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ANALYSIS OF SPIDER TYPE COUPLINGS

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Abstract : *In this paper, the length of the protrusions and the angles between the rigid protrusions of the spider type couplings are varied. The couplings are designed using modeling software PRO/ENGINEER WILDFIRE 3 and then it is imported to analysis software FEMAP NX NASTRAN for static analysis. The spider type coupling is given a constant torque, is analysed using FEM technique rather than mathematical or experimental method because the mesh is made sufficiently fine around the areas of geometric discontinuity or stress raiser.*

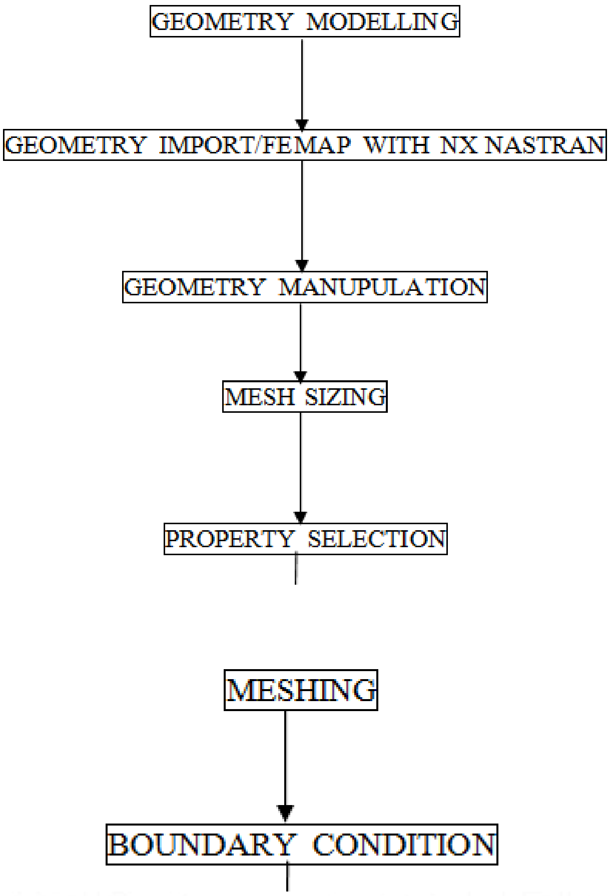
The analysis is performed using FEMAP with NX NASTRAN by constraining all the degrees of freedom in the driving shaft and then the torque is applied on the driven shaft in order to calculate the resultant stress. The analysis is carried out. The results are tabulated and graphically shown. Finally, the comparison is done w ith NASTRAN results and manually calculated results.

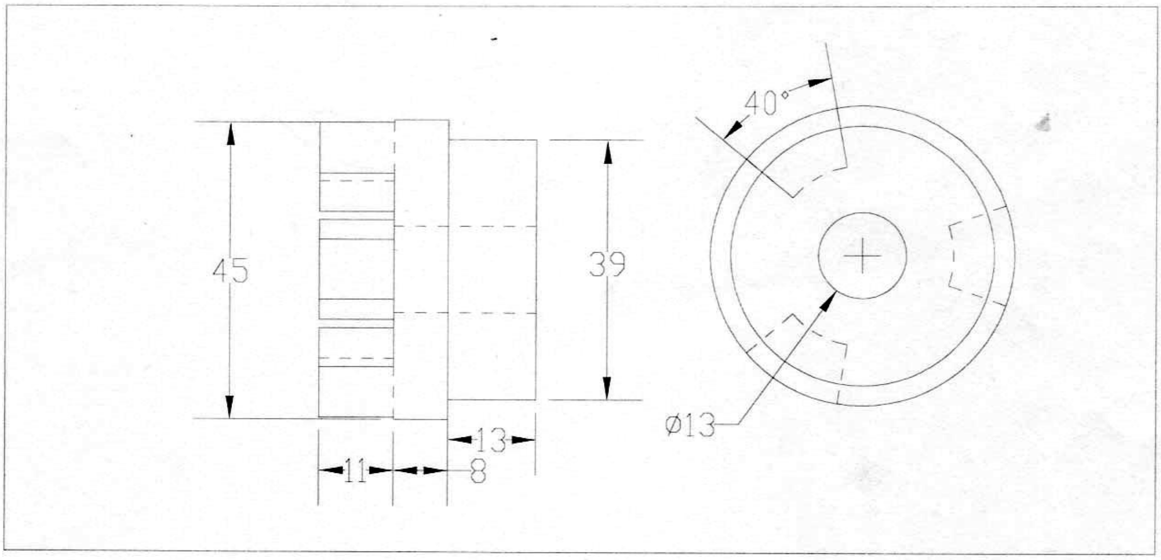
I. INTRODUCTION

It is nearly impossible completely to eliminate all chances of misalignment between the shafts of separately built machines, and such misalignment of shafts always leads to eventual failure of bearings or fatigue failure of shafts. The relative position of the connected shafts, inaccurate at the outset due to inevitable errors of manufacturing, is in course of time aggravated by deformations caused by the working load, temperature fluctuations, the uneven sinking of foundations or supports, etc. In such cases flexible couplings replace ineffective rigid couplings. Therefore the purpose of a flexible coupling is to allow for imperfect alignment of two joining shafts, or to absorb impact from the fluctuation of torsional moment or of angular speed.

II. METHODOLOGY ADOPTED

Chart for Meshing and Analysis Procedure





All dimensions are in mm

Figure- 1. Standard Dimensions of a flange part used for Stress analysis

Material Properties:

CALCULATION:
To Find Torque:

- Given Data:

Power, P = 0 .11 KW
No. Of revolution, N = 100 rpm

Material	Cast iron
Young's modulus, E	1.0×10^5 N/m²
Poisons ratio, n	0.3
Density, ρ	7200 kg/m³

- Formula used:

$$\text{Torque, } T = \frac{P \times 60}{2 \pi N}$$

$$\text{i.e., } T = \frac{11 \times 60}{2 \times \pi \times 100} = 10.5 \text{ N-m}$$

Induced Shear Stress and Principal Stress of a Stepped Shaft of 0.045m

- Given Data: Diameter, d = .045 m

Torque, T = 10.5 Nm

- Formula used:

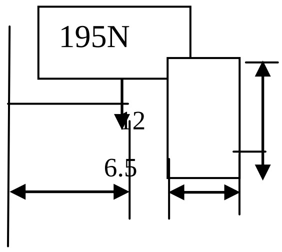
$$\tau_{ss} = \frac{16T}{\pi d^3}$$

Induced shear stress, $\tau_{ss} = \frac{16 \times 10.5}{\pi \times 0.045^3} = 5.872 \times 10^5$ N/m^2

Induced principal stress, $\sigma_{ps} = 5.872 \times 10^5$ N/m²

Calculation of Bending stress of the Rigid Protrusion

DESIGN TORQUE, T_d = nominal torque × service factor



Nominal torque, $T_{nom} = \frac{P \times 60}{2 \times \pi \times 100}$

$= 10.5$ Nm

Maximum shear force, $F_{max} = \frac{10.5}{18 \times 10^{-3}} \times \frac{1}{3}$

$= 195$ N

Maximum shear stress in rectangle section:

=1.5 (F/A) =1.5(195/(9 × 12))

$= 2.708 \times 10^6$ N/m²

Moment, M = W × 6.5= 195 × 6.5

$= 1267.5 \times 10^{-3}$ Nm y =d/2=6mm

$$\frac{M}{I} = \frac{F}{Y}$$

$$F = \frac{1267.5 \times 6}{1296} \qquad I = \frac{bd^3}{12} = \frac{9 \times 6}{12} = 1296 \text{ mm}^4$$

Therefore, Maximum Bending Stress, $\sigma_{bmax} = 6 \times 10^6$ N/m²

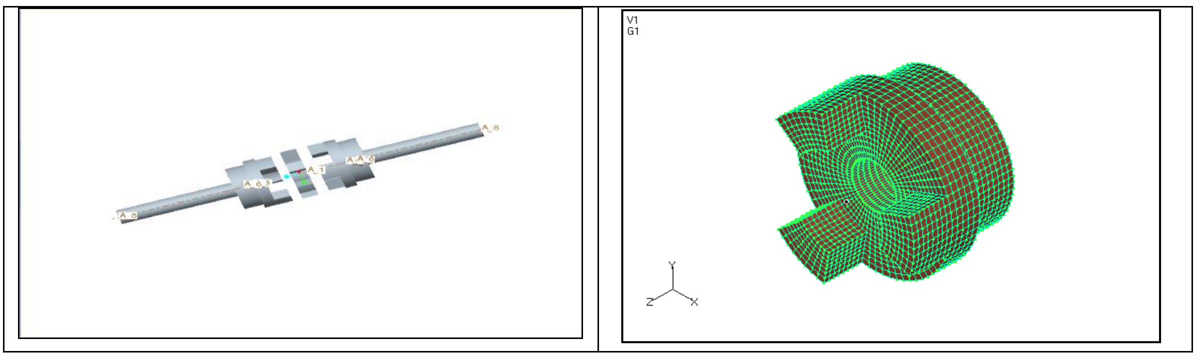


Figure- 2. 3D Model -Exploded view of Spider type coupling and meshed model of coupling

Meshing characteristics of driven flange:

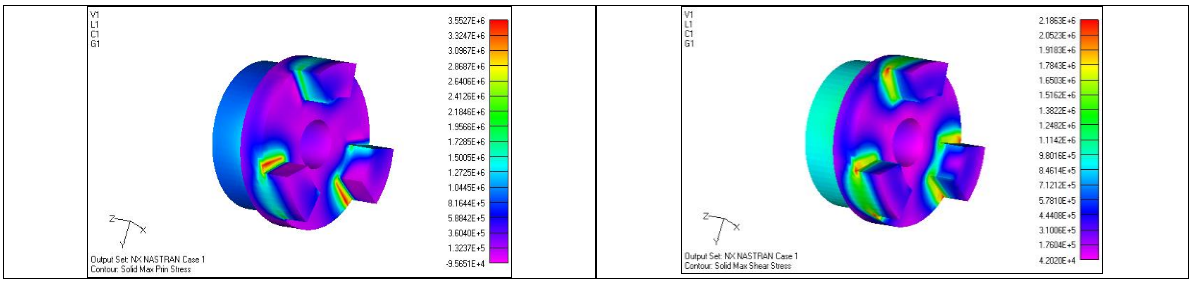


Figure-3. (a)Maximum Principal Stress for Driven Flange of Jaw angle 40 and Jaw length 0.009m

(b)Maximum Shear Stress for Driven Flange of Jaw angle 40 and Jaw length 0.009m

ANGLE (Degree)	LENGTH (mm)	ELEMENTS (n)	NODES (n)
40	9	24229	28603
	11	25633	29179
	13	26245	30907
43	9	25465	30001
	11	25969	30628
	13	27649	32497
46	9	26616	31399
	11	27205	32071
	13	28969	34087

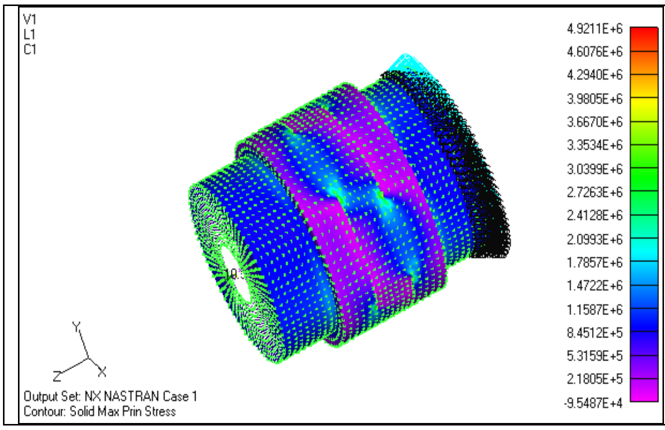


Figure- 4. Spider type Coupling showing Nodes

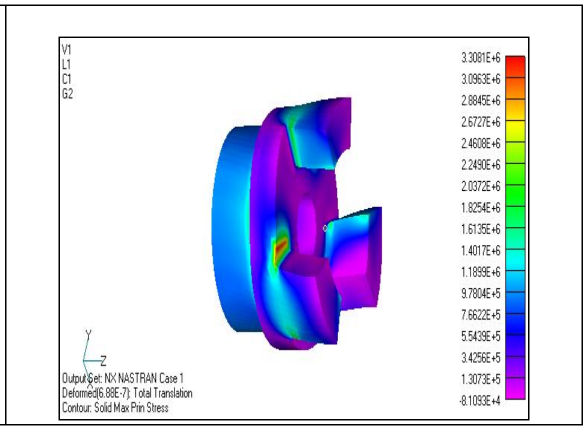


Figure-5 Deformation of Flange

Finding the Stress concentration factor

Maximum shear stress for the coupling $= \tau_{max}$

Maximum principal stress for the coupling $= \sigma_{c\,max}$

Induced shear stress for the stepped shaft τ_{ss} $= 5.72 \times 10^5$ N/m²

Induced principal stress for the stepped shaft σ_{ps} $= 5.99 \times 10^5$ N/m²

Stress concentration factor

Stress concentration factor for torsion $= K_T$

Stress concentration factor for bending $= K_B$

For angle 40 degree length 9mm

$$K_T = \frac{\tau_{max}}{\tau_{ss}} = \frac{218 \times 10^6}{5.72 \times 10^5}$$

$$K_B = \frac{\sigma_{cmax}}{\sigma_{ps}} = \frac{3.5527 \times 10^6}{5.99 \times 10^5} = 3.81$$

For angle 40 degree length 11mm

$$K_T = \frac{\tau_{max}}{\tau_{ss}} = \frac{216 \times 10^6}{5.72 \times 10^5} = 3.77$$

$$K_B = \frac{\sigma_{cmax}}{\sigma_{ps}} = \frac{3.52 \times 10^6}{5.99 \times 10^5} = 5.88$$

For angle 40 degree length 13 mm

$$K_T = \frac{\tau_{max}}{\tau_{ss}} = \frac{215 \times 10^6}{5.72 \times 10^5} = 3.76$$

$$K_B = \frac{\sigma_{cmax}}{\sigma_{ps}} = \frac{3.51 \times 10^6}{5.99 \times 10^5} = 5.86$$

ANGLE (Degrees)	LENGTH (mm)	STRESS CONCENTRATION FACTOR FOR BENDING (K_B)	STRESS CONCENTRATION FACTOR FOR TORSION (K_T)
40	9	5.93	3.81
	11	5.88	3.78
	13	5.86	3.76
43	9	5.83	3.71
	11	5.78	3.67
	13	5.76	3.63
46	9	5.58	3.54
	11	5.54	3.47
	13	5.53	3.46

Table 1 Stress Concentration factor for the analysed Spider type Flexible Coupling

ANGLE (Degrees)	LENGTH (mm)	MAXIMUM PRINCIPAL STRESS IN NASTRAN RESULT σ_c max $\times 10^6$ (N/m²)	MAXIMUM SHEAR STRESS IN NASTRAN RESULT τ max $\times 10^6$ (N/m²)
40	9	3.55	2.18
	11	3.52	2.16
	13	3.51	2.15
43	9	3.49	2.12
	11	3.46	2.10
	13	3.45	2.07
46	9	3.34	2.02
	11	3.32	1.98
	13	3.31	1.99

Table 2 Nastran Results for Principal streses and Shear stresses

Graphs:

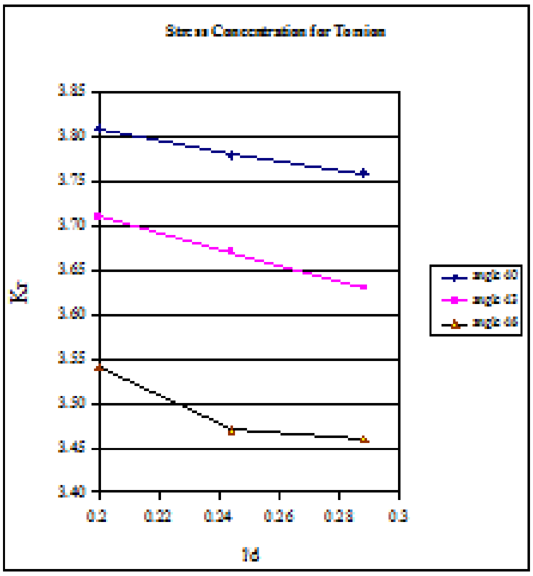
From the table 1 the Stress concentrations for Torsion are plotted. The above Graph 6.1 Stress Concentrations for Torsion plots the l/d (length to diameter ratio) in X-axis Vs Stress Concentration Factor for Torsion (K_T) in Y-axis. Here the Stress Concentration for each angle is plotted.

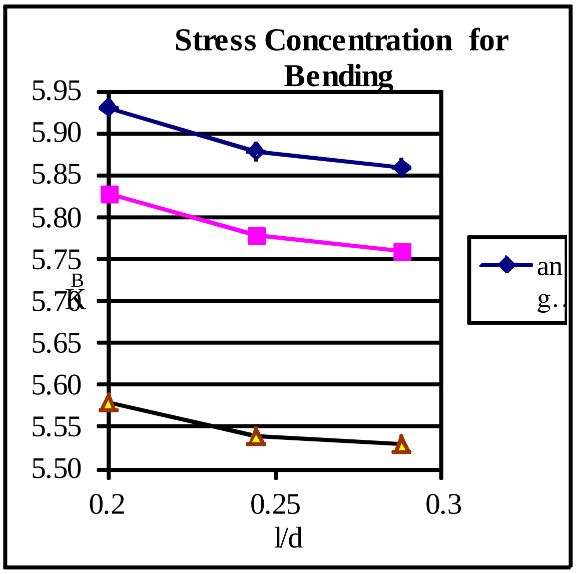
Comparison of Results for Shaft:

Manual calculation Result	Induced shear stress	4.076×10^4 N/m^2
Nastran Result	Maximum shear stress	4.512×10^4 N/m^2

Shear Stresses and Principal Stresses for the Standard type Flexible Coupling

The Principal stress and Shear stress are found from the software NX Nastran and the stress concentration factor is found by manual calculation for both torsion and bending moment. Then it is tabulated in the tables shown in next page





Graphs- (A) Comparison of Stress Concentration Factors for Torsion (B) Comparison of Stress Concentration for Bending

From the table 1 the Stress concentrations for Bending are plotted. The above Graph 2 Stress Concentrations for Bending plots the l/d (length to diameter ratio) in X-axis Vs Stress Concentration Factor for Bending (K_B) in Y-axis. Here the stress concentration for each angle is plotted.

III.CONCLUSION

The stress concentration factor, through this paper was found and the maximum stress concentration occured at the surface of intersection of the stepped shaft and jaws. So by this analysis it was concluded that the maximum stress occurs at that connecting end of the jaw. One can also find the stress concentration factor due to torsion and bending of jaws of the spider type flexible type coupling.

The meshing was easier when compared to Ansys. The ansys results for a shaft were analysed and also shown at the end and comparison was done. The time taken for meshing was also less. While doing this work on FEMAP with NX-NASTRAN, it was found that the meshing was easier and time taken for the mapped mesh was less, when compared with other analysing softwares.

The software FEMAP with NX-NASTRAN is capable of analysing the stress analysis of coupling. The results of FEMAP with NX-NASTRAN were compared with Ansys and manual calculation for a plain shaft, after which the stress analysis of a spider type flexible coupling was done.

Future scope:

Here in this project work the shear stress and principal stress are studied in the driven flange of the spider type flexible coupling. The stress concentration factor for torsion and bending was found. For future scope, based on these results,one can select the proper size for the standard type flexible coupling. Also the mesh is made finer around the stress raiser to get accurate results and analysis can be done in Nx Nastran which is more users friendly.

If necessary even in future a proper design procedure for the spider type coupling can be obtained form the result obtained from this project.

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