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Design and Development of a Setup for Torsional Vibration System

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Abstract: *Torsional vibration is an oscillatory angular motion casing twisting in the shaft of a system; the oscillatory motion is superimposed on the steady rotational motion of a rotating/reciprocating machine. Even though the vibration cannot be detected without a specific measuring instrument, its amplitude can be destructive. Motion is rarely a concern with Torsional vibration unless it affects the function of a system. It affects the functional integrity and life of components and determines the allowable magnitude of the Torsional vibration. Torsional vibratory motion can produce stress reversals that cause metal fatigue. Components tolerate less reversed stress that steady stress. Besides, the stress concentration factor associated with machine members decreases the effectiveness of load-bearing materials.*

By using this Model can calculate the longitudinal and Torsional natural frequencies, forced response analysis, to calculate the vibratory torque acting on the shaft (system), perform the forced response analysis to assess Torsional vibration to avoid Torsional resonances and excessive Torsional we recommended changes such as, but not limited to.

The project aims to design and fabricate the Torsional vibration system and find different materials' natural frequency at different lengths.

Keywords: *Single Disc, Double Disc, Torsion, Shaft, Etc*

I. INTRODUCTION

The vibrations are different kinds; one of the kinds of vibration is Torsional vibration. Our project mainly deals with the Torsional vibrations occurring in shafts of different diameters and different materials in this new design Torsional vibration system with two rotor systems with adjustable disc methodology techniques. The fabricated system gives the number of oscillations by using predefined mathematical formulas with the help of the available date if it will help measure the frequencies of the particular system.

An ideal power generation or transmission, a system using rotating parts, not only the torque applied or reacted on the machines creates vibrations where the power is generated. The torque generated may not be the same or may not react to the torque smoothly or alternating torques because no material can be infinitely stiff. These alternating torques applied at some distance on a shaft, causing twisting vibration about the rotation axis.

To minimize these problems, the study of the Torsional vibration of the shaft on different lengths and materials is required.

The most common way to measure Torsional vibrations is to use equidistant pulses over one shaft revolution.

The methodology aims to find the process chart, which will give a lot of information related to the present work and be understood sequentially.

- Start
- Problem analysis
- Determining expected Model
- Designing
- Fabrication
- Calculation analysis and result
- Stop

The natural frequency of the Torsional vibration is

$$f_n = \frac{1}{2\pi}\sqrt{\frac{GJ}{LI}}$$

II. DESIGN

A. Idea About Setup

The main aim of this project work is how to develop the machine setup structure. To find the detailed design, find out the availability setup design and necessary design equations. With the help of basic principles and information, a base structure has been done.

We created a basic model with a solid frame with two discs having different diameters based on the expected structure. For converting the two-disc setup into a single disc, we provide a movable clamp with a chuck fixed in between the discs; thus, shaft diameter can be varied in a single rotor system.

B. Shaft Design

Let us assume shaft length is 1000mm (1 mtr), allowable shear stress for mild steel is 55 $N/mm^{2,}$ and allowable normal stress is 110 N/mm^2.with the help of necessary input parameters need to find the shaft diameter. It is possible by using the following equation.

$$D = \left\{\left(\frac{16}{\pi \tau_{cd}}\right)(v_t m_t)\right\}^{\frac{1}{3}}$$

For P=0.005KW and speed n=100rpm

$m_t = 477.5N - mm$

D=4mm

For P=0.002KW and n=100rpm

$m_t = 1910N - mm$

D=6mm

C. Disc Design And Specification

The two freely rotating discs assumed the nominal diameter of 200mm and 230mm with a hole in the center for supporting purposes. The discs have two different masses with unequal mass density, which will provide oscillations of large amplitude and last for a larger period.

Maximum principal stress will be at the inside is given by

$$F=\left(\frac{\rho\omega^2}{4g}\right)\left[\left(1-\frac{1}{m}\right)R_1^2+\left(3+\frac{1}{m}\right)R_2^2\right]$$

The maximum shear stress at any radius is given by

$$\frac{1}{2}(f-P)=\left(\frac{\rho\omega^2}{4g}\right)\left[\left(3+\frac{1}{m}\right)\left(\frac{R_1^2.R_2^2}{r^2}\right)+\left(1-\frac{1}{m}\right)r^2\right]$$

Where,

$\rho=7.86X10^{-6}$ Kg/mm^2

$\omega=0.1745$

g=9.81m/s^2

$\upsilon=0.303$

R_1=6mm

R=6mm

R_2=115mm

For disc1: R_2=115mm (outer radius)

r= R_1=6mm (inner radius)

$$p=\left(\frac{\rho\omega^2}{8g}\right)\left(3+\frac{1}{m}\right)(R^2-r^2)$$

p=7.6134 x10^{-4} N/mm^2

At centre maximum stress

$$p=\left(\frac{\rho\omega^2 R^2}{8g}\right)\left(3+\frac{1}{m}\right)$$

p=7.633 x10^{-4} N/mm^2

At outside maximum stress

$$p=\left(\frac{\rho\omega^2 r^2}{g}\right)\left(1-\frac{1}{m}\right)$$

p=3.508 x10^{-6} N/mm^2

Maximum shear stress at any radius

$$=\left(\frac{\rho\omega^2}{g}\right)\left[(3+\upsilon)\left(\frac{R_1^2.R_2^2}{r^2}\right)+(1-\upsilon)r^2\right]$$

=6.1102 x10^{-3} N/mm^2

For disc 2:R_2=105mm (outer radius)

r= R_1=6mm (inner radius)

$$p=\left(\frac{\rho\omega^2}{8g}\right)\left(3+\frac{1}{m}\right)(R^2-r^2)$$

p=6.3557 x10^{-8} N/mm^2

At centre maximum stress

$$p=\left(\frac{\rho\omega^2 R^2}{8g}\right)\left(3+\frac{1}{m}\right)$$

p=6.3639 N/mm^2

At outside maximum stress

$$p=\left(\frac{\rho\omega^2 r^2}{g}\right)\left(1-\frac{1}{m}\right)$$

p=3.5808 x10^{-6} N/mm^2

Maximum shear stress at any radius

$$=\left(\frac{\rho\omega^2}{g}\right)\left[(3+\upsilon)\left(\frac{R_1^2.R_2^2}{r^2}\right)+(1-\upsilon)r^2\right]$$

=4.6392 x10^{-4} N/mm^2

D. COMPONENT DRAWINGS:

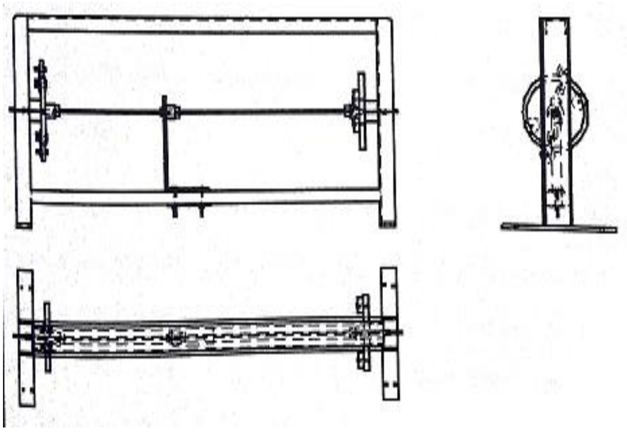

Fig 1: frame

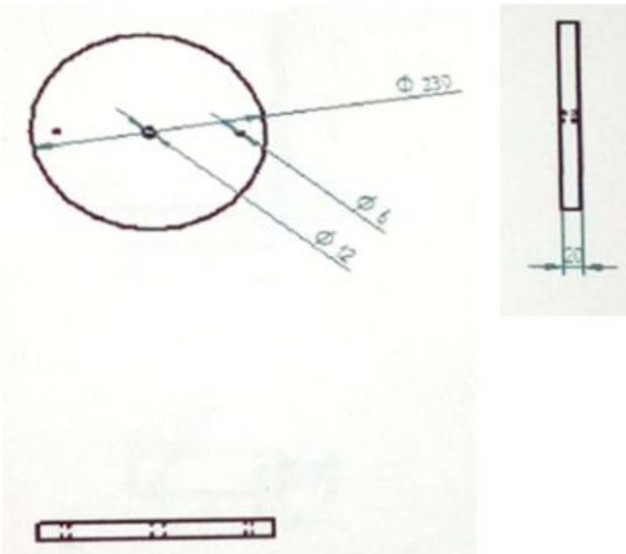

Fig 2: a disc of diameter 230mm

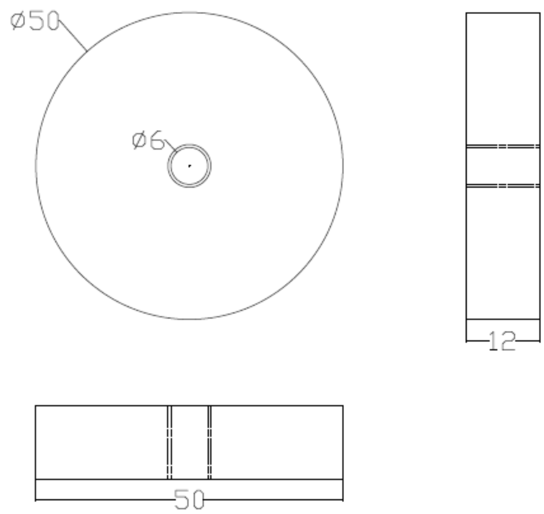

Fig 3: a disc of diameter 200mm

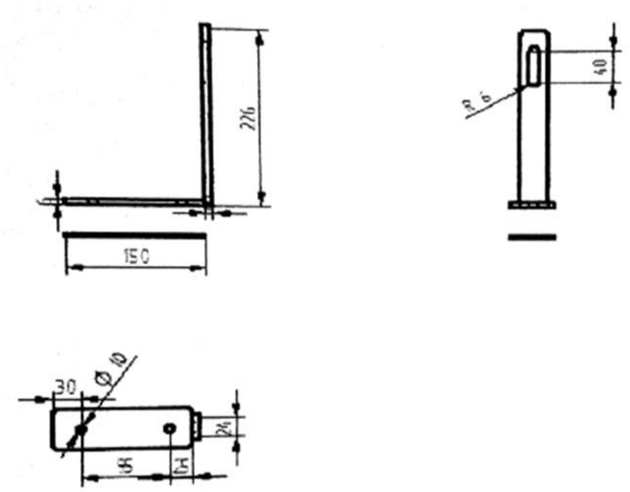

Fig 4: clamp

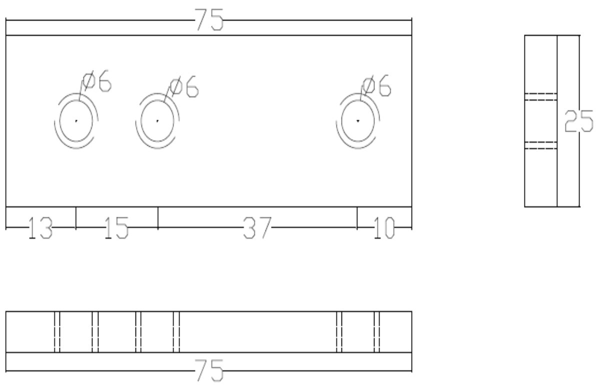

Fig 5: a rectangular metal piece

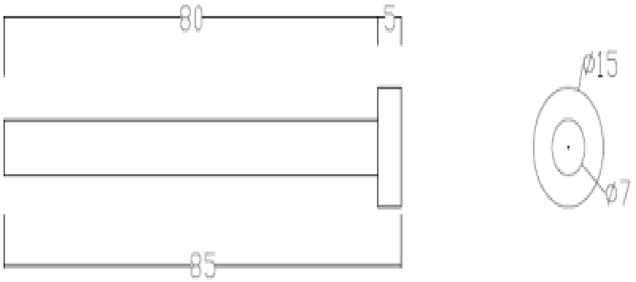

Fig 6: clamp screw

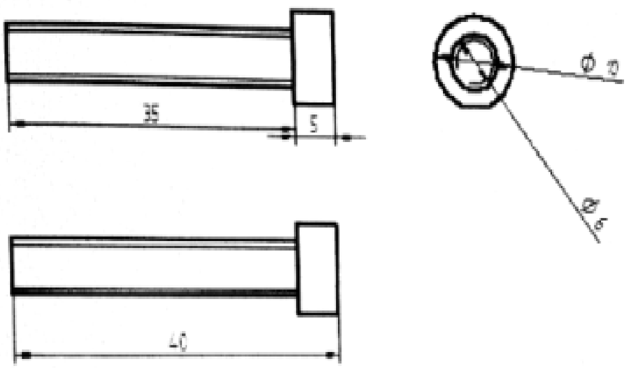

Fig 7: screws

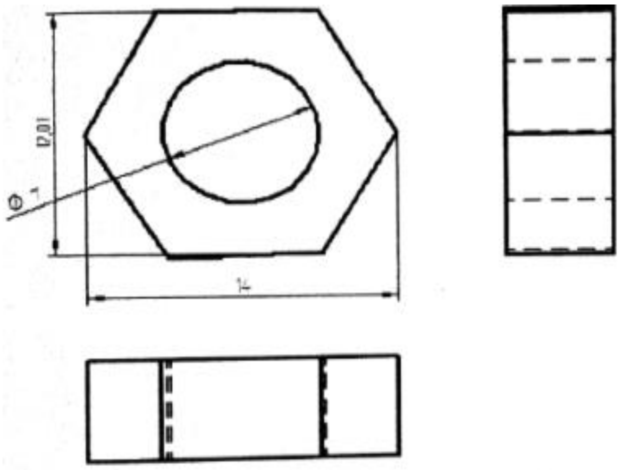

Fig 8: clamp nut

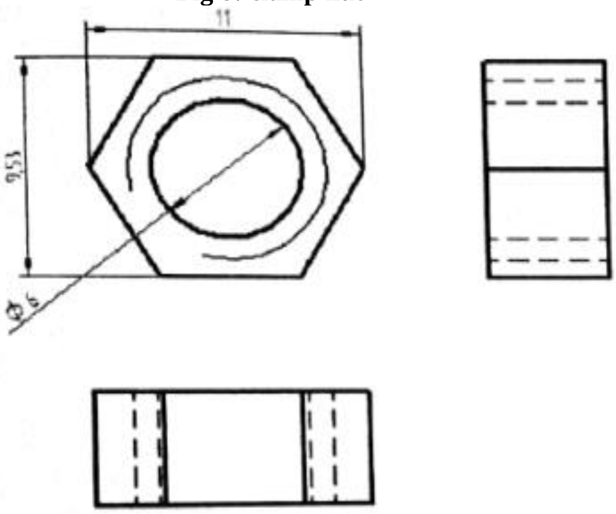

Fig 9: nut

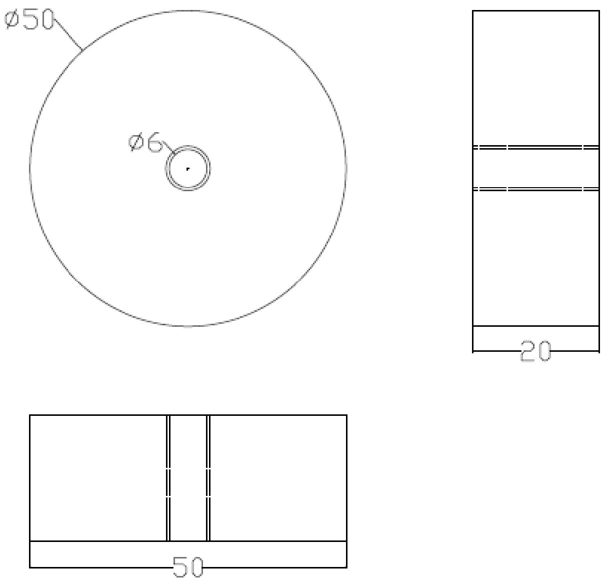

Fig 10: a mass of disc (diameter 230mm)

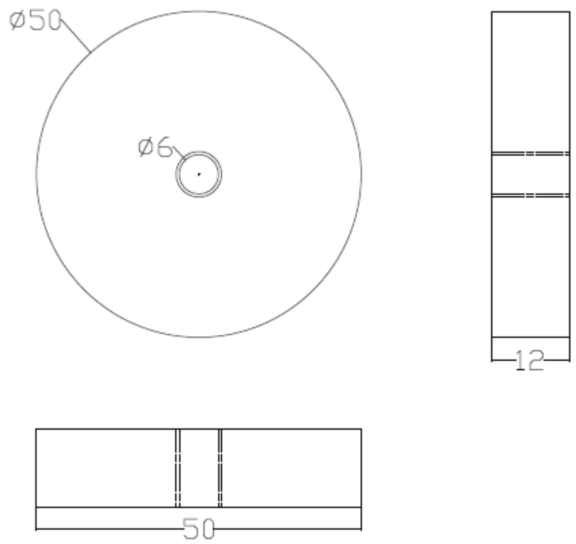

Fig 11: the mass of disc (diameter 200mm)

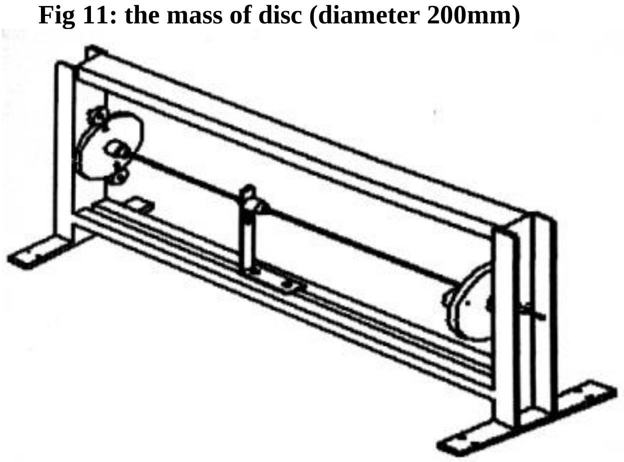

Fig 12: isometric view

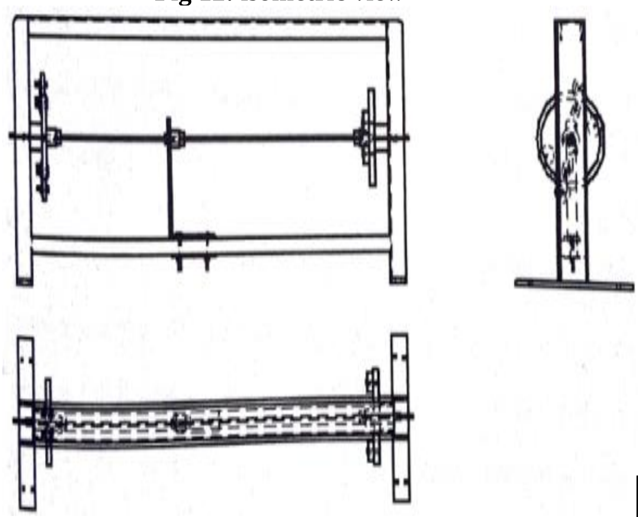

Fig 13: component assembly

III. FABRICATION

Based on component drawings and assembly drawings, the Model has been fabricated. The Torsional vibration system consists of a frame having two free rotating discs of different diameters. Shafts of different diameters and materials are allowed to pass through the discs. The shaft is hooded by two chucks in the center of the two discs, tightening up by a special key.

The system also has the Facility of changing two rotor systems to a single rotar system by providing a clamp between the two discs, which can be placed at any distance between the two discs. In the single rotor system, the shaft is held by another similar chuck which can be tightened by the special key.

Mild steel is used in fabricating all components of the setup. The two-disc clamp, external masses, and the rectangular metal piece are chromium-plated to get a smooth surface finish—the final design setup as given below.

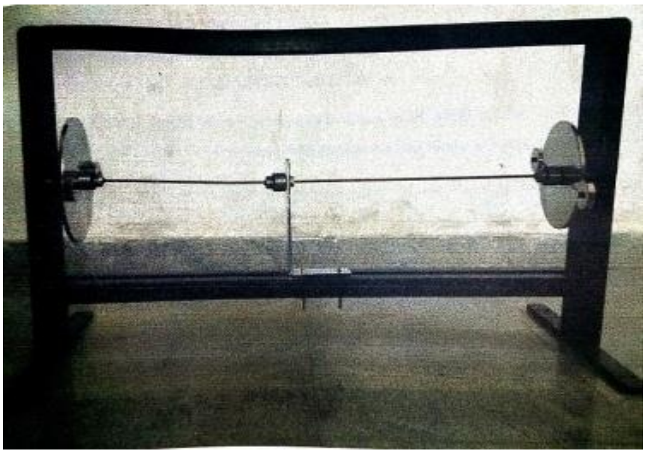

Fig 14: fabricated Model

IV.EXPERIMENTAL RESULTS

A. Single Disc System

Consider a shaft on negligible weight is fixed at one end and carrying a rotor on the free end. The amplitude of Torsional vibration is maximum at the free end that is called a single rotor system. In this experiment, one end of the shaft is gripped in the chuck, and a heavy flywheel free of rotation in the ball bearing is fixed on the other end of the shaft. It can be easily moved in guide one fixed rigidly by nut and bolt for one end.

The natural frequency of the single rotor Torsional vibration is $f_n = \frac{1}{2\pi}\sqrt{\frac{GJ}{LI}}$

Table I: For 6mm (6x10^{-3}) diameter stainless steel shaft

Sl. No.	Length 'L' (meter)	Time for 5oscillations 't' sec.	Tme period for T_{exp}=t/5 sec.	$F_{n_{th}}$ = 1/T_{exp} Hz.	$F_{n_{th}}$ In Hz.	Time period T_{th} =1/f_n
1	0.42 0.42	2.40 2.59	0.481 0.518	1.95 1.93	7.40	0.135
2	0.52 0.52	2.27 2.35	0.454 0.472	2.20 2.12	6.65	0.15
3	0.57 0.57	2.25 2.29	0.450 0.458	2.22 2.18	6.35	0.157
4	0.62 0.62	2.19 2.22	0.438 0.444	2.28 2.25	6.09	0.164

Table II: For 5mm ($5x10^{-3}$) diameter copper shaft

Sl. No.	Length 'L' (meter)	Time for 5 oscillations 't' sec.	Tme period for T_{exp}=t/5 sec.	$F_{n_{th}}$ =1/T_{exp} Hz.	$F_{n_{th}}$ In Hz.	Time period T_{th} =1/f_n
1	0.42 0.42	2.43 2.48	0.486 0.496	2.05 2.01	5.14	0.194
2	0.52 0.52	2.58 2.63	0.516 0.526	1.93 1.90	4.62	0.216
3	0.57 0.57	2.71 2.73	0.542 0.546	1.84 1.83	4.41	0.226
4	0.62 0.62	2.83 2.96	0.566 0.592	1.76 1.68	4.23	0.236

Table III: For 4 mm ($4x10^{-3}$) diameter copper shaft

Sl. No.	Length 'L' (meter)	Time for 5 oscillations 't' sec.	Tme period for T_{exp}=t/5 sec.	$F_{n_{th}}$ =1/T_{exp} Hz.	$F_{n_{th}}$ In Hz.	Time period T_{th} =1/f_n
1	0.42	3.28	0.656	0.52	3.29	0.303
2	0.52	3.56	0.712	1.46	2.96	0.337
3	0.57	3.72	0.744	1.34	2.82	0.354
4	0.62	4.09	0.818	1.22	2.71	0.369

B. Double Disc System

The double rotor systems consist of a shaft mounted with two rotors A and B at its two ends. Both shafts are freely rotated in the ball bearing. In this system, Torsional vibration occurs only when rotor A and B rotate in the opposite direction. It must be noted that the natural frequency of the rotors must be the same.

The natural frequency of the double rotor Torsional vibration is $f_n = \frac{1}{2\pi}\sqrt{\frac{GJ}{I_B L_B}}$

Table IV: results of the double-disc system

Sl. No.	Length 'L' (meter)	Diameter 'd' (meter)	Time for 5 oscillations 't' sec.	Tme period for T_{exp}=t/5 sec.	$F_{n_{th}}$ =1/T_{exp} Hz.	$F_{n_{th}}$ In Hz.	Time period T_{th} =1/f_n
1	1.02	$6x10^{-3}$	2.26	0.452	2.21	3.63	0.275
2	1.02	$5x10^{-3}$	2.44	0.488	2.03	2.52	0.369
3	1.02	$4x10^{-3}$	3.69	0.738	1.35	1.61	0.619

V. CONCLUSIONS

The Torsional vibration system's design with a two-disc changeable shaft of different diameter had been fabricated. The shaft of different materials and diameters are mounted on the system, and the discs were given a manual torsion force such that the maximum vibration occurs. The system has a facility of changing the vibrations occurring to a single rotor or disc with a clamp mounted at the discs' center.

The conclusions we arrived at different materials used in systems give different values for natural frequency concluded that the material used for different engineering purposes should be given different Torsional forces to avoid wearing materials and noise.

The calculated natural frequencies were not dependent on the force given to the two discs to rotate them.

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