cost of production by selecting proper designing process. The stress analysis that acting on the bolts, keys, hub and flange by making it uniform strengthens. The stress in the threaded part of the bolt will be higher than that in the shank. Hence a greater portion of the bolt will be absorbed at the region of the threaded part which may fracture the threaded portion because of its small length. An axial hole is drilled at the centre of the bolt through the head as far as thread portion such that the stress in the bolt is uniformly distributed along the length of the bolt. This consideration may also be taken in designing hub and flange. A special care should be taken during operation of key way in the hub portion to avoid stress concentration in keys and hub. In this paper there are explanation of detailed designing process for effective cost analysis.**

Keywords*— Shearing, Crushing, Uniform Strength, Cost analysis.

INTRODUCTION

A coupling is a device that serves to connect the ends of adjacent shafts which are co-axial or non-co-axial. Couplings are basically of two types: 1. Rigid couplings 2. Flexible couplings. Rigid coupling is also classified into - Sleeve or muff coupling, Clamp or split-muff or compression coupling and Flange coupling. Similarly Flexible coupling also classified as - Bushed pin type coupling, Universal coupling and Oldham coupling. The strength of coupling mainly depends on designing process consider, material and workmanship. The cost of coupling is also main considerable factor in the competitive market. In this paper the designing and cost calculations are explained in details.

Objectives of shaft couplings used in machinery are -

- To provide for the connection of shafts of units that are manufactured separately such as a motor and generator and to provide for disconnection for repairs or alternations.
- To provide for misalignment of the shafts or to introduce mechanical flexibility.
- To reduce the transmission of shock loads from one shaft to another.
- To introduce protection against overloads.
- It should have no projecting parts.

Rigid couplings are used when precise shaft alignment is required; any shaft misalignment will affect the coupling's performance as well as its life span, because rigid couplings do not have the ability to compensate for misalignment. Due to this, their application is limited, and they're typically used in applications involving vertical drivers. Requirements of good coupling are - Easy to connect or disconnect the coupling, this does allow some misalignment between the two adjacent shaft rotation axes, no projecting parts, goal should be to minimize the remaining misalignment in running operation so as to maximize power transmission and to maximize machine runtime. It is recommended to use manufacturer's alignment target values to set up the machine train to a defined non-zero alignment, due to the fact that later, when the machine is at operation temperature, the alignment condition is perfect.

DESIGN AND CALCULATIONS

Problem statement:
Design and cost estimation of a C.I. unprotective type flange coupling to transmit 15 kW at 900 r.p.m. from an electric motor to a compressor. The service factor may be assumed as 1.35. The permissible stresses are:
1) Shear stress for shaft, bolt & key = 40 Mpa
2) Crushing stress for bolt & key = 80 Mpa
3) Shear stress for cast iron = 8 Mpa

Input data for CI flange coupling –

1. Power – 15kW
2. RPM - 900
3. Shear stress for shaft, bolt and key =40Mpa
4. Crushing stress for bolt and key =80Mpa
5. Shear stress for cast iron =8Mpa
6. Service factor = 1.35

STEP - 1

Design of Shaft:

$P = \frac{2\pi N T_m x100}{60}$

$T_m = \frac{15x60x1000}{2x\pi x900}$ =159.15 N-m

T_{max} =1.35x159.15=215 N-m

$\frac{\pi}{16} * d^3 * \tau = 215 * 10^3$ $d = \sqrt[3]{\frac{16 \, x \, 215x \, 10^3}{\pi \, x \, 40}}$

=30.13 =35mm (according to market availability)

STEP - 2

Design of Hub:

Outer diameter of hub = D=70mm
Inner diameter of hub = d =35mm

Length of the hub = L =52.5mm

Maximum shear stress developed in the outmost layer of the Hub material = τ_h

Torque (T_{max}) = $\frac{\pi}{16}\left(\frac{D^4-d^4}{d}\right)*\tau_h$

$\tau_h = \frac{16*215*10^3*70}{(70^4-35^4)*\pi}$

=3.40 Mpa

STEP - 3

Design of Key:

Width of the key = w = $\frac{d}{4} = \frac{35}{4}$ = = 10mm

Thickness of key = t = $\frac{d}{6} = \frac{35}{6}$ = 8mm

Length of the key = l_k = 52.5mm

1. Consider shearing failure :

Shearing resisting area = $w*l_k$

$T_{max} = w*l_k*\tau*\frac{d}{2}$

$\tau = \frac{215*10^3*2}{10*52.5*35}$ = 23.40 Mpa

2. Consider Crushing Failure

Crushing Resisting Area

= t / 2 * l_k

$T_{max} = \frac{t}{2}*l_k*\sigma_c*\frac{d}{2}$

$\sigma_c = \frac{215*1000*4}{52.5*8*5}$ = 58MPa

STEP - 4

Design of Flange:

t_f=17.5mm

Consider shearing failure at the junction of Hub.

Shearing resisting area = $\pi*d*t_f$

$T_{max}=\pi*d*t_f*\tau*\frac{d}{2}$

$\tau_H = \frac{215*1000*2}{\pi*35*17.5*35}$ = 6.38 MPa.

STEP - 5

Design of bolt:

No. of bolt (n) = 4 / 150 * d * 3 4 / 150 * 35 + 3 10^3

= 3.93 ≈ 4

$T_{max} = \frac{\pi}{4}*d_b^{\,2}*4*\tau*\frac{D1}{2}$

$d_b = \sqrt{\frac{215*8*10^3}{\pi*4*40*105}}$

= 5.70 mm

= 8 mm (according to market availability)

Material Cost of Flange & Hub:

Total volume of flanges and hubs

= $[\frac{\pi}{4}\{(70^2-35^2)*52.5+(140^2-70^2)*17.5\}]$

= 3.53×10^5 mm^3

For two flanges and hubs

= $3.53*10^5*2$

= $7.06*10^5$ mm^3

Density of CI = 7.8gm/cc

Weight of two flanges and hubs

= $7.06*10^5/10^3*7.8/1000$

= 5.5 kg

One kg of cast iron price is Rs. 78

Then, 5.5 kg of cast iron price is = 5.5*78

= Rs.430/-

Material Cost of Bolts:

Volume of hexagonal bolt = $2.59*(8)^2*8$, (where, a = 8)

= $1.32*10^3$ mm^3

Length of the bolt = (17.5+17.5) +8

= 43 ≈ 50mm

Volume of 4 bolts = $4*(1.32*10^3+2.51*10^3)$

= 15320 mm^3

Total weight of bolts = 15320/1000*7.85/1000

= 0.120kg

Material cost for bolts = 50*0.120

Where, 1kg = Rs.50

= Rs.6/-

Material Cost of Key:

Volume of the key = 10*8*60

= 4800 mm^3

For two keys,

Volume = 4800*2 = 9600 mm^3

Weight of the key = 9600/1000*7.85/1000

= 0.075kg

Cost of the key = 50 * 0.075

= 4/- [Where, 1kg = Rs.50]

So, total material cost for flange coupling = 430+6+4

= Rs.440/-

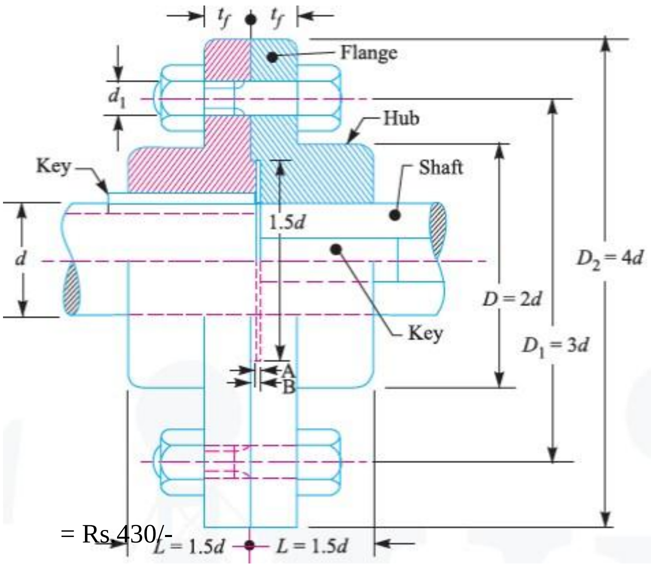

FIGURE I. SECTIONAL VIEW OF FLANGED COUPLING TABLE I. DETAILS OF STRESS & COST ANALYSIS

Stress and Material cost summary				
Sl. No.	**Component & materials**	**Input stress in MPa**	**Designed stress in MPa**	**Cost per unit (Rs.)**
1	Shaft M.S.	Shear stress 40	Shear stress 25.54	
2	Hub C.I.	Shear stress 8	Shear stress 3.40	430/-
3	Flange C.I.	Shear stress 8	Shear stress 6.38	
4	Bolt M.S.	Shear stress 40	Shear stress 20.37	4 * 1.5/-
5	Key	Shear stress 40	Shear stress 23.40	4/-
	M.S.	Crushing stress 80	Crushing stress 58	
Total Cost				**440/-**

CONCLUSION

From the design calculations of flange coupling it is concluded that all dimensions of different parts of coupling are safe to transmit input power. The cost of the coupling is reasonable in competitive market. For future work, in the analysis process computerized fuzzy logic techniques will be utilized to reduce the error of design calculation and cost calculation.

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