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Measurement of Vibration Amplitudo and Shaft Deflection with Mass Loading Variations

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ABSTRACT: *The rotating shaft receives a number of stresses that repeat and work at the same time, causing the shaft to bend at critical rotation. Repetitive movements over time intervals give rise to vibrations and deflections.*

The aim of this research is to measure the amplitude of shaft vibration using an accelerometer and Arduino sensor device. Apart from that, the shaft deflection value was also measured based on the length of the shaft and the loading using a disk on the shaft.

The method used is to create a device for making miniature rotating machines which are then used to simulate machine vibrations. Next, the ADXL345 accelerometer senses the magnitude of the amplitude that occurs on the rotating shaft. Arduino Uno becomes a signal processor to acquire data obtained from ADXL345.

A small variation in the amplitude value was obtained at a number of RPM values. The amplitude variations ranged from 0 to 0.3 mm. The largest amplitude value is obtained at the radial point Y1 position. From the critical rotation test using a deflection distance measuring sensor, the results of the critical rotation and deflection at maximum rotation were obtained, namely when the shaft reached the highest deflection. The largest critical rotation value is at a shaft length of 0.4 m with mass positions on the right and left with a maximum rotation of 2400 rpm.

NOMENCLATURE

Symbol	Description	Unit
A	Amplitude	*Amperemeter*
a	Length 1	*m*
b	Length 2	*m*
t	Time	*s*
X	X direction	
Y	Y direction	
Z	Z direction	
l	Length of shaft	*m*
N	Rotation	rpm
m	Mass	kg
f	Frequency	Hz

Greek letter

Δ	Deflection	mm

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I. INTRODUCTION

The shaft is a rotating stationary part, attached to elements such as gears, pulleys, flywheels, cranks and other power transfer elements. The shaft can accept bending, tension, compression or twisting loads, which act independently or in combination with one another. If these loads are combined, static stresses, alternating stresses and repetitive stresses will work at the same time [1].

A rotating shaft is actually not in a straight position, but rotates in a curved position. At a certain point of rotation the curvature of the shaft reaches its maximum value. The rotation that causes the shaft curvature to reach its maximum value is called the critical rotation. This situation is called the whirling shaft effect [2].

In a rotating shaft there is usually movement on both a small and large scale due to the load on the shaft. Where such a movement repeats itself at certain time intervals, the movement is known as a vibration [3]. As a result of vibrations that occur in the shaft, it can damage machine parts and cause unwanted forces.

Apart from vibrations that occur due to loading, there is also shaft deflection which will be measured by the amount of deflection that occurs and also the rotation of the shaft due to variations in the length and mass weight of the disc load [4].

Vibration measurement is one of the most common measurements in monitoring the condition of rotating machines. The higher the measured vibration value indicates that the disturbance is likely to cause damage to the machine [5]. The vibration parameters to be measured determines the type of sensor used. This is due to differences in the objects being measured and for ease of use. The eddy-current sensor is a sensor commonly used for displacement parameters, generally used to measure the displacement of the shaft relative to the bearing housing [6]. The swing coil velocity sensor is a sensor commonly used for speed parameters (velocity). Meanwhile, acceleration parameters usually use a piezoelectric accelerometer sensor. The last two sensors are usually used to measure vibrations in bearing housings [7-8].

Research regarding vibration measurements is still wide open considering that there are a number of components in moving machines. Apart from that, the influence of vibration on engine performance also still requires in-depth research, especially the many determining factors involved, including the type of material, type of damper, and so on [9]. Therefore, in this research, a prototype engine vibration measuring tool was developed using the ADXL345 accelerometer MEMS sensor. Using Arduino-based measurements, the measurements are processed until they are displayed on the LCD and PC. On the PC, Megunolink software is used to plot the measurement data. A miniature rotating machine was also created to simulate how the engine rotation conditions affect the measurement results.

II. EXPERIMENTAL SETUP

The measurement system design is described in a design block diagram which is the most important part of the process of designing and manufacturing vibration measuring instruments (Fig. 1). Miniature rotating machines simulate vibrations that occur under normal and abnormal conditions. The ADXL345 accelerometer senses the magnitude of vibrations that occur in miniature rotating machines. Arduino Uno becomes a signal processor to acquire data obtained from ADXL345 [6-7]. The LCD is a display that is installed with the Arduino. Meanwhile, Megunolink is used as data visualization software on computers.

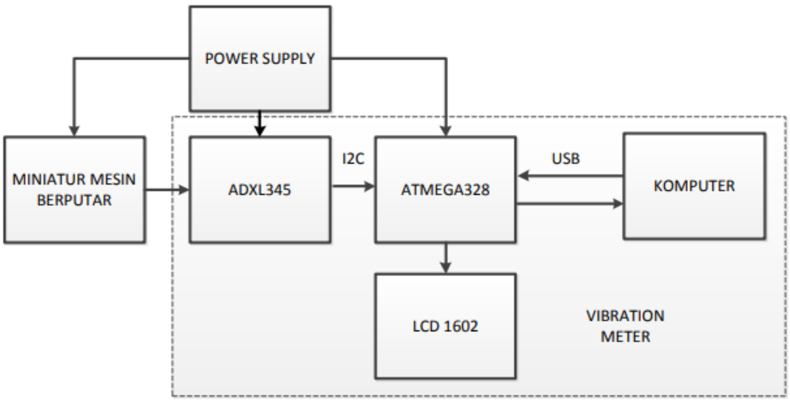


Fig. 1 Vibration measurement system design

An accelerometer is placed on a rotating machine to sense the vibration amplitude with acceleration parameters. The sensing results are then processed by a microcontroller to then display the measurement results into computer graphics.

TOOLS AND MATERIALS

The main tools and materials used in this research are:

1) Hardware (Hadware) includes ADXL345 accelerometer sensor, Arduino Uno R3, 2x16 LCD character, transformer and others.

2) Software includes Arduino IDE, Megunolink, and PCB Wizard.

MECHANICAL DESIGN

Mechanical design is the creation of a miniature rotating machine which is then used to simulate machine vibrations (see Fig. 2).

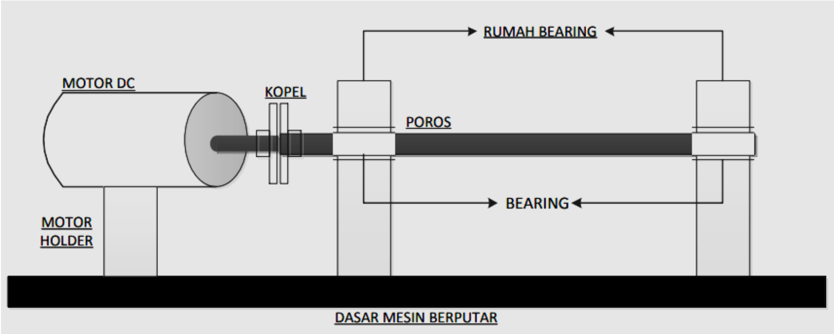


Fig. 2 Design of a miniature rotating machine

Components used in making miniature rotating machines include DC motors, bearings, bearing housings, motor holders, disruptive pendulums, couplings and bases/coasters. The motor used is a 6V DC motor. The bearings used are 22 mm outer diameter and 10 mm inner diameter.

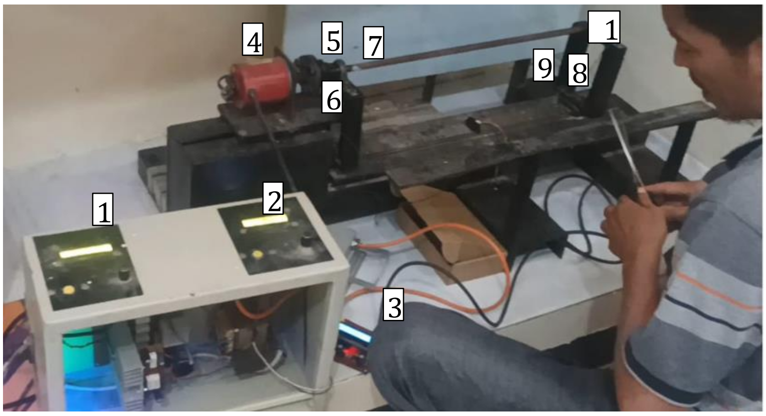
The tools used in this research are as follows

a. 12 volt 32 watt 6000 rpm DC motor.
b. ST 52 steel shaft
c. Motor rotation regulator (PID) to vary motor rotation.
d. Tachometer to measure the rotation speed of the drive rotor.
e. Infrared sensors
f. Camera as a documentation tool.
g. A ruler is used to measure the length of the shaft, the distance from which the load is placed on the shaft.
h. Grinda is used to cut shafts, solid iron and others.
i. Wrench to open and install (adjust) the bearing support shaft to suit the length of the shaft.

ELECTRONIC CIRCUIT DESIGN

In designing electronic parts, it is necessary to make a PCB (Printed Circuit Board) which can connect each electronic part into one functional circuit. The PCB manufacturing technique in this research is drawing a PCB design with the help of PCB wizard software. The resulting PCB design is then printed onto photo paper using a laser printer. The use of photo paper and a laser printer is intended so that the PCB design results in the form of wiring patterns can be attached to the CCB. After the wiring pattern is attached to the CCB, an etching process is carried out to remove the unnecessary copper layer using a ferrite solution.

Next, it displays the 1602 character LCD display media which is installed with the microcontroller. LCD character format that displays acceleration values on the x-axis, y-axis and z-axis (Fig. 3 and Fig. 4). Another viewer used to display data into a graph is Megunolink (Fig.5)..



Notes :
1. Display RPM, 2. Frequency display, 3. Deflection sensor, 4. Motor, 5. Bearing-1,
6. Accelerometer-1, 7. Shaft, 8. Accelerometer-2, 9. Bearing-2.

Figure 3 Assembly of components for measuring vibration amplitude and shaft deflection.

Fig. 4 RPM and deflection control assembly

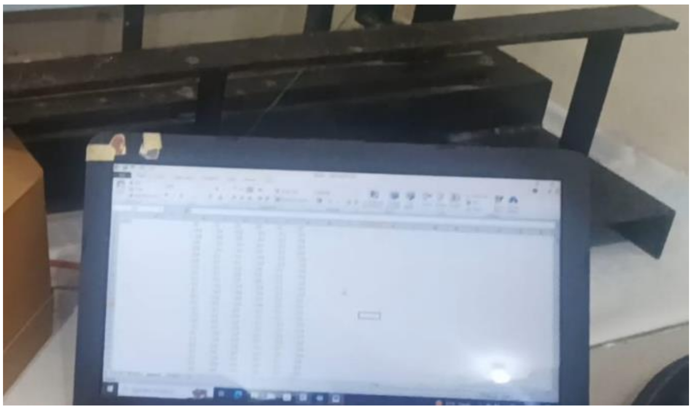


Fig. 5 Display of amplitude data results

III. RESULTS AND DISCUSSION

Data from the shaft rotation test results on amplitude values are shown in Table 1. There are small variations in the amplitude values that occur at a number of RPM values. The amplitude variations ranged from 0 to 0.3 mm. This can be categorized as stable. Except for RPM rotation above 1500, the amplitude value tends to fluctuate. deviation The furthest amplitude measured from the balance point of the vibration. occurs in a sine wave. It is also a non-negative scalar measurement of the magnitude of the wave oscillation. This is the back and forth movement of the axis from one point to returning to that point repeatedly.

It can be seen that the largest amplitude value is obtained at position Y1. This is because point Y1 is the closest point to the transmission bearing from the motor. So that point becomes the location for energy transfer from the motor to the transmission and then forwarded to the shaft (Fig. 6). Vibration is movement with an alternating pattern that only occurs around equilibrium. Waves in vibration are transverse and have a perpendicular direction of propagation. In this experiment, the deviation point or amplitude occurs due to the rotation of the shaft with variations in rotations per minute (RPM) over time. Meanwhile, the relationship with vibration frequency is calculated based on the vibration period.

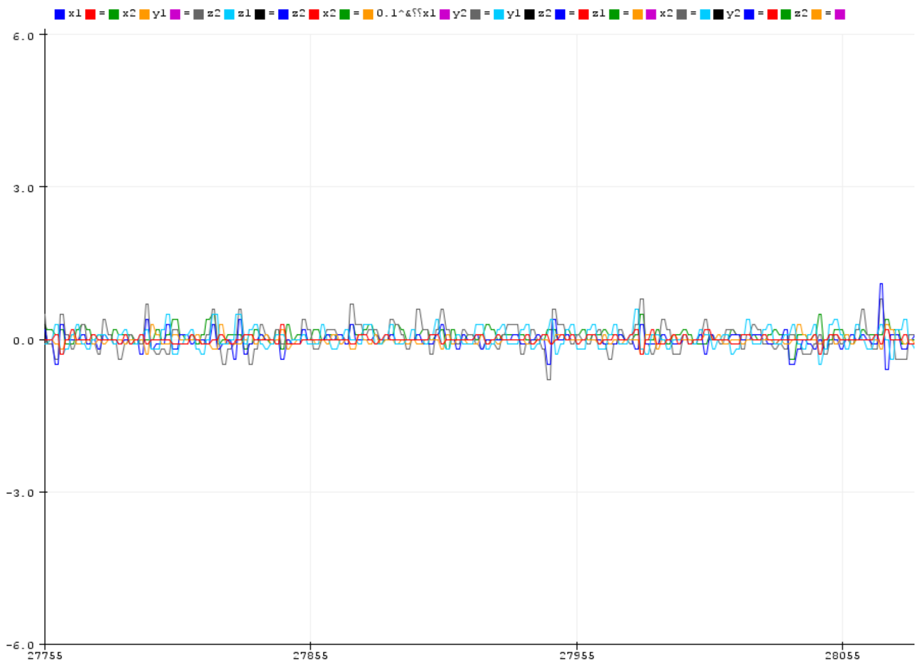


Fig. 6 Rotating shaft amplitude sensor graph

Table 1 Amplitude data regarding the position of two bearings for each x, y and z axis.

Times (s)	Axis directions					
	X1	Y1	Z2	X2	Y2	Z2
1	0.1	-0.0	0.0	0.0	0.1	0.0
2	0.1	-0.0	0.0	0.0	0.1	0.0
3	0.1	0.0	0.0	0.0	0.1	0.0
4	0.1	0.0	0.0	-0.0	0.1	0.0
5	0.1	0.0	0.0	-0.0	0.1	0.0
6	0.2	0.2	0.0	-0.0	0.1	-0.0
7	0.2	0.2	0.0	-0.0	0.1	-0.0
8	0.0	0.0	0.0	-0.0	0.0	-0.0
9	0.0	0.0	0.0	-0.0	0.0	-0.0
10	0.0	-0.3	-0.0	-0.0	-0.1	-0.0
11	0.0	-0.3	-0.0	-0.0	-0.1	-0.0
12	0.1	-0.3	0.0	-0.0	-0.2	-0.0
13	0.1	-0.3	0.0	-0.0	-0.2	-0.0
14	0.2	-0.2	-0.1	-0.0	0.1	0.0
15	0.2	-0.2	-0.1	-0.0	0.1	0.0
16	0.2	0.2	0.1	-0.1	0.1	-0.0
17	0.2	0.2	0.1	-0.1	0.1	-0.0
18	0.2	0.2	0.1	-0.1	0.1	-0.0
19	0.2	0.1	-0.0	-0.0	0.1	0.0
20	0.2	0.1	-0.0	-0.0	0.1	0.0
21	0.3	-0.0	0.0	-0.1	0.1	-0.1
22	0.3	-0.0	0.0	-0.1	0.1	-0.1
23	0.1	-0.0	-0.0	0.1	0.1	0.0
24	0.1	-0.0	-0.0	0.1	0.1	0.0
25	-0.1	0.1	0.0	-0.1	-0.1	-0.0
26	-0.1	0.1	0.0	-0.1	-0.1	-0.0
27	0.1	0.2	0.0	-0.0	-0.1	0.0
28	0.1	0.2	0.0	-0.0	-0.1	0.0
29	0.1	0.3	0.1	-0.0	-0.0	-0.0
30	0.1	0.3	0.1	-0.0	-0.0	-0.0
31	0.1	0.1	-0.0	-0.0	0.1	-0.0
32	0.1	0.1	-0.0	-0.0	0.1	-0.0
33	0.0	-0.0	0.0	-0.0	0.1	0.0
34	0.0	-0.0	0.0	-0.0	0.1	0.0
35	0.0	-0.0	0.0	-0.0	0.1	0.0
36	0.0	0.0	0.0	-0.0	0.1	-0.0
37	0.0	0.0	0.0	-0.0	0.1	-0.0

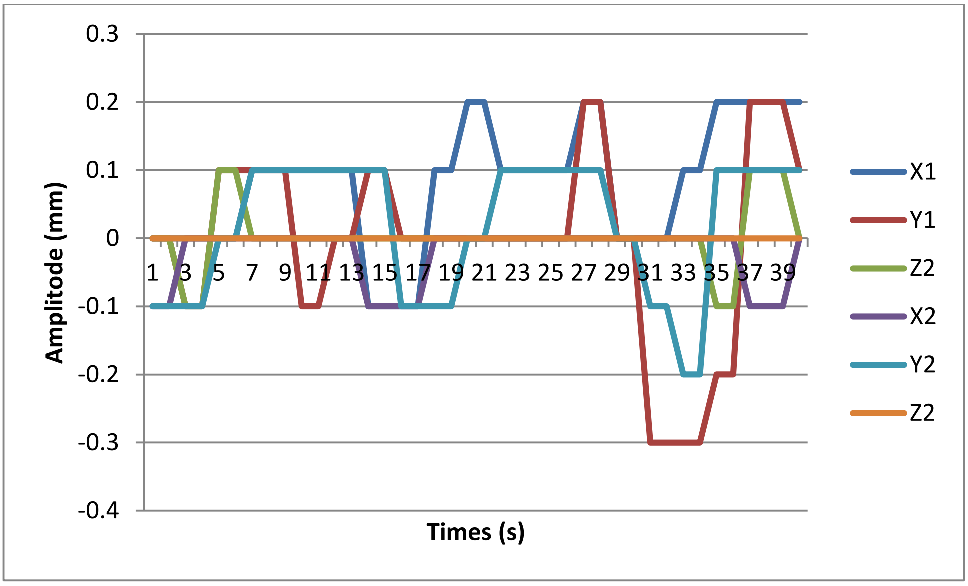


Fig. 7 Relationship between amplitude and time on two bearings in positions X,Y, and Z with a motor speed of 1400 rpm

From the results of the vibration signal analysis, it can be concluded that the spectrum of the ADXL345 accelerometer bearing normal conditions and critical rotation gives different characteristics. In normal bearing conditions, the amplitude value tends to be stable and only shows a peak at the primary frequency (1x running speed), whereas in critical rotation conditions, the amplitude value tends to vary in the frequency range 18 – 35 Hz (Fig. 7).

Table 2. Data from experimental critical cycle testing results.

Length (m)	Mass (kg)	N (rpm)	δ (mm)
	0,5	1800	1,27
0,4	1	1800	0,96
	1,5	1800	1,64
	0,5	1600	2,92
0,5	1	1800	1,82
	1,5	1400	3,24
	0,5	1800	3,22
0,6	1	1600	2,43
	1,5	1400	5,45

From the critical rotation test using a deflection distance measuring sensor, test data was obtained with 3 variations in shaft length, 40 cm, 50 cm and 60 cm. and left, middle and right disk mass positions with a fixed mass of 500 kg (Table 2).

Based on experiments, the results of critical rotation and deflection at maximum rotation are obtained, namely when the shaft reaches the highest deflection.

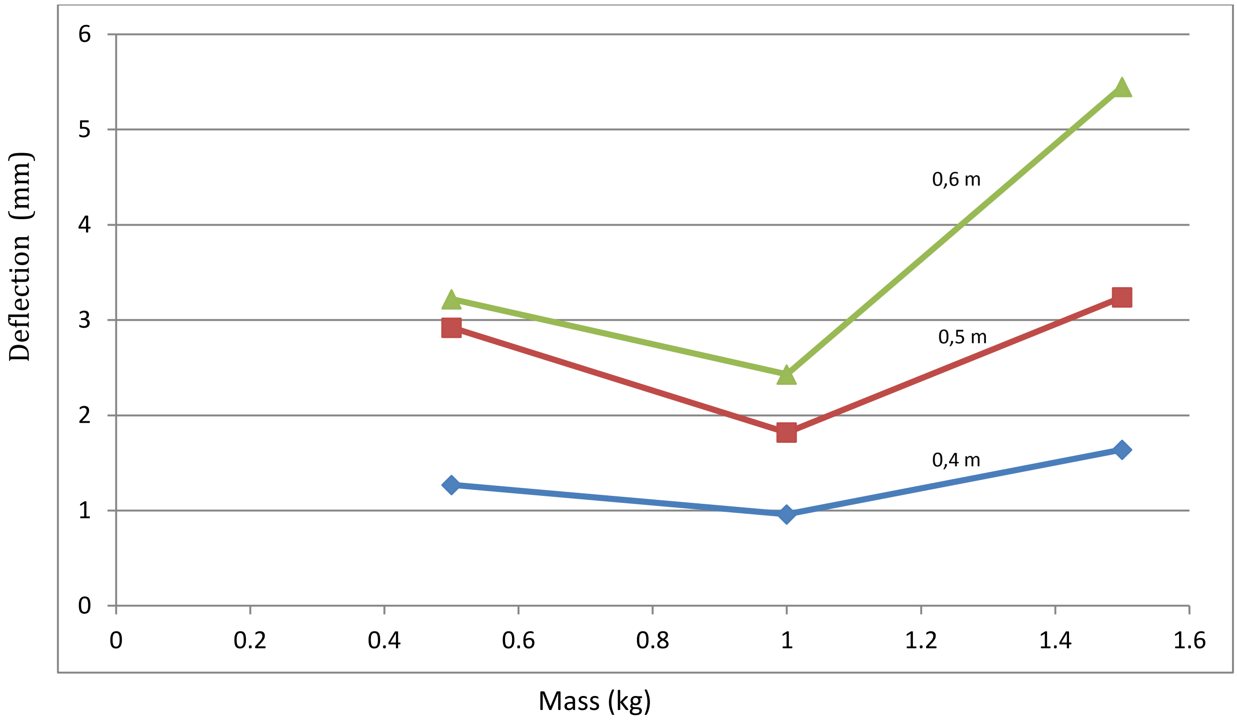


Fig. 8 Graph of the effect of disk mass on experimental deflection values

The length of the shaft affects the deflection that occurs. From the mass installed on the left, middle and right of the shaft, different deflection values are obtained according to the position of the mass.

The critical rotation values occur at shaft lengths of 0.4 m, 0.5 m and 0.6 m with the left, middle and right mass positions respectively. The largest rotation value is obtained at the shaft length of 0.4 m with the right and left mass positions with rotation. maximum 2400 rpm (Fig. 8). For the same shaft length with the mass positioned right in the middle of the shaft, the maximum rotation is 2000 rpm. This is caused by the short shaft so that the position of the left and right masses is not different because the support distance is the same. Meanwhile, the largest rotation value is at a shaft length of 0.5 m with mass positions on the right and left with a maximum rotation of 2200 rpm, for the same shaft length with a mass position right in the middle of the shaft, the maximum rotation is 1800 rpm.

Meanwhile, at the largest rotation value at a shaft length of 0.6 m with mass positions on the right and left with a maximum rotation of 2000 rpm, for the same shaft length with a mass position right in the middle of the shaft, the maximum rotation is 1600 rpm. This is caused by the short shaft so that the position of the left and right masses is not different because the support distance is the same. This is caused by the short shaft so that the position of the left and right masses is not different because the support distance is the same. When using the shaft repeatedly, the shaft is not completely straight, whereas for short shafts the rotation is greater than for long shafts.

If the deflection that occurs is smaller, then the natural frequency that occurs will be greater. Because the deflection is inversely proportional to the natural frequency. Therefore, the critical rotation that occurs on a short shaft is large because the critical rotation is directly proportional to the natural frequency. Likewise, the critical rotation will be smaller if the shaft is longer. The whirling phenomenon will be different again when the disk that functions as a ballast mass varies its mass position.

The lowest deflection was also obtained at a shaft length of 0.4 m with a disk mass of 1 kg. The deflection was obtained at 0.96 mm. At a mass of 0.5 kg, the deflection value was 1.27 mm and the highest was 1.64 mm at a disk mass of 1.5 kg. . Meanwhile, at a shaft length of 0.5 m with a load of 0.5 kg, the deflection value is 2.92 mm and 1 kg has a deflection value of 1.82 mm, 1.5 kg has a deflection value of 3.24 mm and the largest deflection is in the disk mass. 1.5 kg by 3.24 mm. At a length of 0.6 m, the largest deflection was obtained for a 1.5 kg disk mass of 5.45 mm, while for disk masses of 0.5 kg and 1 kg, deflections were 3.22 mm and 2.43 mm. This phenomenon shows that the deflection that occurs increases with the addition of mass as ballast and due to the influence of the longer shaft.

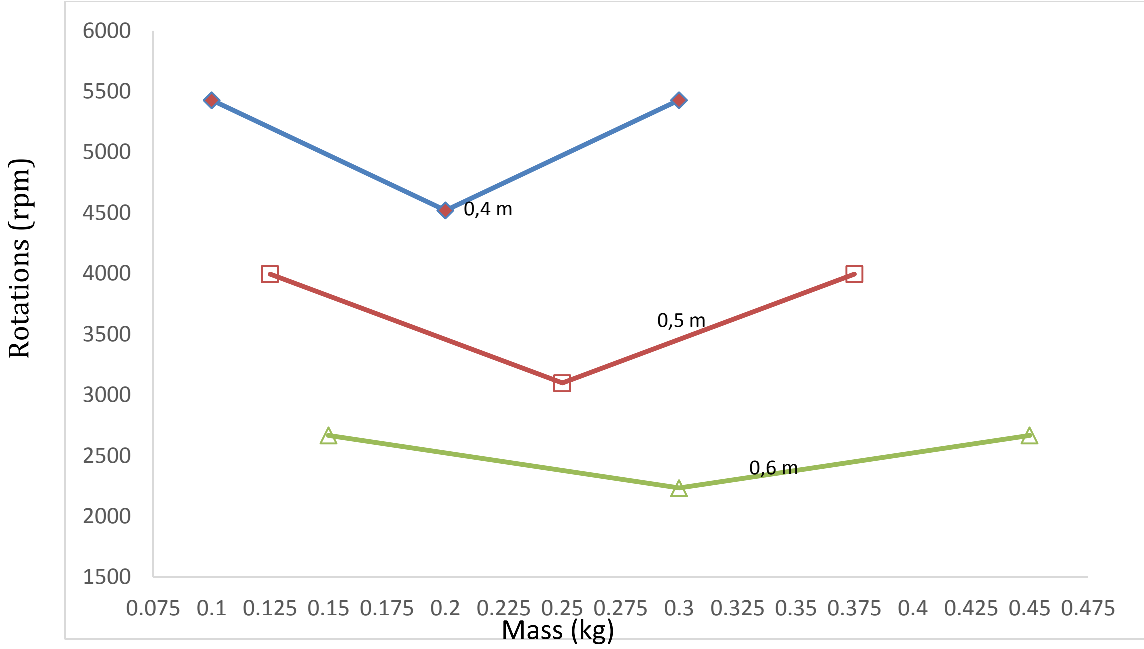


Fig. 9. Effect of rotation on mass position.

From Fig. 9, the relationship between rotation and disk mass theoretically shows that the smallest rotation is 2289 rpm for a shaft length of 0.6 m with a mass of 1.5 kg, for masses of 1 kg and 1.5 kg, rotation is obtained at 2441 rpm and 2629 rpm in this case there is an increase due to the smaller variation in the given mass. Meanwhile, for a length of 0.5 m with a mass of 0.5 kg, the rotation is 3596 rpm, for a mass of 1kg the rotation is 3321 rpm, and for a mass of 1.5 kg, the rotation is 3100 rpm. And for a length of 0.4 m, the largest rotation was 3463 at a mass of 0.5 kg, and for masses of 1 kg and 1.5 kg, the rotation was 2625 rpm and 1918 rpm. This rotation value is compatible with theoretical formula.

IV. CONCLUSION

There is a small variation in the amplitude value caused by a number of RPM values. The amplitude variations ranged from 0 to 0.3 mm. This can be categorized as stable. Except for RPM rotation above 1500, the amplitude value tends to fluctuate. The largest amplitude value is obtained at the radial point Y1 position. This is because point Y1 is the closest point to the transmission bearing from the motor. So that point becomes the location for energy transfer from the motor to the transmission and then forwarded to the shaft.

From the critical rotation test using a deflection distance measuring sensor, the results of the critical rotation and deflection at maximum rotation were obtained, namely when the shaft reached the highest deflection. The length of the shaft affects the deflection that occurs. masses installed on the left, middle and right of the shaft obtain different deflection values according to the position of the mass. The largest critical rotation value is at a shaft length of 0.4 m with the right and left mass positions with a maximum rotation of 2400 rpm. For the same shaft length with the mass positioned right in the middle of the shaft, the maximum rotation is 1800 rpm.

REFERENCES

[1]. Amiruddin M. B., Haryadi, G. D. and Umardani, Y. [2023] "Analysis of failure of the hydraulic power unit (HPU) shaft in the pump hydraulic axial 1000 LPS" Journal Teknik Mesin, Vol. 11, Issue III: pp. 5-10.
[2]. Endriatno, N. [2021] "Analysis of vibration due to unbalanced mass on a rotating motor" Dinamika : Journal Ilmiah Teknik Mesin, Vol. XII, Issue II: pp. 58-65.
[3]. Ferrina, Q., Ratna Sulistiyanti, S., and Junaidi [2022] "Accelerometer sensor calibration testing results ADXL345" Journal Theory and Aplikasi Fisika, Vol. X, Issue II: pp. 187–196.
[4]. Kalili, S., Thenu, N. L. T., Noya, M. F., & Hadi, A. [2022] "Analysis of torsional vibration of propeller shaft on KN ULAR LAUT 405" ALE Proceeding, Vol. V, pp. 37–45.
[5]. Mahmudin, O.F. [2023] "Functional test and validation analysis of axle critical rotating test equipment with load" Journal ALMIKANIKA, Vol. V, Issue III.
[6]. Poernomo, H. [2015] "Measurement of torsional vibration on a rotating shaft using the digital image processing method. Kapal: Journal Scienceand Maritim Technology, Vol. XII, Issue II: pp. 106–111.
[7]. Nugroho, D. A., Naubnome, V., & Hanifi, R. [2022] "Analysis of shaft and peg calculations in modern brand hand grinders M-2300B" Wahana Education Scientific Journal, Vol. XIV: pp. 24–28.

[8]. Rohman, A. [2015] "Design and construction of vibration measuring instruments using micro electro mechanical system sensors" (Mems) Akselerometer Edu Electrical Journal, Vol. IV, Isuue I: pp. 8-16.
[9]. Zainal A., Gustini, M. Bimo Cahyo, P. [2017] "Design of a vibration measuring tool to detect damage to bearings", National Symposium AVoER IX, Palembang, 29 November 2017, Engineeering Faculty, University of Sriwijaya.