The Improvement of Angular Acceleration Measurement in Rotational Rigid Body Inertia Experiment

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Abstract: In measurement of rigid body inertia by the falling body method, we obtain the angular acceleration through the angle sensor measuring angular velocity, instead of photo gates measuring angular displacement. By using angle sensor, the formula of angular acceleration becomes simple and the improved method has a result with higher accuracy.

Key words: angular acceleration; rotation inertia; angle sensor

The measurement experiment of rigid body’s moment of inertia can deepen students’ understanding of the fixed axis rotation theorem and the nature of the moment of inertia. It is a compulsory basic physics experiment for science and engineering students.

In the experiment of measuring the moment of inertia of a rigid body by using the constant moment rotation method, according to the law of fixed axis rotation of a rigid body, only the total external moment of the rigid body when it rotates is measured , and the angular acceleration of rigid body rotation under the action of this moment , the moment of inertia of the rigid body can be calculated , therefore angular acceleration the accurate measurement of is very important. The traditional photoelectric gate uses a counter to record the number of occlusion times and the corresponding time, selects any two groups of data to eliminate the initial angular velocity and then calculates the angular acceleration. This formula is more complex and cannot directly reflect the rotation of the rigid body. In addition, due to the limitation of the height of the operating platform, the original experimental device provided weights with constant torque, and the walking distance was relatively short. For students who were not skilled in operation, the measurement data of the light switch had not been completed before the weights landed, resulting in large experimental errors.

We use an angle sensor to measure the angular velocity of rotation at an equal time interval directly calculate the angular acceleration, and can draw the figure directly reflects the rotation of the rigid body and timely finds the abnormal height value. In addition, we set the time interval to 0.3s. Without changing the walking distance of the weight, more data can be obtained by using the angle sensor, which improves the accuracy of the results and reduces the experimental error.

1 Measuring principle of moment of inertia

As shown in Figure 1, in ZKY-WZS rotary inertia tester, the winding tower wheel is installed on the main shaft through a specially made bearing, so that the friction moment during rotation is very small. The loading platform is connected with the tower wheel with screws and rotates with the tower wheel. Compared with the experimental platform, the moment of inertia of aluminum small pulley can be ignored.

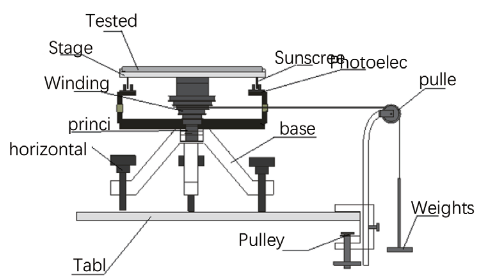

Fig. 1 Schematic diagram of tower wheel type moment of inertia tester

According to the fixed axis rotation law of rigid body, the no-load stage rotates at a uniform deceleration under the action of friction resistance torque:

$$-M_{\mu}=I\beta_{派} \tag{1}$$

The quality is the weight of is wound by a thin wire with a radius of and let the weight fall through the fixed pulley, and the system makes uniform acceleration movement under the action of constant external torque:

$$m(g-R\beta_{加})R-M_{\mu}=I\beta_{加} \tag{2}$$

The above two types are simultaneous, eliminating the resistance torque<p mtid=’216 ‘/>M_{μ}, the moment of inertia of the measured rigid body can be obtained I:

$$I=\frac{mR(g-R\beta_{加})}{\beta_{加}-\beta_{减}} \tag{3}$$

It can be seen from the above formula that the angular acceleration in the experiment β the accurate measurement of is very important. We will optimize the angular acceleration β the determination method of β the solution of is more simple and intuitive.

2 Photogate for measuring angular acceleration

The rotating inertia experimental device used in the original experiment is shown in Figure 2. Peripheral edge difference of stage two light shielding thin rods are fixed at the corners, and each half turn blocks the photoelectric door fixed on the base once, which generates a counting photoelectric pulse.

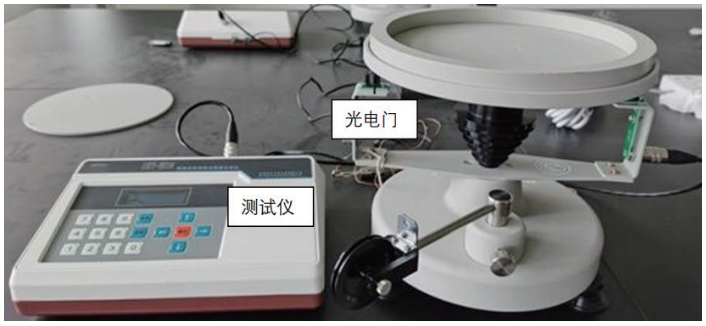

Fig. 2 Experimental device before improvement

In the experiment, a general computer meter was used to record the number of files blocked K and corresponding time t. If the light is blocked for the first time(K=0,t=0)Start counting and timing, and the initial angular velocity is ω_0, then any two groups of data measured in the constant velocity movement(K_1, t_1),(K_2, t_2), corresponding angular displacement θ_1, θ_2 they are:

$$\theta_1 = K_1\pi = \omega_0 t_1 + \frac{1}{2}\beta t_1^2 \quad (4)$$

$$\theta_2 = K'_2\pi = \omega_0 t_2 + \frac{1}{2}\beta t_2^2 \quad (5)$$

Deleted from (4) and (5) , we can get:

$$\beta = \frac{2\pi(K_2 t_1 - K_1 t_2)}{t_2^2 t_1 - t_1^2 t_2} \quad (6)$$

3 Angle sensor measures angular acceleration

We modified the original instrument, used the ATK-IMU901 angle sensor to measure the acceleration of the object, coupled with Bluetooth HC-05 to transmit the data to the mobile phone, and used the STM32 microcontroller to integrate the above components into the printed circuit board, as shown in Figure 3 (a). We fix it under the platform of the moment of inertia tester. In order to make the shaft connecting the stage and the base bear uniform force, we symmetrically install a counterweight plate with the same weight as the single-chip board. Compared with the original equipment, the improved device no longer requires a tester and a photoelectric door, as shown in Figure 3 (b).

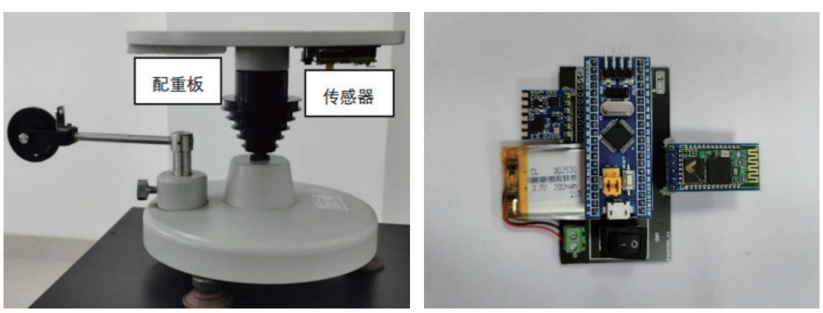

Fig. 3 (a) Integrated circuit board of sensor, bluetooth and microcontroller; (b) Improved experimental device

In the experiment, the measuring range of the angle sensor is set to , the accuracy is 0.05 °, and the number of times shall be recorded every 0.3s. According to the calculation formula of uniform speed change rotation

$$\omega=\omega_0+\beta t \quad (7)$$

Measure any two groups value to eliminate the initial angular velocity , the value of angular acceleration can be obtained:

$$\beta=\Delta\omega/\Delta t \quad (8)$$

The advantages of using equal time interval to record angular velocity are as follows:

1. The reliability of sampling data increases. When using weights to generate tension moments to measure angular acceleration, after the weights are released, it is necessary to wait for the load tray to rotate stably before starting the measurement, and stop the measurement before the weights are about to land, otherwise the instrument will record wrong data. Due to the height limitation of the operating platform, the eight times counting of the original photoelectric gate is not sufficient in time, especially when selecting a tower with a smaller radius, the experimental error is large. After the sensor is used to measure the speed, the measurement of equal angular displacement becomes the measurement of equal time interval. We set the time interval to be shorter. After the weight falls steadily and is about to fall, we can still

obtain more experimental data than the traditional photoelectric gate, and the reliability is greater.

2. The evaluation is simple and accurate, and the image is intuitive. The angular acceleration is given by Formula (8), and the result can be obtained by least square fitting, which is simpler than the original formula (6). In the experiment, when the load tray is moving at a constant speed, if the force applied by turning the load tray by hand is uneven, or there is a large swing before the weight is released, it will make the height anomaly in the figure affects the calculation results. By drawing fig., these abnormal values can be found in time to avoid human error in experimental operation.

4 Conclusion

In the rigid body moment of inertia measurement experiment, we reset the angular acceleration measurement method, using an angle sensor, at equal time intervals angular velocity of a rotating rigid body with constant acceleration (deceleration) measured internally the change of, by the formula the angular acceleration can be calculated concisely. After speed measurement based on sensor, compared with the instrument before improvement, under the same conditions, the improved instrument can obtain more data in a single measurement, which not only improves the accuracy of experimental measurement, but also can plot the figure directly reflects the rotation of the rigid body and reduces the experimental error.

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