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Design and Failure Analysis of Bibby Coupling

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Abstract - *A coupling can be defined as a mechanical device that permanently joins two rotating shafts to each other. The most common application of coupling is joining of shafts of two separately built or purchased units so that a new machine can be formed. Bibby couplings consist of 2 radially slotted hubs that mesh with a serpentine strip of spring steel (grid) which provides a good torsional flexibility and resilience; therefore, this coupling is still one of the most sought-after flexible couplings for heavy shock applications. The present study of the paper is to design the coupling based on the rated power and also to check the given coupling for failure with the help of Computer Aided Analysis Software. Mathematical calculations and Computer Aided Analysis are performed on the individual components of the coupling assembly, which not only helps us to identify the most stressed component in the overall assembly but also to ensure whether the coupling is safe for the industrial use.*

Key Words: **Coupling, Grid Spring, Hub, Housing, Stress, Strain**

1. INTRODUCTION

Bibby coupling is a sought of flexible couplings which are generally used for heavy shock applications. The Coupling consists of two flanges or hubs specifically mounted on the drive and the driven shafts respectively. These hubs contain axial grooves cut on their circumference. The two couplings are joined or held together by means of a specially designed grid spring. The total assembly is enclosed in a casing or shell filled with grease for low speed applications or, in high speed application with high viscosity oil. **[7]**

Fig -1: Bibby coupling

The specially designed spring is wound up through the grooves forming a series of resilient bridges throughout the periphery of the coupling. The grooves are tapered up at the edges (see photo) in order to provide extra flexible spans to the spring at normal loads and tends to support the spring at the sides whenever overloading occurs. The stiffness of the spring depends on its unsupported length of each of its flexible span. The unsupported length tends to vary with the loads producing a varying stiffness for the coupling based on the loading. This action tends to produce a detuning action altering the torsional vibration frequency of the system that prevents the build-up of resonance. **[8]**

2. WORKING MECHANISM

The specially designed spring is wound up through the grooves forming a series of resilient bridges throughout the periphery of the coupling. The grooves are tapered up at the edges (see photo) in order to provide extra flexible spans to the spring at normal loads and tends to support the spring at the sides whenever overloading occurs. The stiffness of the spring depends on its unsupported length of each of its flexible span. The unsupported length tends to vary with the loads producing a varying stiffness for the coupling based on the loading. This action tends to produce a detuning action altering the torsional vibration frequency of the system that prevents the build-up of resonance **[8]**

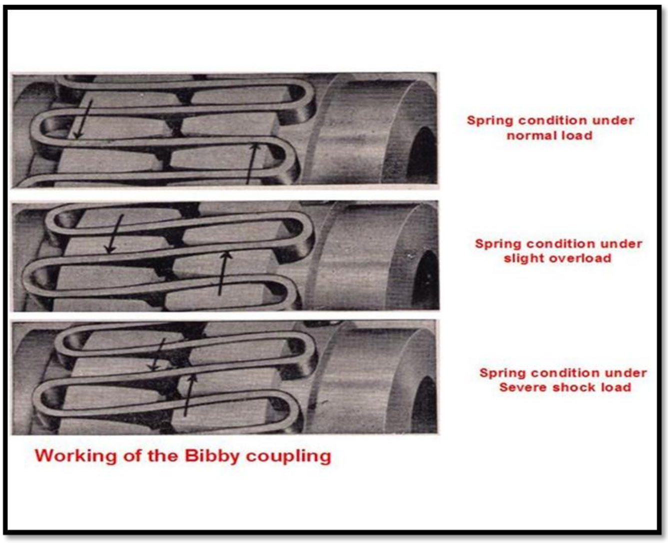


Fig -2: Working Mechanism

3. DESIGN METHODOLOGY

Given: Power = 10 HP = 7.46KW

Service factor = 1.5

Design power (P_d) = 7.46 ×1.5

P_d = 11.19 KW

N = 48.33 rpm

$$P_d \text{ at 100 rpm} = \frac{11.19 \times 100}{48.33}$$

P_d = 23.15

Therefore, selecting LGF-295 grid coupling (Referring LGF catalogue) **[6]**

From catalogue we got the standard dimensions of our coupling **[6]**

d = 104mm

D = 155mm

D_2 = 295mm

L = 102mm

A. Design of shaft [4]

$$\text{Twisting moment } (M_t) = \frac{P_d \times 60}{2\pi N}$$

$$= \frac{11.19 \times 10^3 \times 60}{2\pi \times 48.33}$$

$$\mathbf{M_t = 2210.97 \times 10^3 \text{ N-mm}}$$

Shaft material C45
σ_{yt} = 380 N/mm² **[5]**

$$[\tau] = \frac{0.5 \times [\sigma_{yt}]}{FOS}$$

We take factor of safety as (FOS) = 3

$$[\tau] = \frac{0.5 \times 380}{3}$$

$$\mathbf{[\tau] = 63.33 \text{ N/mm}^2}$$

since we have diameter given of shaft in catalogue, we check shaft for shear failure.

$$\tau = \frac{16 \times M_t}{\pi d^3}$$

$$\tau = \frac{16 \times 2210.97 \times 10^3}{\pi \times 104^3}$$

$$\mathbf{\tau = 10.01 \text{ N/mm}^2 < [\tau]}$$

Hence the shaft is safe in design.

B. Checking hub for shear failure (at the junction of spring/slot) [3]

Shear area = 14×4.15 mm
Material = Structural Steel
σ_{yt} = 250 MPa
FOS = 4

$$[\tau] = \frac{0.5 \times \sigma_{yt}}{FOS}$$

$$[\tau] = \frac{0.5 \times 250}{4}$$

[τ] = 31.25 N/mm² (Permissible shear stress)

Now, Torque = 2210.97 N-m

Radial distance of slot from shaft axes(R) = 88 mm = 0.088 m

$$\text{Total Shear force} = \frac{M_t}{R}$$

$$= \frac{2210.97}{0.088}$$

F = 25340.9 N

Shear Force on hub section between two consecutive slots (F_P) = $\frac{F}{N_{slots}}$

Where N_{slots} = No. of slots

$$F_P = \frac{25340.9}{38}$$

F_P = 666.86 N

$$\text{Shear stress}(\tau) = \frac{F_P}{Area}$$

$$\tau = \frac{667}{14 \times 4.15}$$

$$\mathbf{\tau = 11.48 \text{ N/mm}^2 < [\tau]}$$

Hence the hub is safe in design

C. Checking Grid Spring for failure [1]

Shear area (A) = 11×6.91 mm
Material = SAE 9255
σ_{yt} =486 MPa **[5]**
FOS = 3
Radial distance of grid from shaft axis (R) =88 mm

$$[\tau] = \frac{0.5 \times [\sigma_{yt}]}{FOS}$$

$$[\tau] = \frac{0.5 \times 486}{4}$$

$[\tau]$ = 81 N/mm² (Permissible shear stress)

Now, Shear resistance of one coil = $2A[\tau]$

Shear resistance of N coils = $2A[\tau]N_{coil}$

Resisting Torque $[M_t] = 2A[\tau]N_{coi}R$

Where, N_{coil} = No. of coils in spring

$$[M_t] = 2\times11\times6.91\times81\times19\times88$$
$$[M_t] = 20588.37\times10^3 \text{ N-mm}$$

But, applied torque = 2210.97×10³ N-mm < $[M_t]$

Hence the grid spring is safe

D. Checking Key for failure [3]

For shaft diameter (d) = 104 mm,
Flat key dimension = 28×16×10 mm **[5]**
Length of key = 102 mm **[5]**

The key is subjected to shear and compression stress

Material = C45
σ_{yt} =400 MPa
FOS = 2

$$[\tau] = \frac{0.5 \times \sigma_{yt}}{FOS}$$

$$[\tau] = \frac{0.5 \times 400}{2}$$

$[\tau]$ = 100 N/mm² (Permissible shear stress)

$$[\sigma_c] = \frac{1.5 \times \sigma_{yt}}{FOS}$$

$$[\sigma_c] = \frac{1.5 \times 400}{2}$$

$[\sigma_c]$ = 300 N/mm² (Permissible compressive test)

Now, $\tau = \frac{2\times M_t}{d\times h\times L}$

$$\tau = \frac{2\times2210.97\times10^3}{104\times16\times102}$$

τ = 26.05 N/mm² < $[\tau]$

Hence key is safe in shear

$$\sigma_c = \frac{4 \times M_t}{d\times h\times L}$$

$$\sigma_c = \frac{4\times2210.97\times10^3}{104\times16\times102}$$

σ_c = 52.11 N/mm² < $[\sigma_c]$

Hence key is safe is compression.

E. Checking bolt for failure [3]

Material C45

Bolt diameter $(d_1)^2 = \frac{8\times M_t}{\pi D_1 N\tau}$ where $D_1 = 2.25\times d$

$D_1 = 2.25\times104$
D_1 = 234mm

$$d_1^2 = \frac{8\times2210.97\times10^3}{\pi\times234\times4\times100}$$

d_1 = 7.75mm or 8mm

Therefore, taking M8 bolts

Compressive stress $(\sigma_c) = \frac{2\times M_t}{Nd_1tD_1}$

$$\sigma_c = \frac{2\times2210.97\times10^3}{4\times8\times52\times234}$$

σ_c = 11.36 N/mm² < $[\sigma_c]$

Hence bolt is safe in design

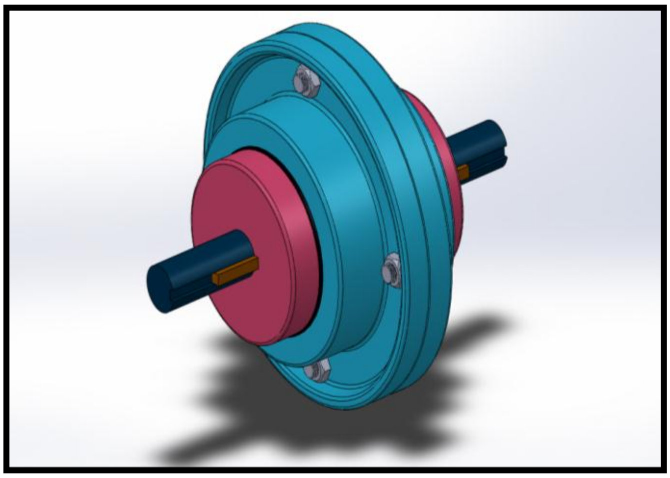
Hence overall the Bibby coupling is safe in design and can be implemented

4. CAD ANALYSIS

ANSYS WORKBENCH 18.1 software was used for performing Computer Aided Analysis

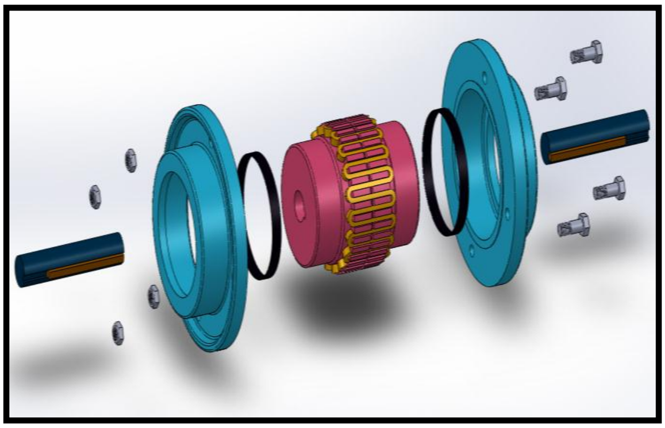
4.1 Assembled CAD Model

Fig -3: Assembled Bibby Coupling



4.2 Exploded View of the Model

Fig -4: Exploded View of Bibby Coupling



4.3 Permissible strength of Coupling components

No.	Part Name.	Material	Strength (MPa)	
			Tensile Yield Strength	Tensile Ultimate Strength
1.	Shaft	C-45 Carbon Steel	360 MPa	710 MPa
2.	Key	C-45 Carbon Steel	360 MPa	710 MPa
3.	Hub	Structural Steel	250 MPa	460 MPa
4.	Grid Spring	SAE 9255 Spring Steel	486 MPa	774 MPa
5.	Housing	Stainless Steel	207 MPa	586 MPa
6.	Bolt	C-45 Carbon Steel	360 MPa	710 MPa
7.	Nut	C-45 Carbon Steel	360 MPa	710 MPa

4.4 Solution of various loads applied to Coupling

1. **Von Mises Stress-**
   The Maximum value of stress is 1.76×10^7 Pascal or 17.671 MPa.

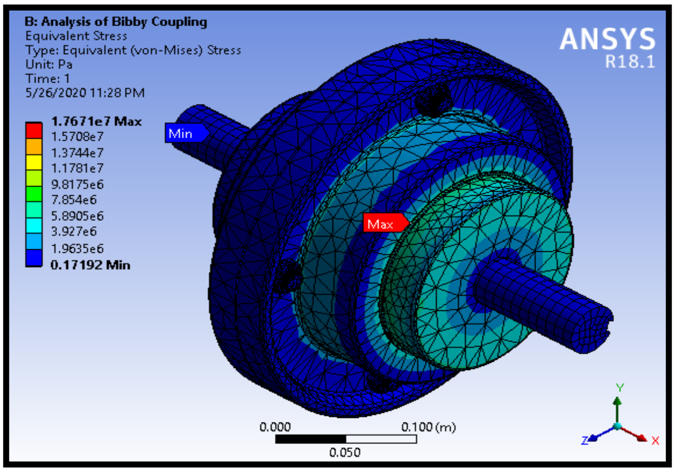


Fig -5: Von mises Stress (grid coupling)

2. Maximum Shear Stress-

The Maximum value of stress is 9.1243×10^{6} Pascal or 9.1243 MPa.

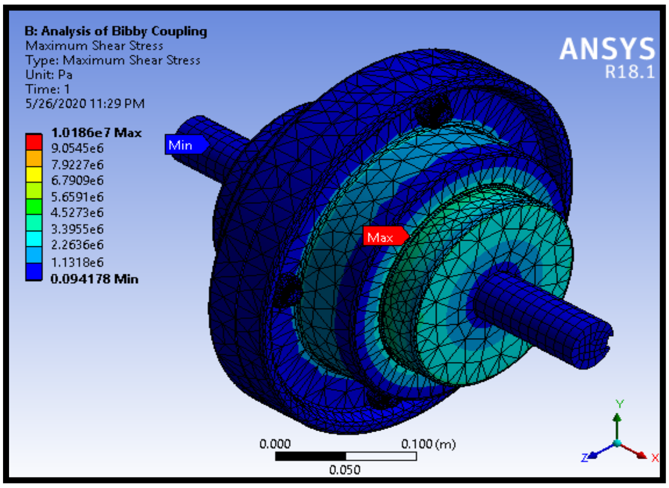


Fig -6: Maximum shear stress (grid coupling)

3. Total Deformation

The Total Deformation is 9.6514×10^{-6} meters or 9.6514×10^{-3}millimeters.

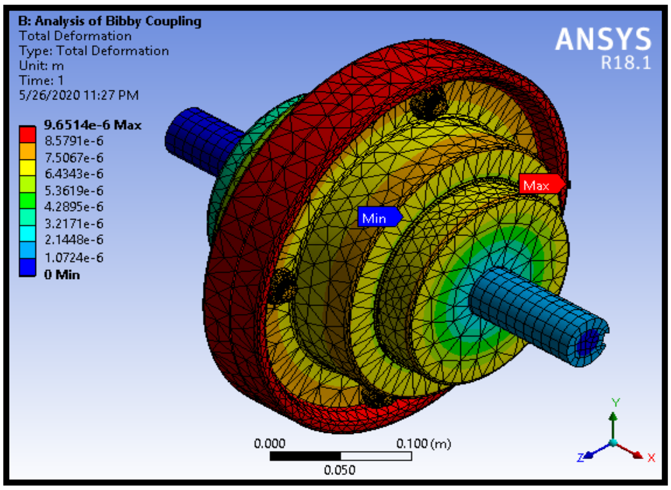
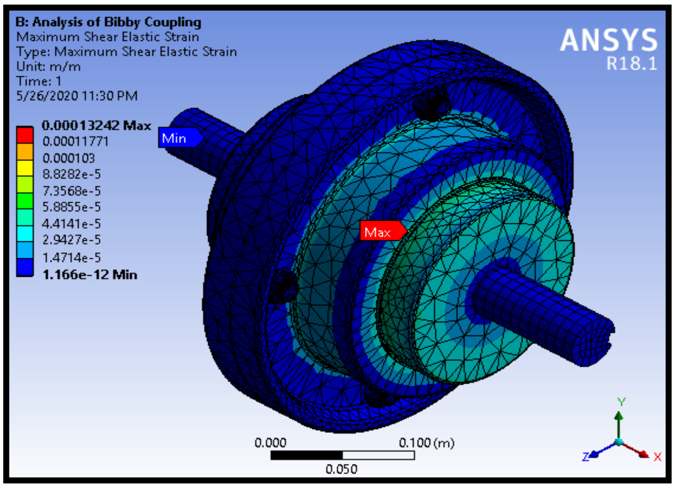


Fig -7: Total deformation (grid coupling)

4. Maximum Shear Strain-

The Maximum value of Shear Strain is 13.242×10^{-5}

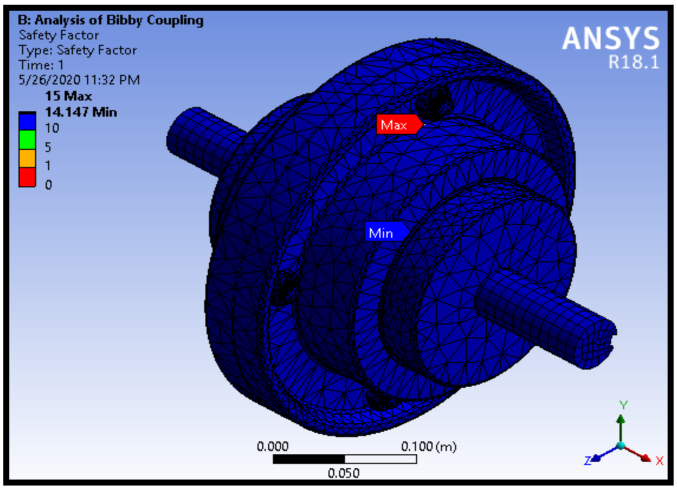
Fig -8: Maximum shear strain (grid coupling)



5. Factor of Safety-

The Minimum FOS is 14.147 and the assembly is very safe.

Fig -9: Factor of safety



4.5 Maximum Values of analytical solution

1. Von Mises Stress –

Maximum Von-Mises Stress is developed on the Driven Hub of value 17.671 MPa which is less than the permissible stress value and the component is marked SAFE.

2. Maximum Shear Stress –

Maximum Shear Stress is developed on the Driven Hub of value 10.186 MPa which is less than the permissible stress value and the component is marked

3. **Total Deformation –**
Maximum Total Deformation takes place on the outer edges of the Driver Cover of value 9.6514×10^{-6} meters, but is too less and is perfectly under elastic limits of the component and the design comes out to be safe.

As seen so far from the analysis on ANSYS WORKBENCH 18.1 we came to a conclusion that the Coupling assembly is far SAFER for the applied forces and loads that it needs to face in the Industry and will perform perfectly well for its application.

4.6 Statistical Representation of the solution

A. Stress (MPa)

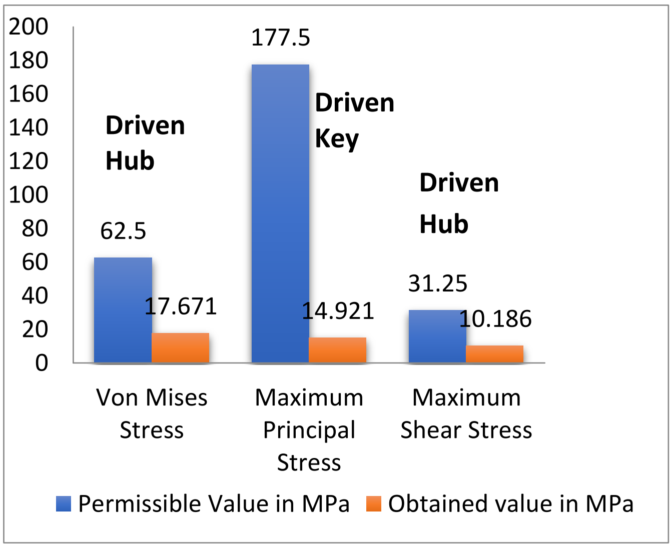


Fig -10: Maximum Stresses in coupling

B. Strain ($\times 10^{-5}$)

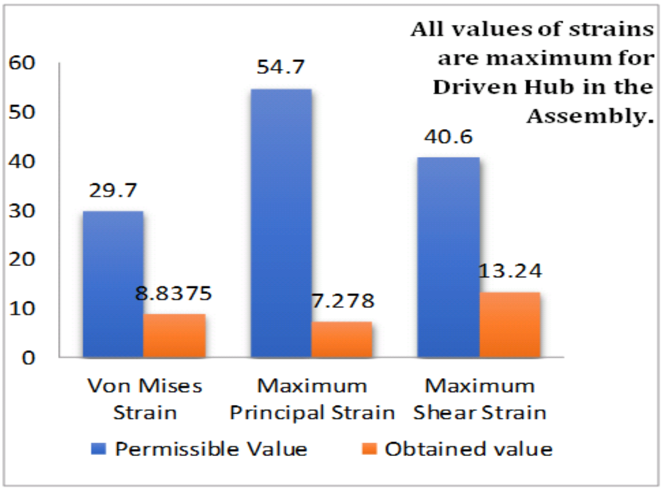


Fig -11: Maximum Strains in coupling

C. Deformation

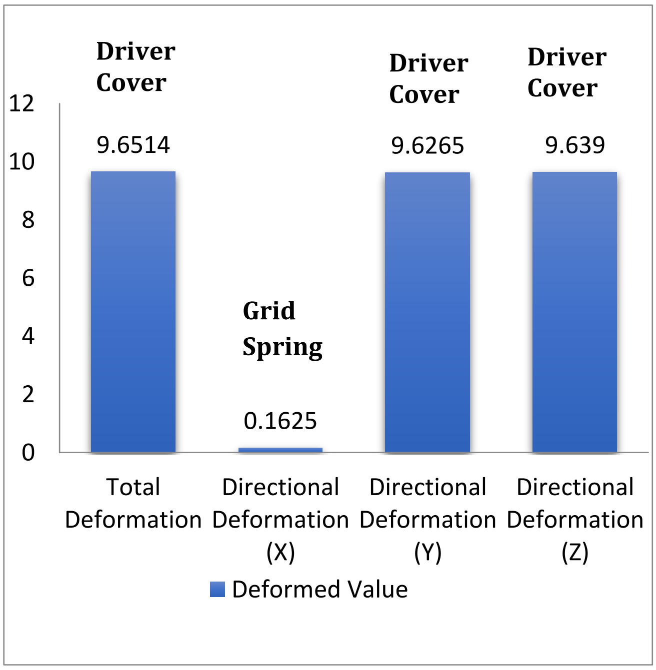


Fig -12: Maximum deformation in coupling}

5. CONCLUSIONS

From the above data we conclude that the bibby coupling designed on the basis of mathematical calculations is safe for the use in industry. The values of the stresses, strains and deformation are well under permissible limits and also, we are getting a good factor of safety.

We checked the components for failure on the basis of von mises stress, principal shear stress, Maximum shear stress, Maximum shear strain and Total Deformation. By checking each and every component of bibby coupling we also concluded that the key (which attaches the two shaft and maintain the alignment) experiences the maximum induced stress. But the key too is well within the permissible limits and hence we conclude that the bibby coupling is completely safe and can be used for industrial purpose.

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