

Measurement of Rotational Inertia (Ring and Disc) with High Percentage Accuracy Using Rotary Motion Sensor and Three Step Pulley

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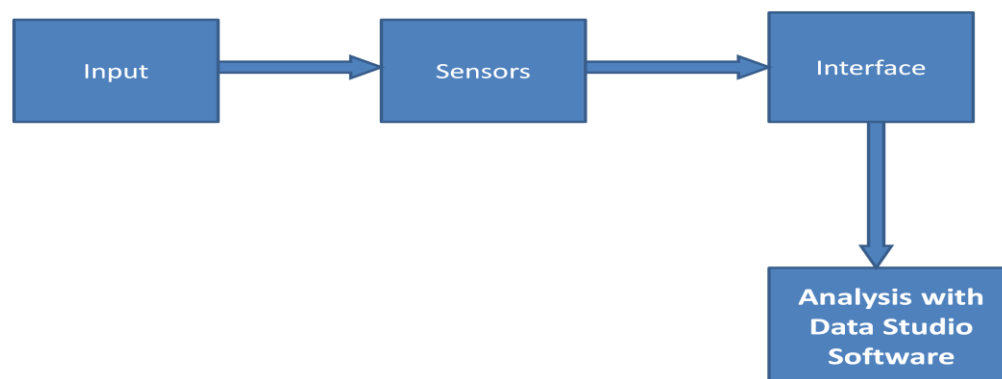
Abstract

This paper describes the experimental work to measure the Rotational Inertia using a Rotary motion sensor and a three step pulley, and analysis with data acquisition software. The result of this experiment provides high percentage accuracy in the measurement of Rotational Inertia; importance of sensors to analyze the Angular acceleration and Rotational Inertia in order to obtain accurate measurements.

Key Words: Rotational Inertia, Rotary Motion Sensor, Interface-500, Data Acquisition Software and Percentage Error.

1. Introduction

The conventional way to measure the rotational inertia of a ring and a disk is that we have slide the ring and disc from the top of the sliding surface and then find the rotational inertias towards the difficulty in the execution and also the exact estimation of time period in the rotational Inertia formula. The traditional approach is difficult to execute and data is rarely sufficient for an understanding of relationship of the Rotational Inertia with mass and the radius. The difficulties are removed by the adopting a modern experimental technique by using sensors to measure the Rotational Inertia and angular velocity of the Ring and Disc as rotates and verify that these values correspond to the calculated theoretical values. A known torque is applied to the pulley on the Rotary Motion Sensor, causing a disk and ring to rotate. The resulting angular acceleration is measured using the slope of a graph of angular velocity versus time.



1.1. Rotary Motion Sensor

The sensor is designed for the move in bidirectional position. It contains an optical encoder which gives a maximum of 1440 counts per revolution (360 degrees) of the rotary motion sensor shaft. The resolution can be set by software to 360 or 1440 times per revolution (1 degree or $\frac{1}{4}$ degree). The direction of rotation is also sensed. The 3-step pulley keys into the rotating shaft and can be mounted on either end of the shaft.

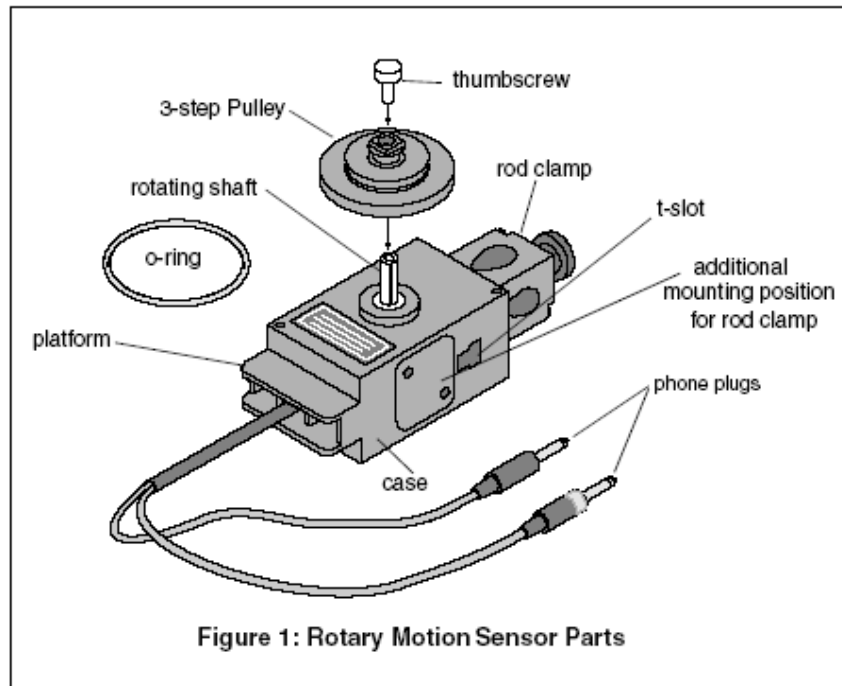


Figure 1: Rotary Motion Sensor Parts

1.2 Use of Rotary Motion Sensor or its (related work)

- Measure the Rotational Inertia of Ring and Disc.
- Measure the Torque applying on three step pulley.
- Measure the change of Angular velocities and Angular Acceleration.
- Study damped and undamped harmonic motion using a mass and string system.

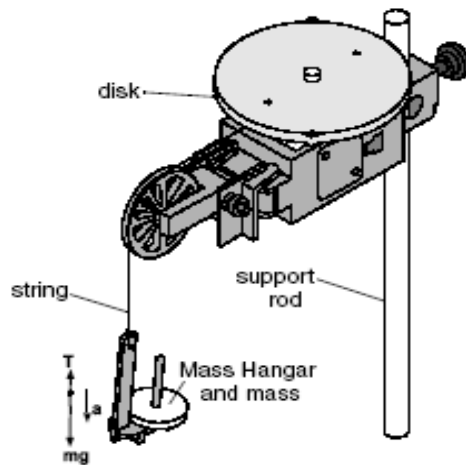


Figure Rotary Motion Sensor and Free Body Diagram

1.3 Specifications

3-Step Pulley :10mm ,29mm,and 48mm diameters

Resolution: 1° and 0.25°

Accuracy: +/- 0.09 degrees

Maximum Rotation Speed : 13 rev/sec at 1° resolution
 3.25 revs/sec at 0.25° resolution

Default Sample Rate: 10 samples/ second

Maximum Sample Rate: 1000 samples /second

2. Experimental Setup

The apparatus is set to find the rotational inertia of a ring and a disk experimentally and to verify that these values correspond to the calculated theoretical values. A known torque is applied to the pulley on the Rotary Motion Sensor, causing a disk and ring to rotate. The resulting angular acceleration is measured using the slope of a graph of angular velocity versus time.

Theoretically, the rotational inertia, I , of a ring is given by

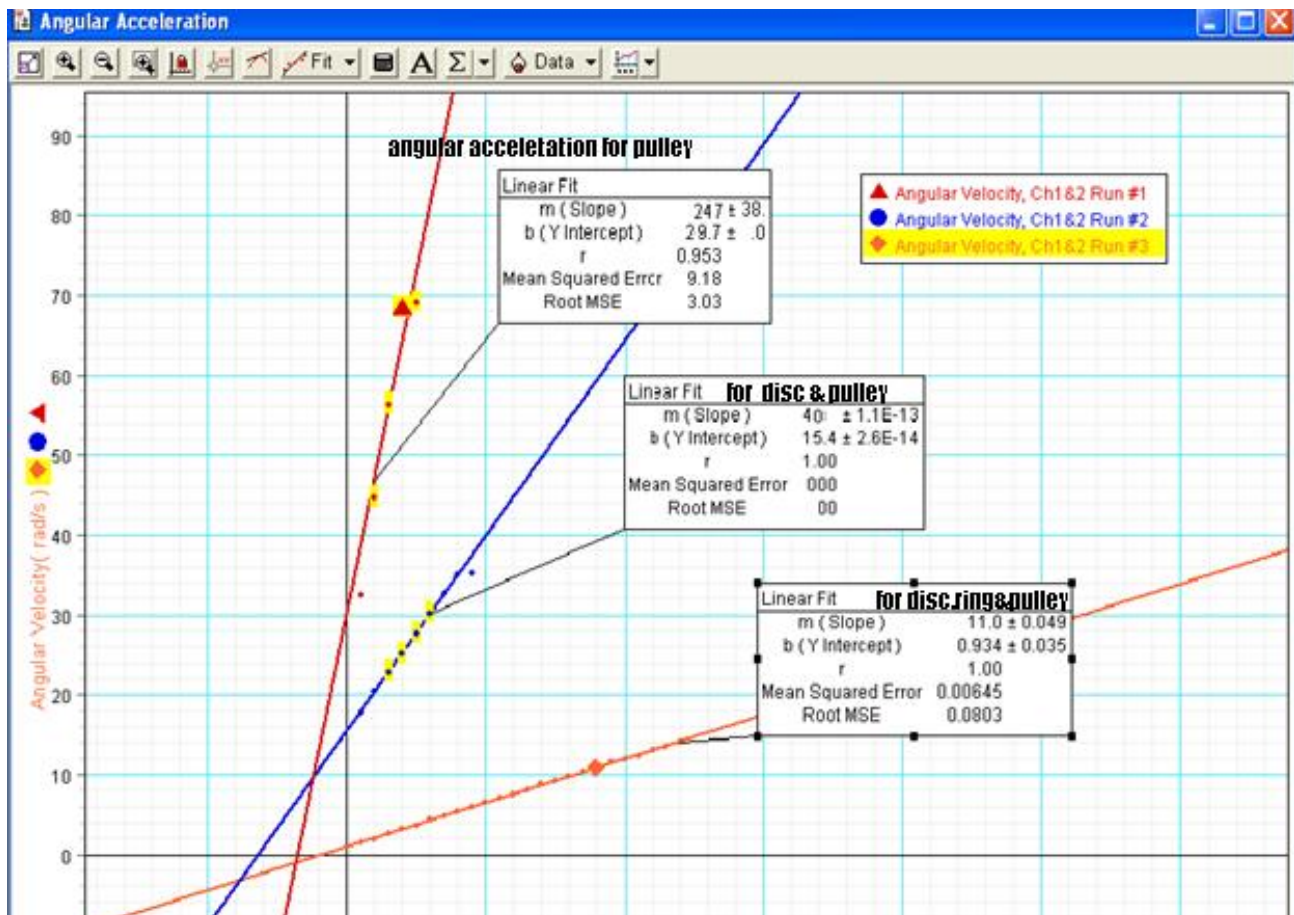
$$I = \frac{1}{2} M (R_1^2 + R_2^2) \tag{1}$$

where M is the mass of the ring, R_1 is the inner radius of the ring, and R_2 is the outer radius of the ring. The rotational inertia of a disk is given by

$$I = \frac{1}{2} MR^2 \tag{2}$$

where M is the mass of the disk and R is the radius of the disk.

3. Graphs and Calculations



Graph: Angular Velocity and Time

3.1 Graphical Analysis

The graph is between angular velocity and time whose slope gives the angular acceleration (rad/sec²). The slope of the orange line represents the angular acceleration for disc+ring+pulley. The slope of the blue line gives the angular acceleration for disc +pulley and that of red line is the angular acceleration for the pulley. This graph shows that angular velocity is directly proportional to the time

3.2 Calculations

(Radius) _{pulley}	=	0.015m
(Mass) _{disc}	=	0.12k g
(Diameter) _{disc}	=	0.095m
(Radius) _{disc}	=	0.041m
(Mss) _{ring}	=	0.468kg
(Internal diameter) _{ring}	=	0.054m
(External diameter) _{ring}	=	0.0765 m
(Internal radius) _{ring}	=	0.027m
(External radius) _{ring}	=	0.038m

Using eq # (1) and eq no (2) to find the rotational inertia of Ring and disc,

$$I = \frac{1}{2}M(R_1^2 + R_2^2) \text{ and } I = \frac{1}{2}MR^2 \text{ respectively,}$$

$$(I)_{\text{ring}} = 5.08 \times 10^{-4} \text{ kg m}^2.$$

$$(I)_{\text{disc}} = 1.34 \times 10^{-4} \text{ kg m}^2.$$

Calculate the experimental value of the rotational inertia of the Rotary Motion Sensor ring and disc.

$$\alpha_{1(D+R+P)} = 11.0 \text{ rad/s}^2$$

$$\alpha_{2(D+P)} = 40.0 \text{ rad/s}^2$$

$$\alpha_{3(P)} = 247.0 \text{ rad/s}^2$$

$$m = 50 \text{ g}$$

Now calculate the experimental value of the rotational inertia of the ring and disc.

$$I_1 = r_p mg / \alpha_1 - m r_p^2 = 6.97 \times 10^{-4} \text{ kgm}^2$$

$$I_2 = r_p mg / \alpha_2 - m r_p^2 = 139 \times 10^{-4} \text{ kgm}^2$$

$$I_3 = r_p mg / \alpha_3 - m r_p^2 = 1.84 \times 10^{-4} \text{ kgm}^2$$

Calculate the experimental values of the rotational inertia of the ring and disk .

$$\text{Rotational Inertia of ring} = I_1 - I_2 = 5.51 \times 10^{-4} \text{ kgm}^2$$

$$\text{Rotational Inertia of Disc} = I_2 - I_3 = 1.37 \times 10^{-4} \text{ kgm}^2$$

Use percent differences to compare the experimental values to the theoretical values.

$$\text{For ring} = \% \text{ difference} = \left| \frac{\text{Experimental} - \text{Theoretical}}{\text{Theoretical}} \right| \times 100 = 8\%$$

$$\text{For disk} = \% \text{ difference} = \left| \frac{\text{Experimental} - \text{Theoretical}}{\text{Theoretical}} \right| \times 100 = 3\%$$

3.3 Conclusion

From the last calculation It has been concluded that moment of inertia of ring is larger than a disc. There is 8% error of ring in our experiment that is random error. And there is of 3% error of disk in our experiment. That is also a random error.

Moment of inertia is also depending upon the mass of body. Greater the mass greater will be moment of inertia less the mass less will be moment of inertia.

4. References

[1]Pasco CI-6538

[2]Pasco CI-6693

[3] www.pasco.com

[4] www.google.com