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Analytical Analysis of Relationship among Modal Parameters of Rigid Flange Coupling

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***Abstract*—As a structural analysis is not enough for safe, efficient and durable design of coupling. Therefore modal analysis is conducted to analyze effect of material damping, rotational speed, as well as design of coupling in order to resonance. Though modal analysis system mode shape, natural frequency can be predicted. Determination of natural frequency is helpful to operate system at safer external frequencies to occurrence of resonance. The study has been undertaken to investigate the relationship among modal parameters of rigid flange coupling to optimize the design. The effect on modal parameters of rigid flange coupling having fixed support at the two ends is studied by varying the diameter, material and power to the shaft. Analytical analysis has been carried out referring the standard procedure of design and vibration.**

Keywords*— *Modal Analysis, Natural Frequency, Vibrations.

I. INTRODUCTION

The couplings are widely used in various engineering applications for power transmission and to increase shaft length to achieve intended function. Shafts are usually available in length varying from 6 to 10 meters, so that they can be easily handled, transported and precisely manufactured. But in most of engineering applications shafts of large lengths are required to transmit the torque which can be obtained by joining two or more shafts in order to obtain the required length (Patel, Oza, Gohel, Parmar, & Kadivar, 2014) & (Johnson, 1996).

The two elementary rigid coupling styles are machined set-screw, for smaller shafts, and ribbed, two-piece cast, for larger and higher horsepower applications. The ribbed style, all but unchanged, remains the coupling of choice for large shafts, but it is uneconomical for shafts two inches or less in diameter. The machined, set-screw coupling is basically a cylinder with a key-way and set screws. From a simplistic viewpoint, this is a sound design, but in practice its shortcomings become evident. It can loosen under vibration, and set screws can leave dents or dimples in the shaft or key-way, deforming the surface so that adjusting or removing the coupling becomes difficult.

As coupling is highly important component of rotating system because its failure causes disaster of the system. There are several ways which can become cause of coupling failure such as excessive loading, misalignment, unbalance in system component and resonance. Therefore, coupling should be designed to withstand all these failure conditions. In this research, dynamic structural analysis is conducted to analyze structural integrity.

II. PROBLEM STATEMENT

Basically flange coupling is the very important part in the power transmission system and it is required to design it statically and dynamically considering the weight and other parameters. Many of the time couplings will fail because of vibration and also because of strength problem. So it is required to optimize different parameters of coupling and reduce the vibrations and is required to check for misalignment and unbalance for better performance.

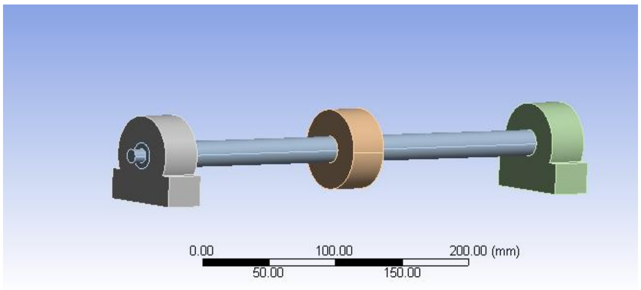


Fig.1 CAD Model for Proposed Experimental Setup for Modal Analysis

III. ANALYTICAL SOLUTION

Permissible Stresses[08]

Shaft: $6 = \frac{Ssy}{f.s} = \frac{0.5Syt}{f.s}$

Keys: $6 = \frac{Ssy}{f.s} = \frac{0.5Syt}{f.s}$

Compressive Stress[08]

Shaft $6c = \frac{Syc}{f.s} = \frac{1.5\ Syt}{f.s}$

Flanges $6c = \frac{Su}{f.s} = \frac{0.5\ Sut}{f.s}$

Diameter of Shaft[08]

Taking into consideration service factor of 3, the design torque is calculated by

$$Mt = \frac{60X10^{6} XKW}{2\pi N} X\ 1.5 \text{ N-mm}$$

$$\tau = \frac{16Mt}{\pi d^{3}};\ d^{3} = \frac{16Mt}{\pi \tau};\ d = \sqrt[3]{\frac{16Mt}{\pi \tau}}$$

Dimensions of Flanges[08]

d_h=2d l_h=1.5d D=3d t=0.5d t_1=0.25d

d_r = (4d+2t_1)

Static Deflection under horizontal shaft position[09]

$$\delta = \frac{Wl^{3}}{192EI}$$

Natural Frequency

$$Wn = \sqrt{\frac{g}{\delta}}$$

IV. RESULT

Results have been calculated using above equations.

Table 1: Computation of Modal Parameters considering Constant Power, Material and Variable Speed

Sr.No	P	N	S_{yt}	S_{ut}	Mt	τ	d	d_h	l_h	D	t	t_1	d_r	d_o	ω	λ_{MAX}
	KW	rpm	N/mm²	N/mm²	N.mm	N/mm²	mm	mm	mm	mm	mm	mm	mm	mm	Hz	mm
1	10	200	400	200	7.160×10⁵	50	40	83.5	62.06	125	20.19	10.4	62.6	188	2303.99	0.4434
2	10	300	400	200	4.774×10⁵	50	36	73.01	54.75	109.5	18.2	9.1	54.75	164.2	1758.28	0.5076
3	10	400	400	200	3.581×10⁵	50	33.2	66.3	49.7	99.5	16.5	8.2	49.1	149.3	1451.42	0.5587
4	10	500	400	200	2.864×10⁵	50	30.7	61.58	46.18	92.37	15.39	7.69	46.18	138.5	1250.8	0.6018
5	10	600	400	200	2.387×10⁵	50	28.8	57.95	43.46	86.92	14.48	7.24	43.46	130.6	1107.64	0.6895

Table 2: Computation of Modal Parameters considering Constant Speed, Material and Variable Power

SR.NO	P	N	S_{yt}	S_{ut}	Mt	τ	d	d_h	l_h	D	t	t_1	d_r	d_o	ω	λ_{MAX}
	KW	rpm	N/mm²	N/mm²	N.mm	N/mm²	mm	mm	mm	mm	mm	mm	mm	mm	Hz	mm
1	10	400	400	200	3.582×10⁵	50	33.1	66.33	49.75	99.5	16.58	8.29	49.75	149	1451.42	0.5587
2	20	400	400	200	7.16×10⁵	50	41.7	83.57	62.68	125.3	20.69	10.4	62.6	188	2303.99	0.4434
3	30	400	400	200	1.07×10⁶	50	47.8	95.67	71.75	143.5	23.91	11.95	71.75	215	3019.09	0.3873
4	40	400	400	200	1.43×10⁶	50	52.6	105	78.97	157.9	26.32	13.16	78.98	236	3657.37	0.3519
5	50	400	400	200	1.8 ×10⁶	50	56.7	113	85	170	28.35	14.17	85.07	255.2	4244	0.3267

Table 3: Computation of Modal Parameters considering Constant Power, Speed and Variable Material Properties

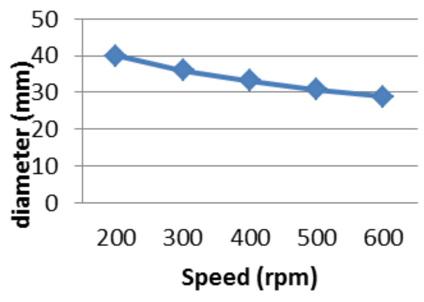
SR.NO	P	N	S_{yt}	S_{ut}	Mt	τ	d	d_h	l_h	D	t	t_1	d_r	d_o	ω	λ_{MAX}
	KW	rpm	N/mm²	N/mm²	N.mm	N/mm²	mm	mm	mm	mm	mm	mm	mm	mm	Hz	mm
1	50	700	380	200	1.02 ×10⁶	47.5	47.8	95.75	71.81	143.6	23.93	11.96	17.81	215.4	3024.13	0.3677
2	50	700	400	200	1.023 ×10⁶	50	47.1	94.13	70.59	141.2	23.5	11.7	70.59	211.7	2922.47	0.3937
3	50	700	460	200	1.023 ×10⁶	57.5	44.9	89.84	67.38	134.7	22.46	17.2	67.38	202.15	2662.47	0.4743

4	50	700	500	200	1.023 ×10^6	62.5	43.6	87.38	65.53	131.1	21.84	10.92	62.53	196.61	2518.5	0.5301

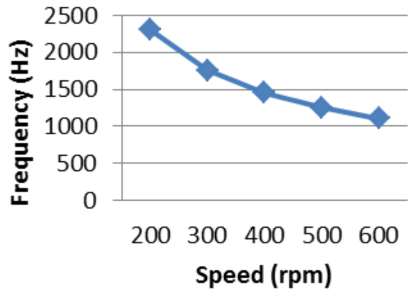
A. Analysing Result

By analyzing the modal parameters, the result have been plotted to define relationship among different parameters.

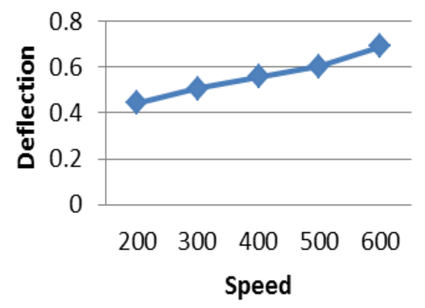
Considering Variable Speed



As the shaft speed increases from 200 to 600 rpm, the diameter also reduces from 40 to28mm.

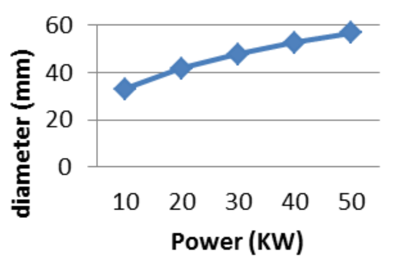


As the speed increases from 200 to 600 rpm, the frequency reduces from 2303.99 to 1107.64 Hz.

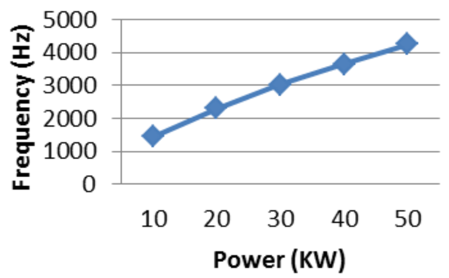


As the speed increases from 200 to 600 rpm, the deflection gets increases from 0.4434 to 0.6895mm.

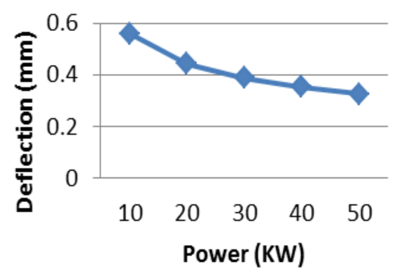
Considering Variable Power



As the power increase from 10 to 50 KW, diameter of shaft increases from 33.1 to 56.7mm.

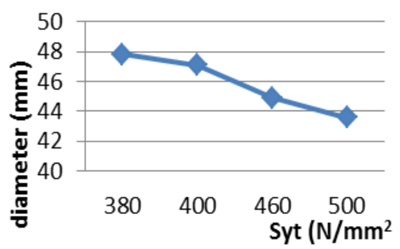


As the power increase from 10 to 50 KW, natural frequency increases from 1451.42 to 4244Hz.

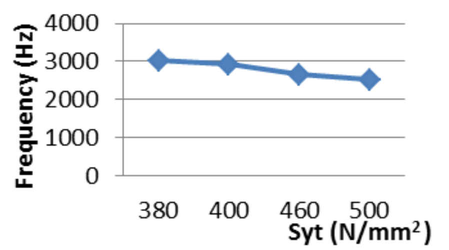


As the power increase from 10 to 50 KW, deflection decreases from 0.55871 to 0.3267 mm.

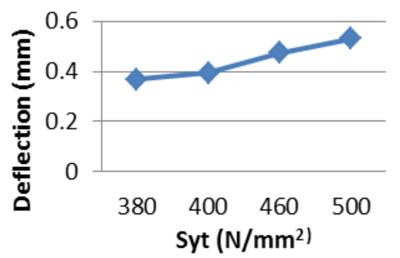
Considering Variable Material Property



As the Yield Strength of material of rigid flange coupling increase from 380 to 500 N/mm^2, diameter of shaft decreases from 47.8 to 43.6 mm.



As the Yield Strength of material of rigid flange coupling increase from 380 to 500 N/mm^2, frequency decreases from 3024.13 to 2518.5 Hz



As the Yield Strength of material of rigid flange coupling increase from 380 to 500 N/mm^2, deflection increases from 0.3677 to 0.5301mm

B. Conclusion

After studying the relationship among different modal parameters these can be concluded that as the speed increases the diameter of flange coupling reduces, resulting in decrease in natural frequency and increase in deflection. Same phenomena are observed when material property is varied. When power is increased, the diameter and natural frequency increases but there is decrease in deflection. This can also be concluded that there is inverse relationship among natural frequency and deflection.

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