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EXPERIMENT MODELING TOOL DEVELOPMENT WHEELS RELATED TO THE CONTROL ADVANCE FOR VIDEO TRACKER ANALYSIS

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ABSTRACT

The concepts explained by Physics can be the basis for the development of new disciplines. Theory explains the results of experiments carried out and subsequent experiments.Observations prove that experiments using manual tools still have many shortcomings . Physics parameters that can be displayed are still a bit of a weakness.This problem can be overcome by modeling tools that analyzed the video using a tracker.This study aims to determine the accuracy, accuracy, and resolution of controlling the speed of a DC motor, determine the performance specifications of the related wheel experimental model modelingtool, determine the accuracy and accuracy of the related wheel circular motion modeling tool, determine the physical magnitude and influence of each of the wheel relations of the modeling tool. This research is classified into laboratory experiment research method. Laboratory experiments are researches that apply science into a design to get performance as expected. Direct measurement is done by varying the speed and type of wheel connection. Indirect measurements are carried out analysis using a tracker software with the resulting data is linear velocity and angular velocity. Data analysis carried out revealed four research results. The performance specifications which consist of a circular motion modeling tool related to the length of 35 cm, width 5 cm and height 20 cm by controlling, average value of accuracy and accuracy of DC motor rate control are 99.06% and 99.55%, respectively. Accuracy value for linear velocity is 99.35%, accuracy at angular velocity is 99.63%, and the accuracy value of each relationship is> 95%. Tangent wheel has the same linear velocity value, different angular velocity , and opposite wheel rotation direction . Centralized wheels have different linear speeds, angular speed and direction of wheel rotation are the same. The wheels connected by ropes have the same linear velocity and direction of rotation of the wheels, different angular velocity values.

Keywords : *Circular motion of the related wheel, Speed control, Video analysis, Tracker software.*

I. INTRODUCTION

Science describes natural phenomena in a measurable manner which is the basis or basis for the development of current technology. For example in the field of education, where currently space and time are no longer a barrier to accessing education [1]. The concepts described in physics can become the basis for the development of ideas for new scientific disciplines. Scientists from all disciplines take advantage of ideas from physics, from chemists who study molecular structure to engineers who use the principles of physics in designing various sophisticated technological equipment [2].

Theory can explain the results of experiments that have been carried out and the results of subsequent experiments. While experimentation serves to determine the process and symptoms of a phenomenon and to prove the justification of the theory. Physics can explain how the principles of the world work. Besides, physics is also able to explain the relationship between real-world quantities [3]. The essence of physics is to describe and verify the relationships between physical quantities which these relationships are often simple [4]. The correctness of a relationship between a physical quantity and an unknown parameter value can be proven experimentally. Description and verification of a physical phenomenon are closely related to experiments [5]. This is a strong reason for the very rapid development of physics that has been obtained from the results of experiments.

Experimental activities in high school sometimes experience many obstacles. Information about the experimental equipment contained in the laboratory of SMAN 1 Agam Regency through discussions with the teacher, namely the lack of equipment or tools that can be used, the limited time to conduct experiments [6]. The real conditions found are not following the ideal conditions. This is known through the initial studies that have been conducted. The real condition related to the use of a circular wheel motion experiment tool is related to the Physics Laboratory of the State University of Padang. The circular wheel-related motion experiment tool is not yet suitable for use in practicum activities in the laboratory. The next real condition was obtained from the results of interviews with teachers and students in two schools, namely SMAN 8 Padang and SMA UNP Laboratory Construction. The connected wheel circular motion experiment device is not available in school laboratories.

Experimental activities carried out in each learning activity can be replaced by using virtual experimental media on a computer as a substitute for real experiments. An application is needed that can easily calculate motion with more measured data and is very helpful in analyzing a motion that is difficult to observe directly. A program is a Tracker Software whose framework is based on Java [7].

Video analysis of physics events is an analysis activity carried out on a video of a physics event to prove the concepts contained in the occurrence of physics in real life against existing theories. Physics can be better understood contextually with the use of technology so that the learning process becomes time-saving, free of geographical barriers, economical.

Video analysis of physics events is an analytical activity carried out on a physics incident video to prove the concepts contained in real-life physics events against existing theories. Physics can be better understood contextually with the use of technology so that the learning process is time-saving, free of geographical barriers, and economical[8]. Proving the concept of physics through analysis activities can be done with the help of technology based on video analysis of physics events, for example, the Tracker software, this software is suitable for use with a very good predicate for analyzing videos of physics events [9]. The value of the results of video analysis using tracker software is by the theory so that this tracker software can be used for analysis activities on various other physics events related to motion [10].

Modeling tools that are made not only explain the concepts of physics in the form of facts and phenomena but also can apply them in the field of science and technology [11]. A tracker can easily analyze and the data obtained is more accurate. The accuracy of the data depends on the modeling tools designed. The tracker analyzes the videos that are input into the software tracker. The better the results of the modeling tool that is made, the better the results of the video tracker analysis will be [6]. The position of the camera with the object to be on the track must be perpendicular and at the same level. This can be done by using the tripod. The distance between the camera and the object to be tracked should not be too close. The background used must be homogeneous and contrast with the object to be tracked. The camera used must have a high frame per second (fps) of at least 30 fps because otherwise the object to be tracked will be blurred and its position can be determined. Modeling tools and good video recording results are needed so that it is easy to do analysis using tracker software.

Motion in physics can be defined as a moment or event where an object or anything is experiencing a movement from one place to another. The reference point is defined as the starting point or point of place of the observer. Based on the trajectory, the motion is divided into 3 parts, namely: straight motion, parabolic motion, and circular motion [12]. Circular motion is a motion that has a circular path with a fixed center radius of curvature [2]. GMB is the motion of an object traveling in a circular path with a fixed velocity or velocity value. The speed on the GMB is always constant, but the direction is always changing and the direction of speed is always offensive to the circle. That is, the direction of the velocity (v) is always perpendicular to the line drawn through the center of the circle to the catch point of the current velocity vector [13]. One of the applications of GMB can be observed in the wheel-wheel connection [14]. The wheel-wheel relationship has three types. Each type satisfies the equation of each relationship. Linear velocity (v) is the velocity whose direction is tangent to the path and is perpendicular to the radius of the circular path [15].

$$\bar{v} = 2\pi R / T = 2\pi f R \qquad (1)$$

Angular velocity ($\bar{\omega}$) is the angle that the object travels per unit of time. The angular velocity is defined as

$$\bar{v} = \bar{\omega} \cdot R \qquad (2)$$

Angular acceleration ($\Delta\bar{v}$) is the change in velocity over a short time interval (Δt)

$$\overline{a_s} = \overline{v^2} / R \text{ atau } \overline{a}_s = \overline{\omega^2} R \qquad (3)$$

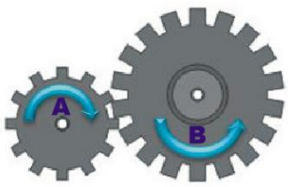
Where
T = Period (s)
f = Frequency (Hz)
$\bar{v}$ = Linear speed (m/s)
$\bar{\omega}$ = Angular velocity (rad/s)
R = Track radius (m)
$\bar{a}_s$ = Centripetal acceleration (m/s 2)

The center wheel is two wheels having the same center point. Example of the relationship between the center wheels in everyday life, namely the movement of the rear wheel and the rear gear of a bicycle [16].

a. The direction of rotation of wheel A is the same as wheel B
b. $\bar{\omega}_A = \bar{\omega}_B$
c. $\bar{v}_A \neq \bar{v}_B$
d. $\frac{\bar{v}_A}{R_A} = \frac{\bar{v}_B}{R_B}$

Fig. 1. Center wheel

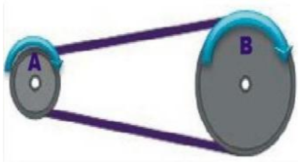
The connection of the wheels that touch is two wheels that are attached to each other so that they touch and have the opposite direction of rotation. Examples of the application of wheels that intersect, namely on a watching machine, wall clock, and wheels on a mechanical machine [16].



a. The direction of turning wheel A is opposite to wheel B
b. $\bar{\omega}_A \neq \bar{\omega}_B$
c. $\bar{v}_A = \bar{v}_B$
d. $\overline{\omega_A} R_A = \bar{\omega}_B R_B$

Fig. 2. Wheel intersection

The wheels that are connected by a rope are two wheels that have a distance but are connected in the form of a rope or the like and have the same direction of rotation. Examples of the application of wheels connected by a rope are the front and rear gears of a bicycle [16].



a. The direction of rotation of wheel A is the same as wheel B

b. $\bar{\omega}_A \neq \bar{\omega}_B$

c. $\bar{v}_A = \bar{v}_B$

d. $\overline{\omega_A} R_A = \bar{\omega}_B R_B$

Fig. 3. Wheels connected by rope

Rate control is a means of limiting the rate deviation to achieve a condition. Controlling the speed of a DC motor has many methods, one of which is the Pulse Width Modulation (PWM) method which is widely used today. In this research, the speed control of the servo relay motor, optocouplers sensor, and IR sensor is equipped with an Arduino Mega 2560 R3 microcontroller, a step-down LM2596, and a Thin Film Transistor Liquid Crystal Display (TFT LCD).

The servo motor used has the MG995 type which added functions, as needed. In a servo motor, the motor is driven with an angle limit according to the specifications. Control of the servo motor rod movement using the PWM method, where this technique uses a pulse-width system to drive the motor rotation [17]. In making the wheel-wheel connection practicum tool, a servo motor is used by eliminating the function. This transistor is used as a switching function as a directional regulator for the motor [18].

A microcontroller is a computer system in which all or most of its elements are packaged on a single chip or known as a single-chip microcomputer [19]. Because it requires a lot of pins in making a series of tools, the Arduino Mega 2560 R3 is used which has a microcontroller board based on the Ic Atmega 2560 which has 54 digital input/output pins, of which 15 pins are used as PWM outputs and 16 analog inputs.

The optocoupler is a component that works based on the optical light trigger. The optocoupler sensor consists of two parts, namely the transmitter and receiver. The way the optocoupler works is that if the phototransistor and the LED are blocked, there is no current flowing in the collector, then the phototransistor is disconnected or off so that the output from the collector will have logic 1.If the light from the LED to the phototransistor is not blocked, a current will arise in the collector so that The phototransistor is turned on so that the output from the collector will logic 0 [20].

The display screen on the device uses a TFT LCD or Thin Film Transistor Liquid Crystal Display. TFT LCD Touchscreen is a component in the form of a small monitor screen with touch screen technology that can display measurement results, images, text, and graphics of the Arduino project created [21]. The 2.4 ”TFT LCD is used as the interface for the circular motion of the connected wheels.

II. METHOD

This research is classified into a Laboratory Experiment research method. Laboratory experiments are research that applies science to a design to get the performance as expected. The research was carried out starting April 2019 at the Electronics and Instrumentation Laboratory, Department of Physics, State University of Padang. Through several activities including the preparation stage, the literature review stage, the props making stage, the implementation stage, the tool testing stage, and the final report preparation stage.

The block diagram contains electronic designs that will greatly affect the performance and the result of the associated wheel circular motion modeling tool. The following is a system diagram of the associated wheel circular motion modeling tool.

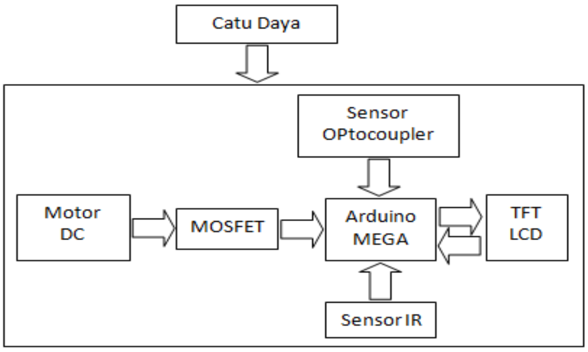


Fig. 4. Block diagram of the associated wheel modeling tool

The design of the software serves as instructions for running the Arduino microcontroller. Instructions are given in the form of input velocity values which are then processed to obtain output in the form of speed, acceleration, and frequency. Programming aims to make the system work properly. The design of the associated wheel circular Motion modeling tool can be seen from the flowchart below.

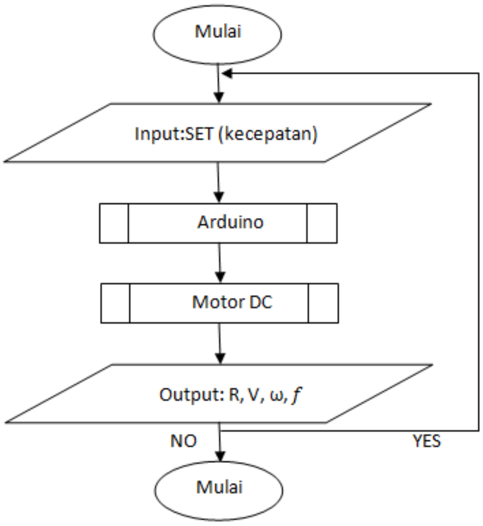


Fig. 5. Flowchart control rate

Figure 5 is a flowchart for programming and controlling the DC motor speed of the experimental modeling tool for the circular motion of the associated wheel. The initial stage of the tool is run by inputting the speed value as needed. The DC motor will move according to the value inputted through the TFT. When the DC motor is ON, the sensor will be active and send a signal to the Arduino for processing speed and the process results will be displayed on the TFT LCD. If you want to repeat the experiment then do the same steps.

The resulting product consists of a box with a disc. 2 boxes measuring 35x5x20 cm and 4 wheels with a diameter of 10 cm and 2 pieces of 5 cm. Wheels also have two forms, namely the shape of a disc and one that has teeth. With a total of 14 teeth for a diameter of 10 cm and 7 pieces for a diameter of 5 cm. The manufacture of a wheel circular motion experiment device related to controlling the speed of a DC motor requires an optocoupler sensor and an IR sensor for reading the control results. LCD is used as a display of the output of this tool. The mechanical design after revision is shown in Figure 6.

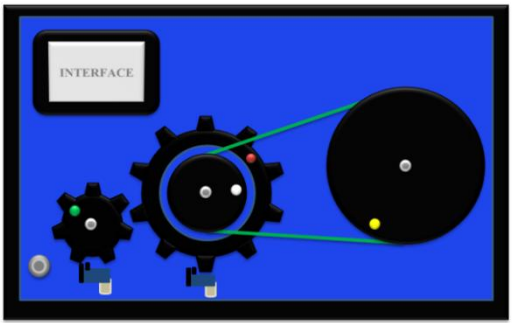


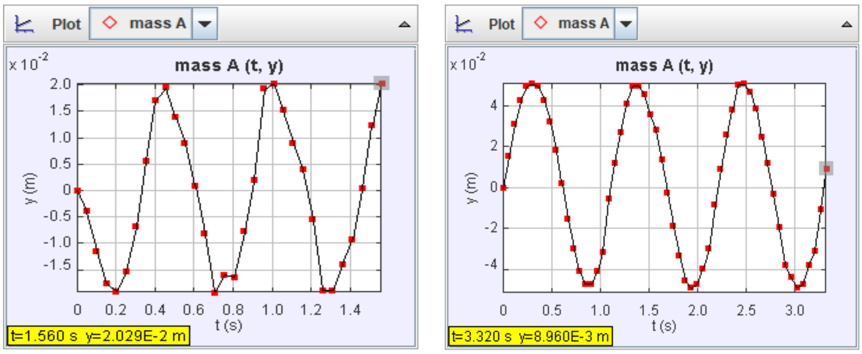
Fig. 6. Mechanical design of modeling tool

III. RESULTS AND DISCUSSION

A. Analysis of The Circular Motion of The Wheel Associated With The Tracker in The Experiment of The Circular Motion of The Associated Wheel.

Determination of the physical quantities on the wheel circular motion modeling tool related to the period, frequency, and deviation. The results of this determination can be displayed in the form of graphs and tables attached. The graph that is displayed is a graph of changes in position on the y-axis, changes in speed on the y-axis, frequency, and time deviation. There are two-speed variations including 50 rpm and 65 rpm.

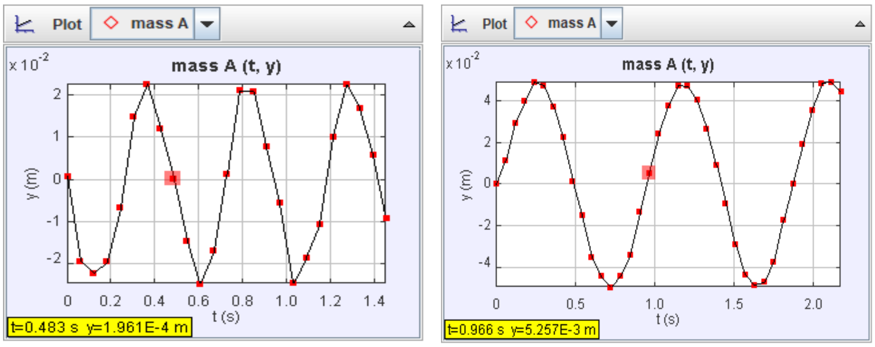
The contact wheels involve wheel 1 and wheel 2a which have a 1: 2 gear ratio. Measurements at the speed value of 50 rpm and the speed of 65 rpm to observe the circular motion of the wheel concerning it were analyzed using tracker software. The results of the analysis at the 50 rpm period will display a graph of the y axis (m) against time t (s).



(a) (b)

Fig. 7. Changes in the position of the wheels against the y-axis at 50 rpm

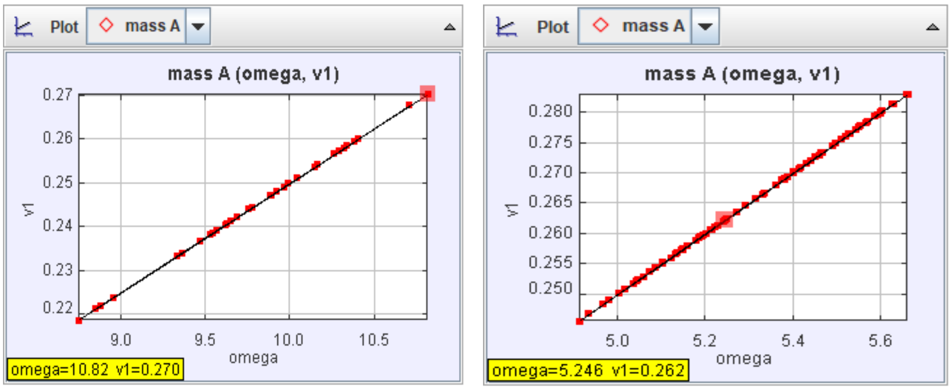
Based on Figure 7, it can be seen that the graph of the change in position on the y-axis at 50 rpm forms a sinusoidal wave. Figure a is the analysis result of wheel 1 which has a radius of 2.5 cm and Figure b is the result of the analysis of wheel 2a which has a radius of 5 cm. The sinusoidal shape is formed by the two wheels, where wheel 2a is more sine than wheel 1 due to the difference in radius. The results of the analysis at the 65 rpm period will display a graph of the y axis (m) against the time t (s) shown by.



(a) (b)

Fig. 8. Changes in the position of the wheels against the y-axis at 65 rpm

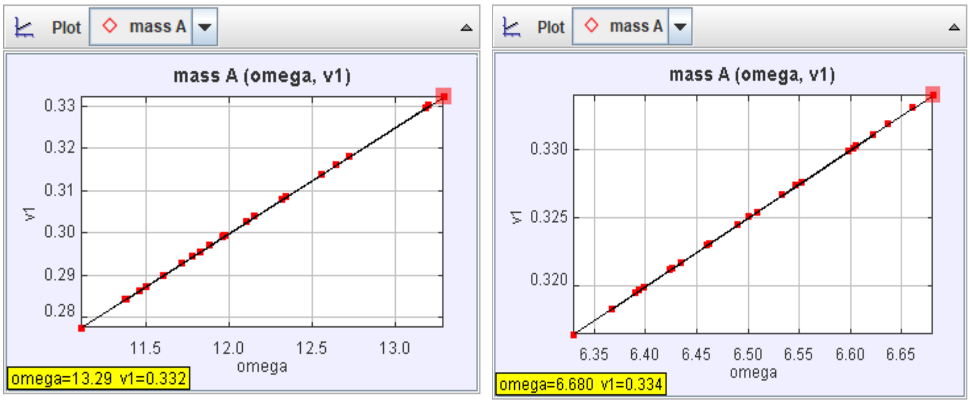
Based on Figure 8, it can be seen that the graph of the change in position on the y-axis at a speed of 65 rpm forms a sinusoidal wave. Figure a is the result of the analysis of wheel 1 and Figure b is the result of the analysis of wheel 2a. In the graph, you can see the difference in sinusoidal shape formed by the two wheels, where wheel 2a is better than wheel 1 because of the difference in wheel radius. A wheel that has a larger radius will produce better analysis results because steps are required to take more time. Figures 7 and 8 show a graphical analysis where there is a difference in the sinusoidal direction which indicates a difference in the direction of the wheel. The graph of the linear velocity and angular velocity from the results of the tracker video analysis at a speed of 50 rpm is shown in Figure 9.



(a) (b)

Fig. 9. Linear speed to the angular speed of the wheel with a speed of 65 rpm

Linear velocity is directly proportional to the angular velocity. Figure a is the analysis result of wheel 1 with a radius of 2.5 cm and Figure b is the analysis result of wheel 2 with a radius of 5 cm. The values for linear velocity and angular velocity at wheel 1 are 0.26 m/s and 10.98 rad/s. While the 2a wheels are 0.26 m/s and 5.23 rad/s. The graphs of linear velocity and angular velocity from the results of the video tracker analysis at 65 rpm can be shown in Figure 10.

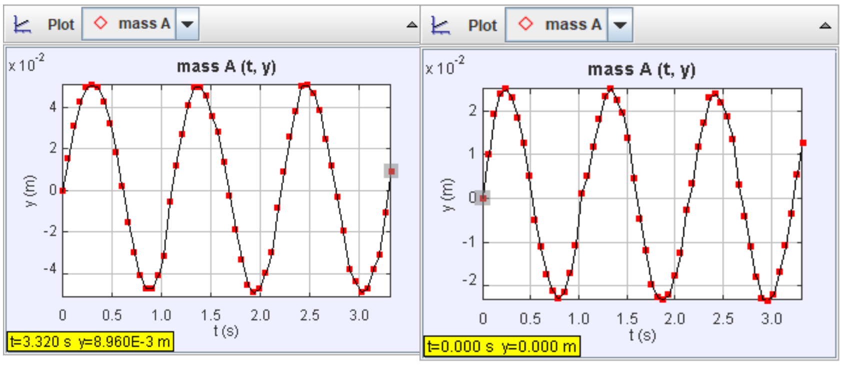


(a) (b)

Fig. 10. Linear speed to the angle of the wheel with respect at 65 rpm

Figure a is the result of the analysis of wheel 1 and Figure b is the result of the analysis of wheel 2a. The values for linear velocity and angular velocity at wheel 1 are 0.34 m/s and 13.60 rad/s. While the 2a wheels are 0.34 m/s and 6.80 rad/s . The greater the linear velocity, the greater the angular velocity. The data also proves that the linear velocity value of wheel 1 and wheel 2a is the same. The angular velocity of wheel 1 and wheel 2a is different, in that the larger radius has the smaller the angular velocity.

The Center Wheel involves wheel 2a and wheel 2b having a radius ratio of 2: 1. Measurement of the speed of 50 rpm and 65 rpm to observe the circular motion of the wheel concerning it was analyzed with tracker software. The results of the analysis will display a graph on the y-axis at a speed of 50 rpm.



(a) (b)

Fig. 11. Changes in the position of the center wheel on the y-axis at 50

Based on Figure 11, it can be seen that a sinusoidal wave is generated by a graph of the change in position on the y-axis at 50 rpm. Figure a is the result of the analysis of wheel 2a which has a radius of 5 cm and Figure b is the result of the analysis of wheel 2b which has a radius of 2.5 cm. The results of the 65 rpm speed analysis display a graph of the y axis (m) against time t (s) shown in Figure 12.

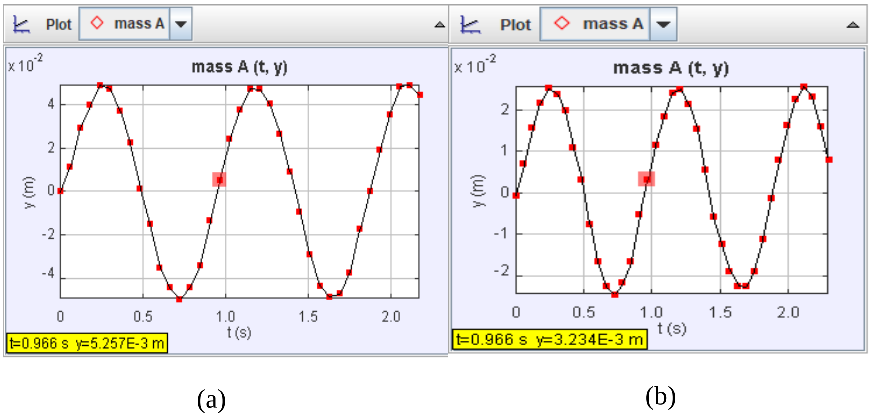


Fig. 12. Change in the position of the center wheel on the y-axis at 65 rpm

Based on Figure 12, it can be seen that a sinusoidal wave is generated by a graph of the change in position on the y-axis at 65 RPM. Figure a is the result of the analysis of wheel 2a which has a radius of 5 cm and Figure b is the result of the analysis of wheel 2b which has a radius of 2.5 cm. The sinusoids formed in Figure 11 and Figure 12 tend to be stable. This is because the motor is on wheels 2a and 2b. So that the resulting rotation is more stable. The same sinusoidal direction indicates the direction of rotation of the wheel in the same direction.

The graph of linear velocity and angular velocity from the results of the tracker video analysis at a speed of 50 rpm can be shown in Figure 13.

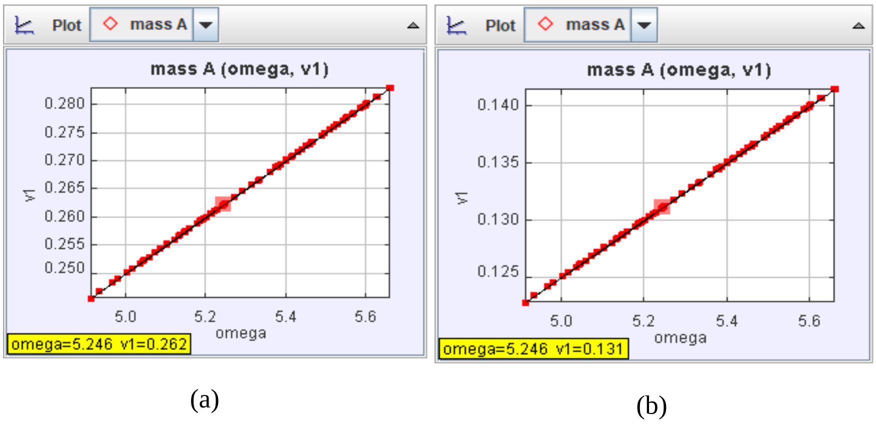
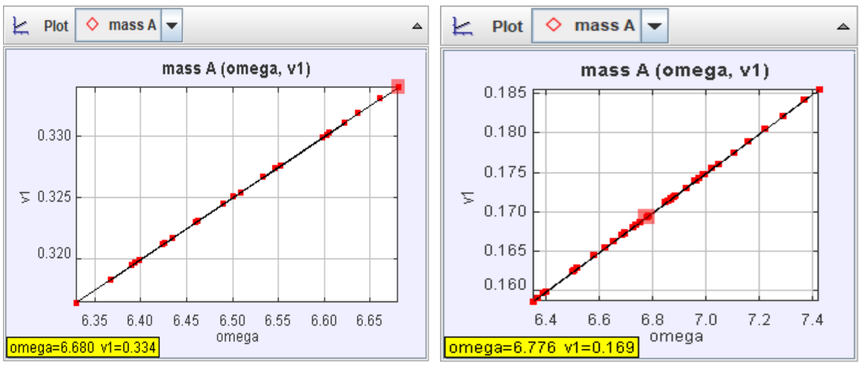


Fig. 13. Linear speed to angle speed wheel concentrically at a speed of 50 rpm

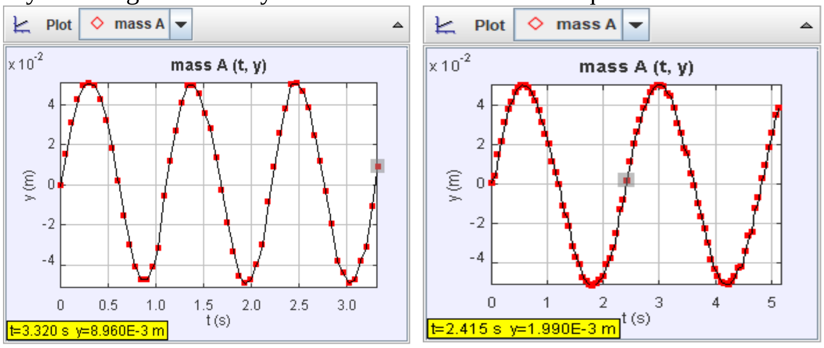
Figure 13 proves that the linear velocity is directly proportional to the angular velocity. The greater the linear velocity, the greater the angular velocity. Figure a is the analysis result of wheel 2a with a radius of 5 cm and Figure b is the analysis result of wheel 2b with a radius of 2.5 cm. The values for linear velocity and angular velocity on wheel 2a are 0.26 m/s and 5.23 rad/s. Whereas the 2a wheel is 0.13 m/s and 5.23 rad/s. The linear velocity and angular velocity graphs from the results of the video tracker analysis at 65 rpm can be shown in Figure 14.



(a) (b)

Fig. 14. Linear speed to center wheel angular velocity at 65 rpm

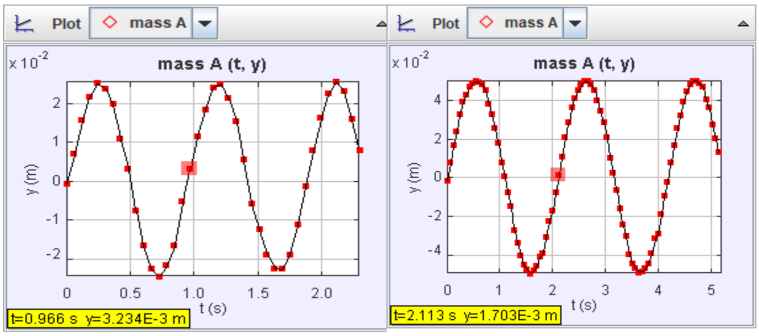
Figure 14 proves that the linear velocity is directly proportional to the angular velocity. The greater the linear velocity, the greater the angular velocity. Figure a is the analysis result of wheel 2a with a radius of 5 cm and Figure b is the analysis result of wheel 2b with a radius of 2.5 cm. The values for linear velocity and angular velocity on wheel 2a are 0.34 m/s and 6.80 rad/s. While on wheel 2b it is 0.17 m/s and 6.80 rad/s . The data prove that the linear velocity values of wheel 2a and wheel 2b are different. Where the larger radius has the smaller linear velocity. The angular velocity of wheel 1 and wheel 2a is equal.



(a) (b)

Fig. 15. Change in the position of a wheel connected to a rope on the y-axis at 50 rpm

Based on Figure 15 a sinusoidal wave is generated by a graph of the change in position on the y-axis at 50 RPM. Figure a is the result of the analysis of wheel 2b which has a radius of 2.5 cm and Figure b is the result of the analysis of wheel 3 which has a radius of 5 cm. The results of the 65 RPM speed analysis display a graph of the y-axis against time t.

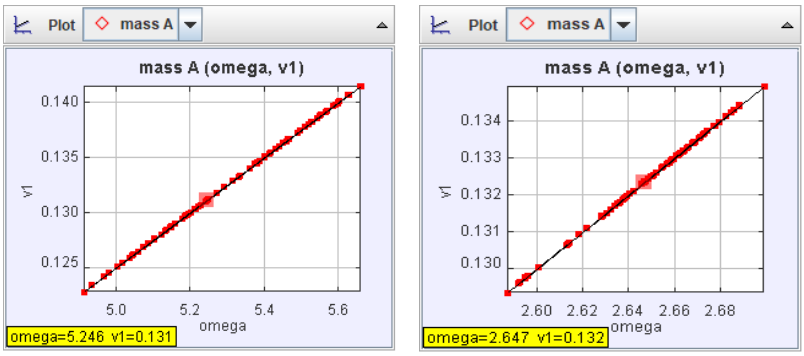


(a) (b)

Fig. 16. Change in the position of a wheel connected to a rope on the y-axis at 65 rpm

Based on Figure 16 a sinusoidal wave is generated by a graph of the change in position on the y-axis at 65 rpm. Figure a is the result of the analysis of wheel 2b which has a radius of 2.5 cm and Figure b is the result of the analysis of wheel 3 which has a radius of 5 cm. The sinusoidal formed is the most stable compared to the intersecting wheels and the center wheels. The two images show a graphical analysis where the same sinusoidal direction shows the direction of the wheel rotating unidirectional.

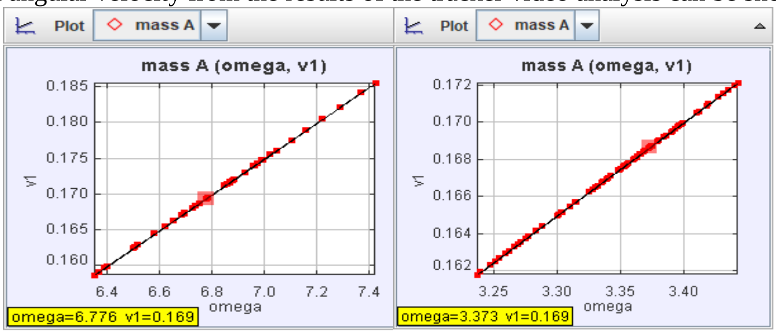
The graph of linear velocity and angular velocity from the results of the tracker video analysis can be shown in Figure 17.



(a) (b)

Fig. 17. Linear speed to wheel angular velocity connected to rope speed 50 rpm

Based on Figure 42 it is proven that the linear velocity is directly proportional to the angular velocity. The greater the linear velocity, the greater the angular velocity. Figure a is the analysis result of wheel 2b with a radius of 2.5 cm and Figure b is the analysis result of wheel 3 with a radius of 5 cm. The values for linear velocity and angular velocity on wheel 2b are 0.13 m/s and 5.23 rad/s. While on wheel 3 it is 0.13 m/s and 2.61 rad/s. The data prove that the linear velocity values for wheel 2b and wheel 3 are the same. The graph of the linear velocity and angular velocity from the results of the tracker video analysis can be shown in Figure 18.



(a) (b)

Fig. 18. Linear velocity to wheel angular velocity connected to 65 rpm rope speed

Based on Figure 18 it is proven that the linear velocity is directly proportional to the angular velocity. The greater the linear velocity, the greater the angular velocity. Figure a is the analysis result of wheel 2b with a radius of 2.5 cm and Figure b is the analysis result of wheel 3 with a radius of 5 cm. The values for linear velocity and angular velocity on wheel 2b are 0.17 m/s and 6.70 rad/s. While wheel 3 is 0.17 m/s and 3.40 rad/s. The data prove that the linear velocity values for wheel 2b and wheel 3 are the same. Meanwhile, the angular velocity of the larger radius has a smaller value, in other words, the angular velocity of wheel 2b and wheel 3 has different values.

B. On Problem Solving

Based on the analysis that has been done, it can provide research results that are following the research objectives. The analysis was carried out both graphically and statistically. The first result is the performance specification of the associated wheel circular motion modeling tool. Performance specifications identify the functions of each component that makes up the system. The performance specification of the modeling tool consists of a box measuring 35x20x5 cm equipped with wheels with different character diameters. The PWM concept in the DC motor driver is to adjust the width of the positive and negative sides of the pulse. The longer the DC motor is in a positive position, the greater the motor speed will be [22]. The results of the modeling tool performance specifications can explain the characteristics of the circular motion of the associated wheels. This experimental set consists of 4 wheels with a thickness of 3 mm.

The second result is the accuracy and accuracy of DC motor speed control. The value of the accuracy of the DC motor speed control measurement, namely comparing the measured data with a standard tool (tachometer), obtained an average percentage of accuracy of 99.06%. The accuracy value is obtained from repeated measurements with an average percentage of accuracy of 99.55%. The results of the motor speed control resolution have a stable value in the range of 50RPM to 80 rpm. The results of the data on the accuracy and accuracy of the DC motor speed control are very good. The third result is the precision and accuracy of the associated wheel circular motion modeling tool. The value of accuracy and accuracy is obtained from the comparison of the results of the analysis using tracker software with calculations using the formula. The fourth result is the determination and influence of physical quantities on the circular motion experiment of the associated wheels. In the experiment to determine the physical quantity in the circular wheel motion experiment, the speed variations used were 80 rpm and 60 rpm. The physical quantities analyzed include the frequency, deviation, and centripetal acceleration. The frequency value will be greater by using a higher speed value.

Based on the results of the research obtained, the circular wheel-related motion experimental modeling tool can be used for experimental tools in the electronics laboratory and instrumentation in the physics department of the Faculty of Mathematics and Natural Sciences UNP, the basic physics laboratory of the Faculty of Mathematics and Natural Sciences UNP and school laboratories. This modeling tool by controlling the speed of a DC motor using a microcontroller, so that the experiment is not done manually. The experiment has been carried out with analysis using tracker software which can prove the characteristics of the circular motion of the wheels in contact.

The advantage of this tool is that it has a simple mechanical system with DC motor speed control. Input the speed value using the TFT LCD so that you can enter the value as needed. Data analysis is done using tracker software which can display physical parameters that are not visible to the physical.

In this study, there were four deficiencies. The first drawback is that the DC motor cannot immediately rotate according to the input value and the motor does not support rotating at low speeds with a value below 50 rpm. This can be overcome by using a motor that can be stable at low speeds or a low-speed motor. The second drawback is that the value of speed is only detected in whole number orders and not in decimal numbers. The reason is that the sensor used is the optocoupler sensor. This can be overcome by using a sensor capable of detecting rotations in decimal order. The third drawback is that at high speeds above 80 rpm, the results of video analysis using a tracker give less good results. The reason for this is because the camera used has a resolution that cannot record well at high speeds. The solution to this is by using a high-resolution camera.

IV. CONCLUSION.

Based on the results of testing and data analysis as well as a discussion of the circular motion experimental instrument related to controlling the speed of this DC motor, several conclusions can be formulated as follows:

1. The results of controlling the speed of the DC motor on the circular motion modeling tool of the associated wheel consist of accuracy, precision, and resolution. The accuracy value is 99.06% and the relative error is 0.94%. The accuracy value obtained is 99.55%. Based on these results, DC motor speed control is accurate. Stable speed control resolution in the speed range of 50 rpm to 80 rpm.
2. The results of the performance specifications from the experimental modeling tool for the circular motion of the associated wheels consist of a box measuring 35x5x20 cm equipped with 4 wheels with different characters. The DC motor speed controller circuit consists of an Arduino Mega optocoupler sensor, L298 driver, TFT LCD as input and display.
3. The results of the analysis on the wheel-related circular motion modeling tool consist of accuracy and precision. The accuracy value for linear velocity is 99.35%. The accuracy at angular velocity is 99.63%. On the other hand, the accuracy value of each wheel-wheel connection is above 95.00%. Based on these results, using the tracker can analyze the physical quantity properly as long as the object recorded experiences movement.
4. Determination of physical quantities, namely the linear velocity and angular velocity at each wheel link. On the tangled wheels, the linear velocity values are the same. Meanwhile, the angular velocity value is different and the wheel rotation direction is opposite.

REFERENCES

[1] E. Y. Wijaya, dkk. 2016. *Transformasi Pendidikan Abad 21 Sebagai Tuntutan Pengembangan Sumber Daya Manusia Di Era Global. Prosiding Seminar Nasional Pendidikan Matematika 2016.* Volume 1 Tahun 2016 – ISSN 2528-259X. Universitas Kanjuruhan Malang

[2] D. E. Darmawati, 2014. *Pembuatan Alat Peraga Hubungan Roda pada materi GMB untuk siswa SMA kelas X*. Pendidikan Fisika. Fakultas Keguruan Dan Ilmu Pendidikan. Universitas Sebelas Maret.

[3] Asrizal, Yulkifli, Melvia Sovia. 2012. "Penentuan Karakteristik Sistem Pengontrolan Kelajuan Motor DC dengan Sensor Optocoupler Berbasis Mikrokontroler AT89S52". *Jurnal Otomasi Kontrol dan Instrumentasi*. Vol 4 (1)

[4] D. R. Halliday, J. R. Walker. 2011. *Fundamental of Physics. 9th Edition.John Wiley & Sons,* Inc, United States of America

[5] H. D. Young. 2012. *College Physics. 9th Edition,* Addison-Wesley

[6] Asrizal. Yohandri. Kamus, Zulhendri. 2018. "Studi Hasil Pelatihan Analisis Video dan Tool Pemodelan Tracker pada Guru MGMP Fisika Kabupaten Agam". *Jurnal Eksata Pendidikan (JEP)* Vol.2, p-ISSN: 2614-1221e-ISSN: 2579-806. Padang: Universitas Negeri Padang

[7] L. K. Wee et al. (2012). "Using Tracker as a Pedagogical Tool for Understanding Projectile Motion". *Physics Education Journal,* P 448-455

[8] L. Fadholi, H. Alex, A. D. Lesmono. 2018. "Analisis Video Kejadian Fisika dengan Software Tracker sebagai Rancangan Bahan Ajar Momentum dan Impuls untuk Meningkatkan Kemampuan Berfikir Kritis Siswa SMA Kelas X". *Jurnal Pembelajaran Fisika.* Universitas Jember

[9] I. Fitrianto, dan I. Sucahyo. 2016. "Penerapan software tracker video analyzer pada praktikum kinematika gerak". *Journal Inovasi Pendidikan Fisika*.Vol. 5(3): 92-97

[10] S. Ristanto, 2012. "Eksperimen Gerak Jatuh Bebas Berbasis Perekaman Video di MA Wahid Hasyim". *Jurnal Penelitian Pembelajaran Fisika. Vol. 3 No. 1 April 2012*

[11] Yulkifli and Ramli. 2018. "The Use of Tracker Application to Enhance Physics Teachers in Senior High School in Making Laboratory Video". *Jurnal Pelita Eksakta,* Vol.01, No.01, 2018 pp. 31-36.

[12] M. D. Setiawan, and Prabowo. 2016. "Pengembangan Alat Peraga Hubungan Roda-Roda pada Materi Gerak Melingkar Beraturan untuk Meningkatkan Kompetensi Siswa Di SMAN 1 Sidoarjo". *Jurnal Inovasi Pendidikan Fisika (JIPF).Vol. 05 No. 03,244-248.* Universitas Negeri Surabaya

[13] S. Nurachmandani, 2009. *Fisika 1 SMA/MA kelas X*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional

[14] S. Handayani, A. Damari, 2009. *Fisika 1: Untuk SMA/MA Kelas X*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional

[15] T. Widodo, 2009. *Fisika: untuk SMA dan MA Kelas X*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional

[16] I. Pamungkas. 2018. "Pengembangan Alat Peraga Rotating Wheels (APRW) Pada Materi GMB Untuk Siswa SMA. Tadris Fisika. Fakultas Ilmu Tarbiah dan Keguruan". Universitas Islam Negeri Syarif Hidayatullah

[17] Sujarwata. 2013. "Pengendali Motor Servo Berbasis Mikrokontroler Basic Stamp 2sx Untuk Mengembangkan Sistem Robotika". Fakultas Matematika dan Ilmu Pengetahuan Alam. Universitas Negeri Semarang (UNNES) Semarang

[18] R. Antoni, 2013. "Perancangan Sistem Pegaturan Kecepatan Motor DC Menggunakan Zig Bee Pro Berbasis Arduino UNO ATMEGA 328P*"*. Jurnal Fakultas Teknik UMRAH. Universita Maritim Raja Ali Haji

[19] B. Widodo. 2005. *Panduan Lengkap Belajar Mikrokontroler Perancangan Sistem dan Aplikasi Mikrokontroler*. Jakarta. PT Elek Media Komputindo

[20] R. Humairah, Asrizal, Z. Kamus.2016. "Pembuatan Sistem Pengukuran Besar Gerak Lurus Berbasis Personal Komputer Menggunakan Sensor Optocoupler". *Pillar Of Physics*. Vol. 7, 65-71

[21] E. Sunandar. 2018. "Rancang Bangun Timbangan Digital dengan Layar Sentuh dan Terintegrasi Ke Android Berbasis Arduino Mega 2560". Fakultas Teknik. Universitas Lampung

[22] Hidayati, 2017. "Pengaturan Kecepatan Motor DC dengan Menggunakan MikrokontrolerAtmega 8535." Balikpapan: Politeknik Balikpapan.