Angular Velocity and Acceleration Using Logger Pro Magnetic Sensor

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Abstract. The Circular motion is one of physics learning topic that has number of physics parameter. There are angular velocity and angular acceleration. They are can be calculated and measured. The aim of this research is to measure angular velocity and angular acceleration using logger pro magnetic sensor on the top of the propeller by varying the speed fan. There is a magnet bar that is attached on propeller top surface. The magnetic sensor is placed on the top of it. The distance is 0.01 meter. The motion of the magnet bar follow the circular motion of the propeller. Hence, circular motion can be tracked by plotting the magnetic field intensity over time. The maximum angular velocity of speed 1, speed 2, speed 3 were 5.709 rad/s, 10.467 rad/s, and 10.467 rad/s, respectively. The maximum angular acceleration of speed 1, speed 2, speed 3 were 0.594 rad/s², 2.492 rad/s², and 2.492 rad/s², respectively. The measuring of angular acceleration for each speed are obtained by value that are different. This is due to wind speed and the changed rotation that are different.

1. Introduction

The circular motion is one of subject of physics learning emphasizing for a knowledge, skill, and attitude. Since, they are categorized as the student’s standard of competence[1]. However, in the classroom, the students only learn about the example of circular motion without the investigation activity on the physical parameter of circular motion[13].

The experiment as one of the most important subject to the students for developing skill and knowledge[2]. Hence, it is needed some experiment for doing investigation physics parameter on the circular motion[10].

The example of circular motion is the movement of the propeller. The physics parameter that can be measured angular velocity and angular acceleration[12]. The measurement of angular velocity and angular acceleration can be done by the sensor technology[15]. It is the important tools to develop measurement analysis and new product development.

Magnetic sensor can be used to measure magnetic field of permanent magnet, coil and electrical device. The working principle follows the Hall effect transducer. The Vernier magnetic sensor can be
used to measure transversal and longitudinal[7]. The data can be displayed on the screen by using Logger Pro[14]. It also can be used for analyzing the curve shape[3].

2. Method

The method to perform the research is the experimental method. A fan as the wind source can be adjusted to three different speed. The fan is generated by 200 V AC voltage, 50 Hz frequency and 35 Watt electrical power. The blade of fan is 0.25 cm in diameter. Vernier magnet sensor and Logger Pro software were used to record and analyze the data. The sensor was measuring the Neodymium magnet magnetic field. The measured magnetic field is 5.723 mT. Laptop with Windows10 pro 64 bit 4GB RAM was utilized to obtain, analyze and store the data. The wind blows from the fan will rotate propeller. The following experimental procedure: The experimental apparatus are assembled as shown in Figure 1. The magnet is attached on propeller top surface so that it can be read by the magnetic sensor. Magnetic sensor is connected with LabQuest to convert signals on magnetic sensors into numerical data so that they can be displayed on laptops using Logger Pro software. The position of the magnetic sensor is set in such a way that will not be distracted by the motion of wind. The propeller distance is set to obtain optimal distance. Logger Pro software is turned on. The fan is turned on and the blade speed is set. The T period is obtained from the rotation of the propeller. Angular velocity ω and angular acceleration α are analyzed.

![Figure 1. The experimental apparatus setup](image)

The data analysis is done by the Logger Pro software to display the results of data that is read by LabQuest on the magnetic sensor. Furthermore, the data will be processed to determine the average period value, the angular velocity value ω_T using equation(1):

\[ \omega_T = \frac{2\pi}{T} \] (1)

The angular velocity value (ω_slope) is obtained by using linear data fittings. The angular acceleration value can be calculated by using equation(2)[5]:

\[ \alpha = \frac{\omega_{\text{final}} - \omega_{\text{initial}}}{\Delta t} \] (2)

Which \( \omega_{\text{final}} \) is the final angular velocity and \( \omega_{\text{initial}} \) is the initial angular velocity. The calculation results obtained from angular velocity value \( \omega_T \) and linear data fittings will then be analyzed using the errata theory. The theory of error is

\[ \Delta \omega = |\omega_{\text{slope}} - \omega_T| \] (3)
3. Results And Discussion

Before this experiment is conducted, it is necessary to measuring the wind speed using an anemometer. The wind speed is obtained by measuring the amount of wind speed during a constant state. Since, there are condition of accelerating and decelerating wind. The value of wind speed can be seen in table 1.

| Speed the fan | Wind speed (m/s) |
|---------------|-----------------|
| Speed 1       | 0.7             |
| Speed 2       | 0.8             |
| Speed 3       | 1.0             |

The propeller need to be placed at optimal distance from the fan. The optimal distance is the distance where the propeller rotate in medium angular velocity. Hence, that the magnitude of the magnetic field peak can be read by the sensor. The optimum distance is 2.3 meters.

The propeller will rotate because of the wind. The magnet attached to the propeller will rotate following the rotation of the propeller. The data of the magnetic field respect to the time for each different speed are shown in Figures 2, 3 and 4. The fan is turned off at 20 seconds.

![Figure 2](image)

**Figure 2.** The magnetic field on speed 1

![Figure 3](image)

**Figure 3.** The magnetic field on speed 2

![Figure 4](image)

**Figure 4.** The magnetic field on speed 3

The magnitude of the magnetic field value is determined by its distance. Hence, the variation in the magnetic field value is the effect of the magnetic distance on the magnetic sensor [8,11]. The calculation of the period is determined by time interval between two successive magnetic field peak. For one period, it is calculated by the difference in time from peak one ($t_1$) to the other peak ($t_2$).
As a comparison of calculations in determining the period, measurements are also made using a tracker. The tracker software will track the propeller motion from the video. The measurement results can be seen in figure 5 and table 2.

![Figure 5. Track the propeller](image)

**Table 2.** Results of period measurement using tracker and sensor

| Period to- | Measurement with tracker | Measurement with sensor | Percentage errors |
|-----------|--------------------------|-------------------------|-------------------|
| 1         | 4.9                      | 4.9                     | 0%                |
| 2         | 1.8                      | 2.1                     | 14%               |
| 3         | 1.2                      | 1.5                     | 20%               |
| 4         | 1.5                      | 1.5                     | 0%                |
| 5         | 1.1                      | 1.4                     | 21%               |
| 6         | 1.2                      | 1.3                     | 8%                |
| 7         | 1.1                      | 1.3                     | 15%               |
| 8         | 1.1                      | 1.3                     | 15%               |
| 9         | 1.1                      | 1.1                     | 0%                |
| 10        | 1.1                      | 1.1                     | 9%                |
| 11        | 0.9                      | 1.0                     | 10%               |
| 12        | 1.1                      | 1.1                     | 9%                |
| 13        | 1.1                      | 1.3                     | 15%               |
| 14        | 1.4                      | 1.5                     | 7%                |
| 15        | 1.6                      | 1.8                     | 11%               |
| 16        | 2.6                      | 2.6                     | 0%                |

average percentage error 9.7%
Based on table 2, the percentage of errors obtained is in the range of 0% - 21% with an average of 9.7%. The average value of error percentage obtained from measurements using tracker and sensor is below 10% so that period measurements using sensors can be used.

The measurement of the period has been repeated for 3 times to get the average value of period. The propeller angular velocity for each speed can be calculated using equation (2) and the period. The graph of the angular relationship velocity can be seen in Figures 5, 6, and 7.

**Figure 6.** Graph of angular velocity relationship with period at speed 1

Based on Figure 5, it can be concluded that the value of the angular velocity obtained at speed 1 changes with time. In the 1st until 6th period, the angular velocity is increasing. Then, it is constant until the 9th period. The angular velocity begins to slow down in the 11th period.

**Figure 7.** Graph of angular velocity relationship with period at speed 2

Similar behavior occurs at speed 2 as seen in figure 7. The angular velocity is increasing during the 1st until the 9th period. The constant angular velocity occurs during the 9th period until the 22nd period. The angular velocity begins to slow down in the 23rd period.

**Figure 8.** Graph of angular velocity relationship with period at speed 3

Figure 8 shows that the angular velocity at speed 3 also varies. The angular velocity is increasing during the 1st until the 10th period. The constant angular velocity occurs during the 12th period until the 20th period. The angular velocity begins to slow down in the 24th period.
Moreover, the angular velocity can also be determined by performing linear data fittings. The data fittings follow equation 4[9].

\[ \dot{\theta} = \alpha t \]  \hspace{1cm} (4)

The plotting angular velocity versus time over 1 period[4] is shown in figure 9.

![Figure 9. fitting angle linear data for a time](image)

Hence, based on figure 9, the angular velocity can be determined since it is the slope value. The linear data fittings are carried out for all period and for each speed and are made plotting the position of the magnet that is attached to the propeller against time. Then, the fitting results are compared with the calculated angular velocity using the magnetic field peak period. They are exactly the same. Hence, the error is zero.

The angular acceleration can be calculated using the angular velocity by using equation (2). The angular acceleration for each speed can be seen in Figure 10, 11, and 12.

![Figure 10. The angular acceleration versus time at speed 1](image)
Based on Figures 9, 10, and 11 the red vertical and blue vertical line indicate the beginning and ending of constant acceleration, respectively. The fan stops at the period that is indicated by blue vertical line. At speeds of 1, 2, and 3 the angular acceleration starts constant at periods 9, 10, and 15. The angular acceleration obtained in the propeller accelerates and decelerates. Angular acceleration accelerates because the angular velocity increases and decelerates because the angular velocity decreases[6].

4. Conclusion

The angular velocity measurements using the magnetic field peak period calculation has same value with the calculation by data fitting. The greater speed the higher number of period is achieved before the constant angular acceleration occurs. This is due to the propeller blade rotate faster as the fan speed increasing.

References

[1] Siti Chodijah, Ahmad Fauzi and Ratna Wulan 2012 J. Pe. Pem. Fis. 1 1-19
[2] Desy, Desnita and Raihanati 2015 Pro. Sem. Nas. Fis. 4 39-44
[3] Nur Ikhwan and Dr. Yudhiakto Pramudya 2018 Wah. Fis. 3 11-18
[4] Pili Unofre and Renante Violanda 2018 Phys. Teach 56 114-115
[5] Mathaios Patrinopoulus and Chrysovalantis Kefalis 2015 Phys. Teach 53 564-565
[6] Paul A Tipler 1998 Fisika Untuk Sains dan Teknik jilid 1 Erlangga
[7] Vernier Magnetic Field Sensor 2018 Website: www.vernier.com/products/sensors/magnetic_field-sensors/mg-bta/
[8] Pili Unofre, Renante Violanda. and Claude Cenize 2018 The Physics Teacher 56 258-259
[9] H.D. Young. R. A. Freedman. And A. L. Ford 2012 Sears and Zemansky’s University Physics Addison-wesley
[10] Salih Demircioglu and Kemal Yurumeziglu 2015 Phys. Teach 53 360-362
[11] E. Arribass, I. Escobar, C. P. Suarez, A. Najera and A. Blendez 2015 Eur. J. Phys 36 1-11
[12] K K Mashood and V A Singh 2012 Eur. J. Phys 33 473-478
[13] Ponimim, Suparmi, Sarwanto and W Sunarno 2017 Eur.J. Phys 795 1-7
[14] Cary A. Supalo 2013 J. Sci. Edu. 16 34-39
[15] T Eadkhong. R Rajsadorn, P Jannual and S Danworaphong 2012 Eur. J. Phys. 33 615-622