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DEVELOPMENT OF A DIP COATING TOOL FOR THIN LAYER GROWERS BASED ON THE RASPBERRY Pi 3

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ABSTRACT

Low cost and precise is a concern in developing instruments for thin-film manufacturing. In this paper, a low-cost dip-coating instrument based on Raspberry pi will be presented. In this work, Raspberry Pi 3 was adopted as a microcontroller for digital data processing. In addition, this tool is also equipped with a user-friendly interface system that is easy to operate by the user. An addition, the Python programming language is also adopted in the development of programming on the Raspberry Pi 3. Furthermore, the Raspberry Pi is also needed to build an interface on the tool with the Qt designer framework. The results of device configurations such as withdraw speed and immersion time can be stored in the data logger system that has been developed in this equipment. The performance and characteristics of the equipment have been tested and produce excellent characteristics and performance that meet the criteria for the production of thin film. Based on the results, a dip coating based on Raspberry pi can be applied to the production of thin film in nanomaterial technology.

Keywords : Dip coating, Raspberry Pi based instrument, user friendly interface.

I. INTRODUCTION

The coating industry on materials nowadays continues to grow by increasing needs. Starting from the coating method, the materials used for coating, to the various layers of the material produced. In the field of electronics, a thin layer is used to make sensors [1]. Apart from sensors, it is also used to make capacitors, semiconductors, and several other electronic components. Coatings on materials are also needed in the construction sector, especially for metal materials to prevent corrosion. There are various types of methods for coating materials, one of which is dip coating. The dip-coating method is a coating method with the principle of immersing the material into a solution with certain precursors to obtain a thin layer as a coating for the material. In the dip-coating process, when the substrate is slowly withdrawn from the solution, evaporation of the remnants of the solution that sticks to the substrate occurs, so that the particles contained in the solution are deposited on the substrate [2]. In this process, the tensile speed has an important role in determining the thickness of the resulting layer.

The addition of speed regulation when the substrate is pulled will facilitate the process of obtaining thickness variations based on variations in the given velocity treatment. The thickness of the layer depends on the speed at which the substrate is drawn, but it is not the same for various types of solutions, depending on the solution and the type of precursor used. In previous research, designed a DC motor speed level regulator on the atmega8535 microcontroller-based dip-coating tool, but still used a DC motor [3]. Another study, designed a tool for coating materials using the Arduino-based dip-coating method using a stepper motor that is more accurate than a DC motor as a speed controller [4]. However, this tool is not equipped with a storage system so the measurement data is still manually stored by the user of the tool. The display of variable data on this tool also still uses a matrix LCD so that the amount of variable data that can be displayed is limited. It is necessary to add a system so that the display of variable data on the tool becomes user friendly than before and can also store measurement data directly and in real-time, making it easier for users to operate the tool.

The dip-coating tool that has been made still uses Arduino [4,8]. Arduino which is used as an acquisition on the system requires the use of a PC to operate the interface on the measuring instrument. However, the use of a PC is currently considered less efficient for the measurement system because it requires a large enough space and is not portable. So that the author will use the Raspberry Pi 3 as an acquisition and a replacement for the presence of a PC that will be applied to the device. There are several advantages of using the Raspberry Pi for a system designed, namely the power consumption is less than a personal computer, and there are GPIO pins that can be used as input or output [5,7]. This pin can be directly connected to sensors or other electronic components that will be used in the system so that it can act as a mini-computer as well as an acquisition in the system. Raspberry Pi also uses the simpler Python language compared to Arduino. This certainly makes it easier to design software for the system.

II. METHOD

This research is classified into research and development (Research and Development). Research and development is a scientific way to research, design, manufacture, and test products that have been produced [6]. Research and development functions to develop products. Developing a product means that the product is there, and the researcher is only testing the effectiveness of the product. Developing a product in a broad sense can be in the form of updating an existing product or creating a new product that has never existed before.

The research and development model used in this research is level 3 research and development. Research and development at level 3 are researching and testing to develop existing products both in terms of form and function. The stages of level 3 R&D research include reviewing existing products based on literature studies and field research. Based on the results of literature studies and field research, the researcher then makes product designs or develops existing products.

The product design is tested internally and then the design is revised. After the design is revised, then proceed to the product manufacturing stage. From this research, a dip coating tool for a thin layer grower based on Raspberry pi 3 was produced. The research procedure is described by a flow chart. The flow chart is made according to the steps in the type of research and development. The research flow diagram can be shown in Figure 1.

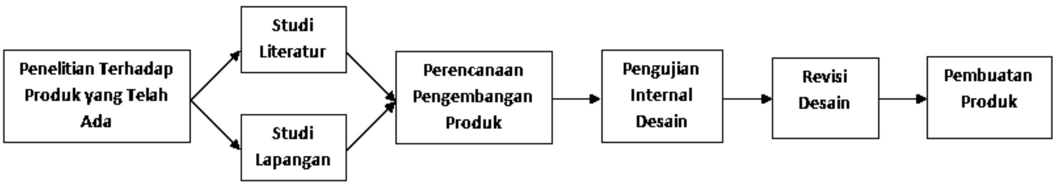

Fig. 1. R & D Research steps that are developing existing products

The design form of the dip-coating tool can be seen in Figure 2.

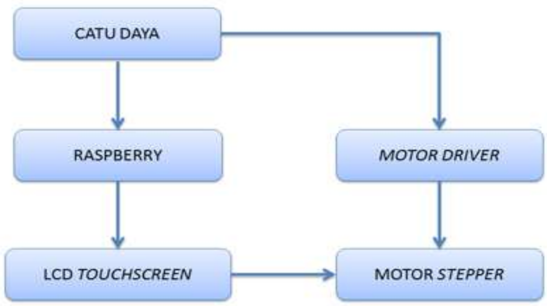

Fig. 2. Flow diagram of the tool work system

The flow chart of the working principle of the dip-coating tool can be shown in Figure 3.

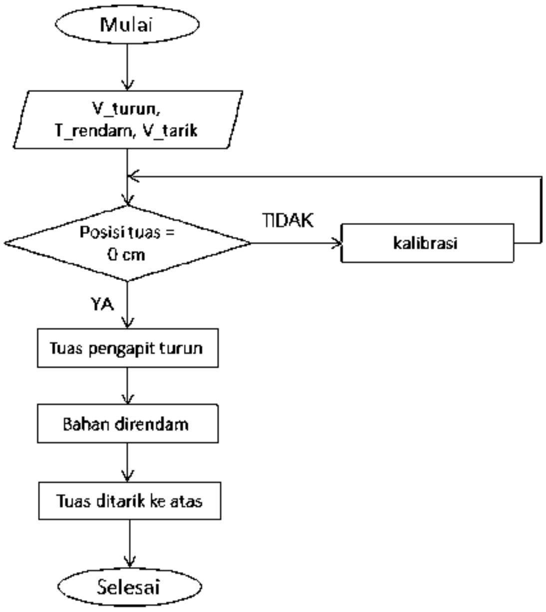

Fig. 3. Flow diagram of the stepper motor program on the tool

Figure 3 is a programming flow chart of the working mechanism of the dip-coating tool for a thin-film grower. The value of each parameter is entered through the interface that appears on the LCD touchscreen on the device. After entering the desired value, the program is executed by pressing the start button on the interface. Before pressing start or starting the immersion process, make sure that the lever position returns to the starting position (0 cm). For this calibration, you can use the calibration button located on the interface which can slide the clamp lever up or down until the position is back at zero (0 cm). The input values will be stored in real-time using a data logger system connected to the device interface. This aims to make it easier for tool users to find out the history of the dyeing process.

III. RESULTS AND DISCUSSION

The results of the research on the dip-coating tool for thin layer growers based on the Raspberry Pi 3 consisted of the accuracy and precision values of the tool. The data obtained from the research have an important meaning in a study. The presentation of the data obtained can be expressed in graphical form. Based on the data obtained, it can be described a relationship between one quantity and another on the dip-coating tool in the thin layer growth process.

A. Dip Coating Tool Performance Specifications

The performance specifications of the dip-coating tool include the functions of each part of the tool. The components contained in this tool are the stepper motor, Raspberry Pi, LCD touchscreen, and a series of electronic components. To make it easier to understand the shape of the dip-coating tool being developed, it can be seen in Figure 4.

Fig. 4. Dip coating tool

Figure 4 is a dip coating tool that will be used for the dip-coating process. You can see in the picture that there is a lever that functions as a clamp position for the material to be coated with the dipping technique. This lever is connected to the stepper motor through a thread as its path. The motor will move the lever vertically to carry out the process of dying and withdrawing the material from the coating solution. In this tool, the Stepper motor is also connected to the Raspberry Pi module. The function of the Raspberry Pi in this tool is as a microcontroller as well as a replacement for the PC. So that the tool has an interface system that is displayed via an LCD touchscreen and a data logger system without the need for a PC. To better understand the system in the dip coating tool, the performance specifications that need to be explained are the stepper motor, Raspberry Pi, LCD touchscreen, and electronic component circuit boards.

1. Stepper Motor

The driving motor used in this tool is the Nema 17 type stepper motor and uses the A4988 as the motor driver. The stepper motor functions to move the lever up and down. This vertical movement of the lever is used for the dyeing process and drawing materials from the coating solution. This process is important in the coating process with the dip-coating method. The position of the stepper motor on the tool can be seen in Figure 5.

Fig. 5. Position of the stepper motor

In Figure 5 it can be explained that the motor is placed under the mechanical position designed on the tool. The shaft on the stepper motor is connected to a thread with a diameter of 8 mm vertically as a passage for the material clamp lever. For the motor to move with a low-value input speed, the micro stepping function in the motor driver is used. The lowest speed value that can be driven by a motor on this tool is 0.01 mm / s and the input of the highest speed value designed for the tool is 10 mm / s.

2.Raspberry Pi

The Raspberry Pi module on the device functions as a microcontroller and has a role as a mini-computer module. The algorithm of the stepper motor function is processed through the Raspberry Pi module with python as the programming language. To better understand the function of the Raspberry Pi module, it can be seen in Figure 6.

Fig. 6.The Raspberry Pi 3 module installed on the tool

There are 40 pins shown in Figure 6. The pins serve as input and output of the Raspberry Pi module. There are 4 pins as input sources, 8 pins as ground, 2 DNC pins, and 21 GPIO pins which function to process input data on the microcontroller. Almost all pins are used in this dip-coating tool. The first pin to pin 26 is used to supply and run the LCD touchscreen. Then the GPIO pins 20 and GPIO 21 are connected to the motor driver along with the ground on pin 39. GPIO pins 13, 19, and 26 are connected to micro stepping on the motor driver which aims to adjust the number of steps on the motor according to the given speed value. The number of steps used in the motor ranges from 200 steps to 3200 steps. The use of several types of the number of steps in this design aims to make the device able to accept speed input with low values.

3. LCD touchscreen

The use of the LCD touchscreen on the tool serves to display the designed interface on the device. The interface on this system tool is built using the Python programming language and Qt Designer. The interface can be seen in Figure 7.

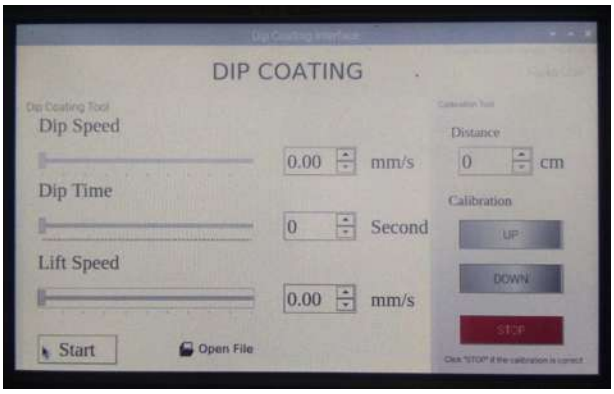

Fig. 7. Screen display on the dip-coating tool

Based on Figure 7, it can be seen that the layout displayed on this interface is for the input velocity value and the required immersion time input. Through the interface, the speed and immersion time value data can be stored directly in the CSV data format. This storage is connected directly when the user of the tool performs the interface functions. So that the historical value of the speed and immersion time used does not need to be stored manually. The data storage file can be called directly through the interface as shown in Figure 8.

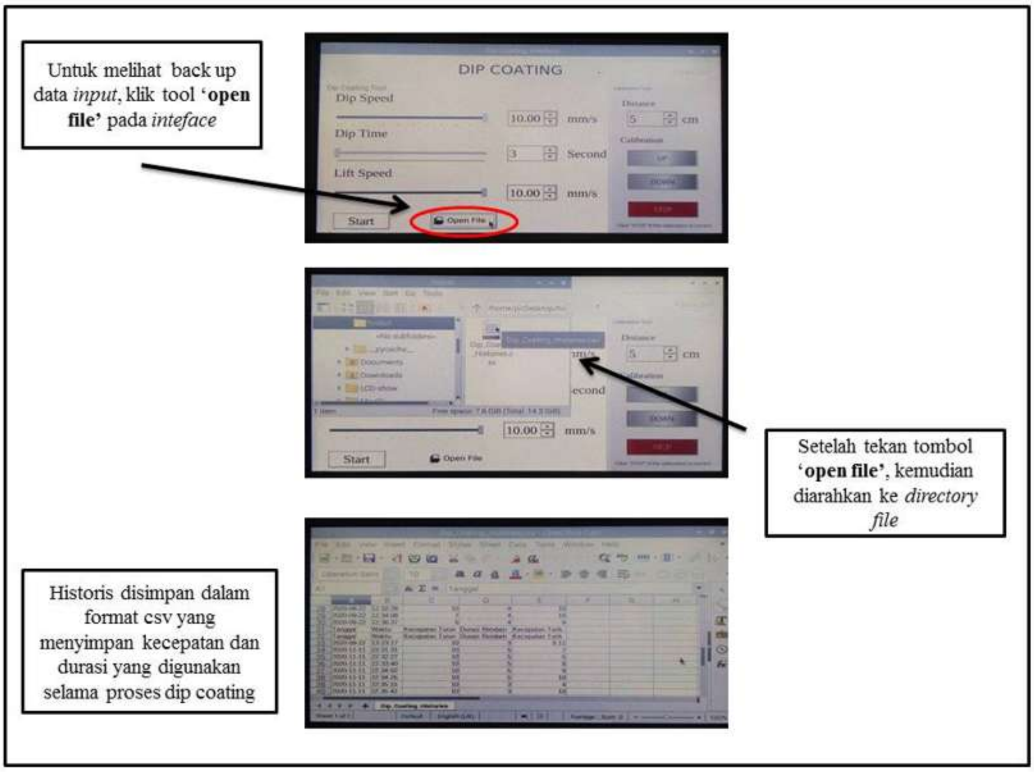

Fig. 8. Data logger on the interface

Figure 8 shows a historical view of the use of dip-coating tools that can be used as data back-up which allows it to simplify the thin layer research process.

4. Circuit Board

There are several electronic components used in the manufacture of this tool. These components can be seen in Figure 9.

Fig. 9. The electronic circuit on the dip coating tool

As seen in Figure 9 the components used such as capacitors, resistors, regulators, and motor drivers. This circuit board is also connected to the Raspberry Pi module. The input source for the stepper motor is also connected to this circuit.

B. Accuracy and Accuracy of Dip Coating Tool

1. The accuracy of the dip coating tool

The measurement accuracy is determined by comparing the data from the measurement results on the dip-coating tool and the measurement results on the standard measuring instrument. Through calculations, it can be determined the percentage of error and accuracy.

Data comparison of program speed values with actual speed values obtained by measuring the lever travel time using a standard measuring instrument in the form of a stopwatch can be seen in Table 1.

Table 1.The Percentage Error and The Percentage of Speed Accuracy in The Dip Coating Tool Program for x = 20 cm

V (program) mm/s	t (measuring) second	V (measuring) mm/s	%KR value V	% Value accuracy V
0.02	10018.1	0.019	0.18	99.82
0.10	2009.8	0.099	0.49	99.51
0.20	1009.7	0.198	0.97	99.03
0.30	671.4	0.29	0.71	99.29
0.40	508.1	0.39	1.62	98.38
0.50	406.3	0.49	1.58	98.425
1.00	207.0	0.97	3.50	96.50
1.50	136.4	1.47	2.30	97.70
2.00	103.7	1.93	3.70	96.30
2.50	83.5	2.39	4.38	95.625
3.00	68.9	2.90	3.35	96.65
3.50	58.6	3.41	2.55	97.45
4.00	51.9	3.85	3.80	96.20
4.50	46.0	4.35	3.50	96.50
5.00	41.6	4.81	4.00	96.00
5.50	36.9	5.42	1.48	98.53
6.00	34.1	5.87	2.30	97.70
6.50	31.6	6.33	2.70	97.30
7.00	29.4	6.80	2.90	97.10
7.50	27.4	7.29	2.75	97.25
8.00	25.7	7.78	2.80	97.20
8.50	23.9	8.37	1.58	98.43
9.00	22.8	8.77	2.60	97.40
9.50	21.4	9.35	1.65	98.35
10.00	20.9	9.57	4.50	95.50
	Average %		**2.47**	**97.53**

Based on Table 1, it can explain the comparison of standard measuring instruments with values from programming. The value of the accuracy of the speed parameters in the tool program ranges from 95.50% to 99.82% with an average value of 97.53%. the percentage of speed input error in tool programming ranges from 0.18% to 4.50% with an average error percentage of 2.47%.

In the process of testing the accuracy of the velocity value input in the program, measurements are taken by taking 4 mm/s and 2 mm/s as samples of the velocity values to be tested. Using the equation, $\Delta x / \Delta t$ the results can be seen in Figure 10.

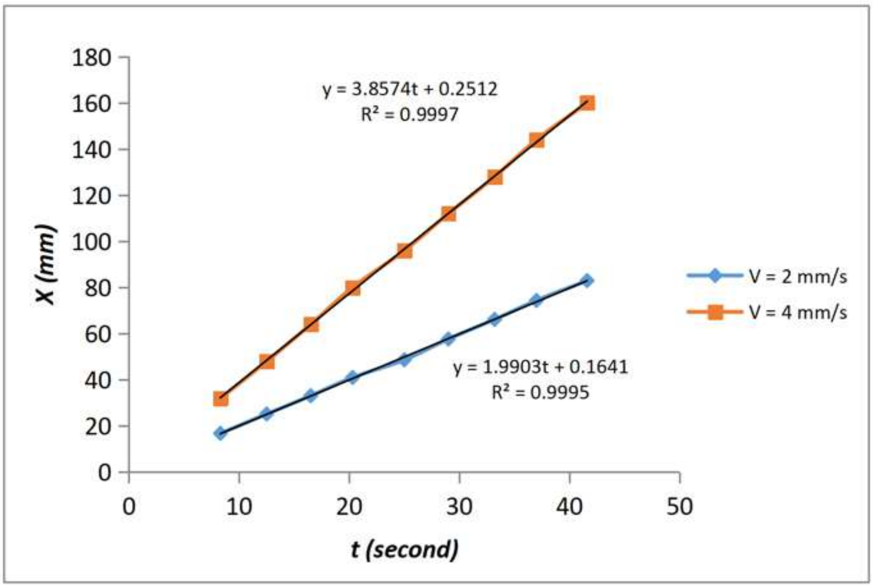

Fig. 10. Graph of the input tensile speed on testing the accuracy of the tool program at a value of 2 mm / s and 4 mm / s

Based on the graph in Figure 10, Equation 1 is obtained

$$X= 1{,}9903t + 0{,}1641$$
$$X= 3{,}8574t + 0{,}2512 \quad (1)$$

In Equation 1, the gradient of the linear equation can be described as 1.9903. This value is the velocity value obtained from the equation for testing the tool speed at a value of 2 mm / s. The value 0.1641 is a constant of the equation. This constant value shows the effect of variations in the distance between the clamp lever on the lever travel time. Based on the velocity value obtained from the equation to test the speed of the tool programmed at a value of 2 mm / s, the percentage of program error is 0.49%.

Measurements are also carried out at a speed value of 4 mm / s. In the equation the gradient of the linear equation is 3.8574. So that this value is the velocity value obtained from the equation $\Delta x / \Delta t$ in the velocity test at a value of 4 mm / s. The value 0.2512 is a constant of the equation. Based on the velocity value obtained from the equation to test the speed of the tool programmed at a value of 4 mm / s, the percentage of program error is 3.7%. The motor on the tool functions to move the lever vertically in the dipping and pulling processes. So that testing is carried out to ensure that the velocity values in the two processes have the same accuracy. These results can be explained in the graph in Figure 11.

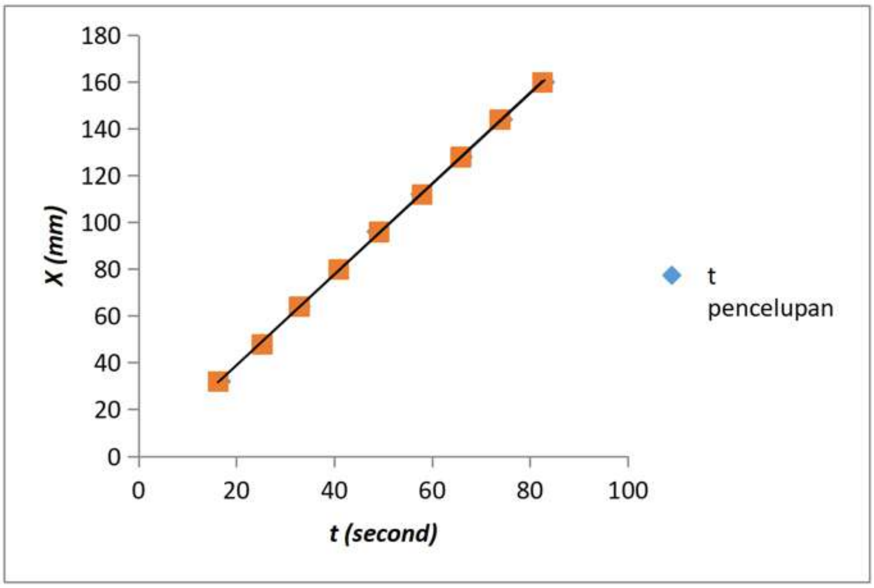

Fig. 11. Graph of tool hysteresis values

Based on the graph that can be seen in Figure 11, the hysteresis value obtains a linear equation. This explains that there is no significant difference in the velocity values for either the dyeing or drawing processes.

2. The accuracy of the dip coating tool

Accuracy is determined from the similarity of measurement data based on repeated measurements. Measurement of the tool velocity value was carried out repeatedly 10 times with a speed value of 4 mm / s as the sample. Based on the repeated measurements, the percentage of accuracy was obtained. Tool accuracy data can be seen in Table 2.

Table 2. Percentage of Dip Coating Tool Adherence

V (program)	T (measuring) second	V (measuring) mm/s	% Accuracy
4 mm/s	20.5	3.90	99.47 %
	20.9	3.83	98.60 %
	20.9	3.83	98.60 %
	20.8	3.85	99.08 %
	20.4	3.92	98.98 %
	20.5	3.90	99.47 %
	20.6	3.88	99.96 %
	20.7	3.87	99.56 %
	20.4	3.92	98.98 %
	20.4	3.92	98.98 %
	Average		**99.17 %**

In Table 2, for the speed value on the tool, the accuracy ranges from 98.60% to 99.96% with an average accuracy of 99.17%. This accuracy value indicates that the tool is feasible to be applied in meeting the needs of the coating activities. This also indicates that this tool has good accuracy.

3. The Effect of Tensile Speed Variations on the Resulting Thin Layer

The thickness of the thin films in the dip-coating process is influenced by the given velocity values. To find out the thickness value of the thin film on some of the samples using a SEM (Scanning Electron Microscope) test tool. Based on the test results, it is found that the relationship between variations in the tensile velocity value and the resulting thickness value is obtained. This relationship can be seen in Figure 12.

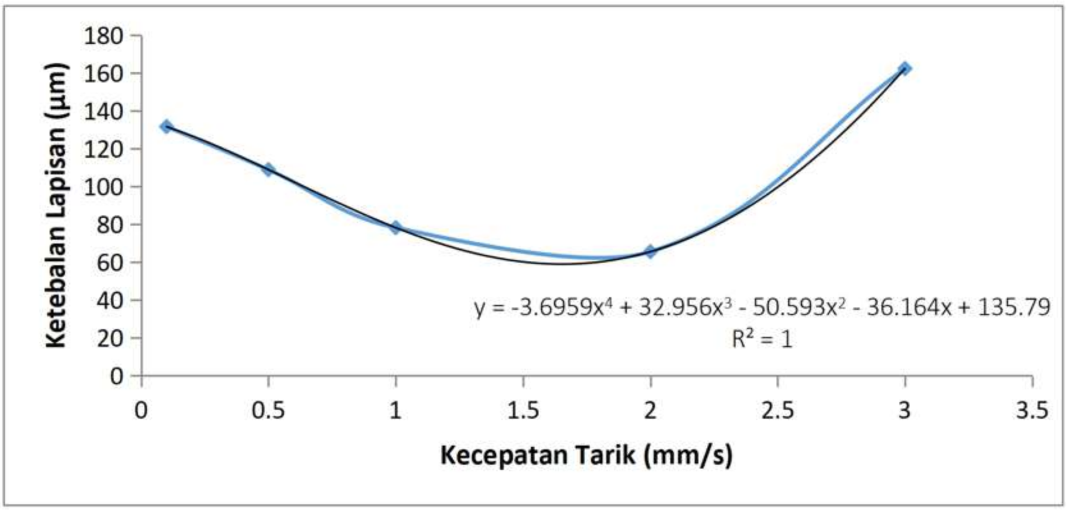

Fig. 12. The graph of the relationship between variations in the tensile velocity value on the resulting thin film

Based on the graph in Figure 12, it can be seen the relationship between the velocity value and the resulting thin film thickness value. The third-order polynomial equation is obtained. Many factors influence the results of the thin film so that anomalies are seen in obtaining the relationship between thickness and velocity values. The value obtained can be influenced by the level of accuracy and sensitivity of the measuring instrument used. In this measurement, the data were obtained with a magnification of 2000 pixels on a scale of 20 µm. The accuracy in carrying out the coating stage also determines the value of the resulting thin film. The data obtained is only based on variations in the velocity value with a fixed immersion time.

IV. CONCLUSION

Based on the results of testing and data analysis and discussion of the dip coating system that has been developed for this thin layer grower, the following conclusions can be formulated: The results of the performance specifications of the dip coating tool consist of a stepper motor, Raspberry Pi 3 module, LCD touchscreen specifically for Raspberry Pi, an electronic circuit supporting component consisting of resistors, capacitors, 5v regulators, limit switches, and power supply adapters. The accuracy and accuracy of the Raspberry Pi 3-based dip coating tool starts from the programmed speed value test. Based on the data from the plot results, a relation coefficient of 0.997 is obtained. The accuracy and accuracy obtained from the Raspberry Pi 3-based dip coating tool were 97.53% and 99.19%. The relationship between the variation in the tensile velocity value in the dip coating process to the thickness of the resulting thin film in some of the samples tested obtained the form of a second order polynomial equation. Anomalies were found in the relationship between the tensile velocity value and the thickness of the thin film caused by several factors in the manufacturing process and the measurement of the thickness of the coating.

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