The Correlation Between the Number of Heater and Energy Saving on Plastic Injection Molding

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Abstract.
The number of human populations is increasing as well as daily needs and consequently increased the number of wastes that being produced including plastic waste. Indonesia itself consumed 17 kg/capita per year. Recycling the plastic waste is one of alternatives way to reduce waste, by melting the plastic waste using six heaters from electrical energy source. This research was conducted to obtain number of heaters that will be used in the injection molding process by considering the time consumed for the temperature of 50º - 210º C. The observation is being done by measuring the temperature and power supplied from 3, 4, 5 and 6 heaters and repeated for 3 times experiment. Based on the measurement data that has been carried out, it is found that the highest average power is the injection with six numbers of heaters consumed 956.80 W. The time measurement required to reach optimal temperature, for 3 number of heaters was taking the longest time which is 2842 Seconds. This condition is in line with the average of electrical power consumed to reach the optimal temperature is the using of the heaters 0.350 kWh. Based on three hypotheses that being done, the result shows that the Ha is accepted and there is significant influence between three models that being made.

Keywords: *Plastic, Injection molding, energy supply, correlation, F test*.

I. INTRODUCTION

Human life that uses various products have caused the production of various kinds of waste. Both household waste, industry, medical, tourism, and various other sectors. Every year, the increasing number of people will be directly proportional to their daily needs and result in an increase in the amount of waste produced [1,2]. Waste that can cause serious environmental pollution problems in every country is plastic waste [3]. Plastic consumption in Indonesia per capita has reached 17 kg per year with consumption growth reaching 6-7% per year [4]. Indonesia in particular, the food and flexible packaging industry occupies 80% of the use of plastic packaging [5].One way that can be done to overcome this plastic waste is the method of reduce, reuse and recycle. Many efforts have been made in the recycling of plastic products, by melting plastic and shaping them into more useful products [6]. One alternative that is done is to recycle plastic waste by melting plastic or plastic seeds that have been chopped [7]. In the melting process, the tool used requires electrical energy which is converted into heat energy through an intermediary in the form of a plate (heater). In the early stages of designing this plastic molding, one heater was used, with a lever length of 65 cm. This is so that when the research is continued and an additional heater is needed, it can be added immediately. Up to now, there are six heaters arranged vertically to produce enough heat to melt the plastic.In its operation, the tool requires heat energy that comes from electricity.

Electrical energy is the result of changing mechanical energy (motion) into electrical energy. The existence of electrical energy is widely used in everyday life such as lighting, heating, and electric motors [8]. In its use, according to Nugroho [9], it is necessary to regulate the use of electrical energy in order to avoid rotating blackouts due to the inability of the power center to supply electricity on demand, to save natural resources, and to provide opportunities for people who have not yet enjoyed electric power.Energy saving is an issue that has been widely discussed in several studies. Calculate the amount of electrical energy consumption in buildings and identify ways to save it (energy audit), for example by choosing a motor according to its use and capacity, choosing an energy and power-saving air conditioner according to the size of the room, choosing a refrigerator with the right size/capacity. appropriate, and use energy-efficient lamps [10,11,12].This research was conducted by conducting experiments to obtain a combination of the number of heaters that will be used in the melting process by considering sufficient time and temperature. The purpose of the research is to save on the use of electrical power which will be related to processing costs.

II. METHODS

The implementation of this research was carried out in the Manufacturing Process Laboratory of the Industrial Engineering Study Program, Faculty of Engineering, University of Muhammadiyah Palembang. The injection molding machine used is a plastic molding that has been fitted with six heaters and a temperature counter. Observations were made by measuring temperature and power for the number of heaters 6, 5, 4, and 3 with each repetition 3 times.Based on the background and objectives of the research made, the conceptual framework of this research is made as follows:

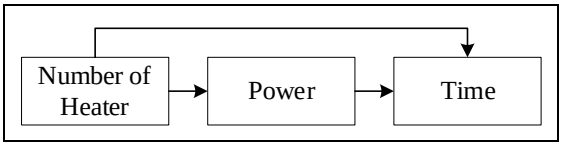

Fig 1. Research Framework

From the concept above, the authors make initial hypotheses for further testing of each hypothesis. There are 3 hypotheses in this study, namely:

Hypothesis 1:

Ha = There is a significant effect between the number of heaters on the power used.

H0 = There is no significant effect between the number of heaters on the power used.

Hypothesis 2:

Ha = There is a significant effect between the power used and the time required to reach the optimal temperature.

H0 = There is no significant effect between the power used and the time required to reach the optimal temperature.

Hypothesis 3:

Ha = There is a significant effect between the number of heaters on the time required to reach the optimal temperature.

H0 = There is no significant effect between the number of heaters on the time required to reach the optimal temperature.

Thermometer

To measure the temperature of this tool is done by using a thermometer, to measure the degree of heat of an object. The plastic molding already has a temperature sensor connected to the heater, so we can see the temperature movement on the indicator screen.

Clamp Meter

Clamp Meter or ampere pliers is a measuring instrument used to measure the electric current in a conductor cable that is electrified. Clamp Meter has two clamping jaws, thus there is no need to interfere with the electrical circuit to be measured. The clamp meter only needs to be placed around the perimeter of the electrical wire being measured.

Stopwatch

In general, a stopwatch is a handheld watch that can be used to measure the amount of time that has elapsed or taken. In this study, a stopwatch was used to measure how much time it took for the melt to reach its optimal temperature.

Ampere to watt calculation:

$P=I\times V$ (1)

P = Power (watts/W)

I = Current (amperes / A)

V = Voltage (volts/V)

The cost of electricity used by customers is calculated based on the amount of electrical energy used. In the calculation of National Power Company (PLN), the unit of electrical energy used is kWh (kilo watt hour) or in Indonesian it means kilo watt hour. From this unit, the time base is in hours.

The formula for calculating the cost of electricity:

W=W×h (2)

W = Electrical energy (Watt hour / Wh)

P = Power (watts/W)

t = Usage time (hours / h)

Convert Watt hour to kilo Watt hour (kWh):

$$\text{Kilo Watt hour} = \frac{W}{1000}$$

III. RESULT AND DISCUSSION

Temperature and power measurements were carried out for the type of HDPE (High Density Polyethylene) plastic which optimal temperature was known to be 210º C, with the melting process being ±600 seconds per 25 grams of melted HDPE plastic.

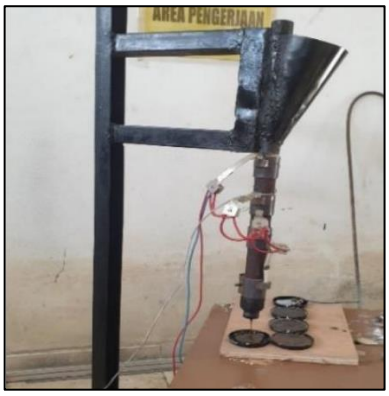

Fig 2. HDPE Molding Experiment

The results of the measurements that have been carried out can be seen in table 1. below:

Table 1. Measurement Results

Jumlah *Heater*	Replikasi 1		Replikasi 2		Replikasi 3	
	Waktu (s)	Arus (A)	Waktu (s)	Arus (A)	Waktu (s)	Arus (A)
3	2759	2.06	2815	2.04	2952	2.08
4	1684	2.83	1663	2.78	1343	2.83
5	578	3.57	642	3.53	537	3.52
6	362	4.40	385	4.38	406	4.39

Ampere to watt calculation:

1. Number of heaters 3, 1st replication:

P=I×V

P=2.06×220

P= 453.2 W

2. Number of heaters 3, 2nd replication:

P=2.04×220

P= 448.8 W

3. Number of heaters 3, 3rd replication:

P=2.08×220

P= 457.6 W

The results of all ampere-to-watt conversion calculations can be seen in Table 2. below:

Table 2. Results of Ampere to Watt Conversion

Jumlah *Heater*	Repl. 1	Repl. 2	Repl. 3	Rata-Rata
	Daya (W)	Daya (W)	Daya (W)	
3	453.2	448.8	457.6	453.20
4	622.6	611.6	622.6	618.93
5	785.4	776.6	774.4	778.80

6	968	963.6	965.8	965.80

From the conversion results that have been obtained, it can be displayed in a line chart to see the pattern. The diagram is shown in Figure 3. below:

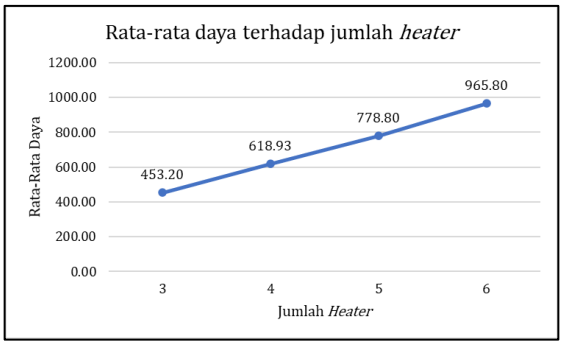

Fig 3. Power Average Pattern Graph (W)

If seen in the graph above, it is known that the average power consumed continues to increase as the number of heaters increases. This happens because each heater used uses energy Meanwhile, the time required for the melt to reach the optimal temperature shows a graph (Figure 4) on the contrary, namely, the greater number of heaters used, the less the average time required.

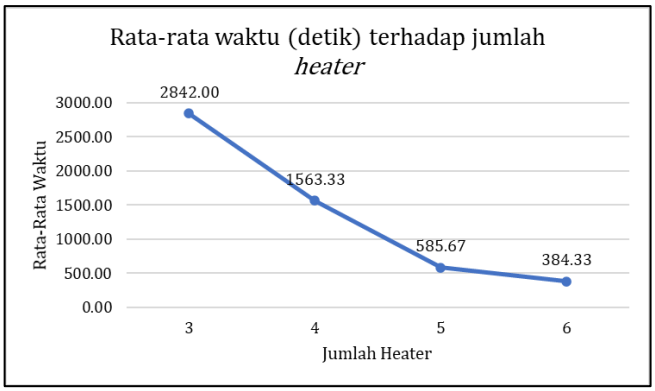

Fig 4. Graph of Time Average Pattern (seconds)

The conversion of electrical energy used by the melter in kilo watt hour shows that the number of heaters 3 requires a higher amount of electrical energy than the others, this is because the time required to reach the optimal temperature is longer so the energy required is also greater. However, it should also be noted that the power measurement with the number of heaters 3 shows a lower value, so this will have an impact on the length of time the plastic melts.

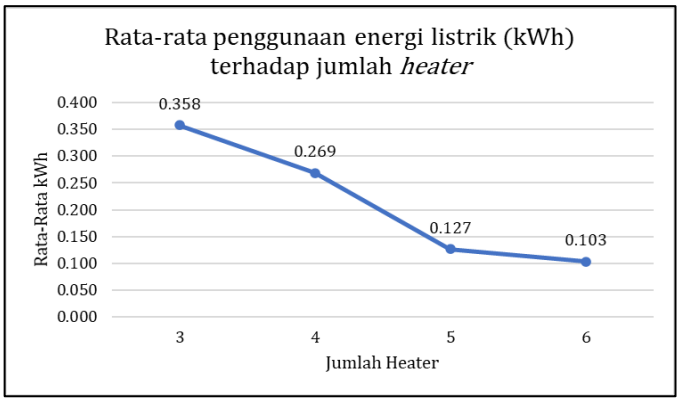

Fig 5. Graph of The Average Pattern of Electrical Energy Use in Reaching The Optimal Temperature (Kwh)

If the tool is used to do one plastic melting cycle with a time of 10 minutes, then the number of heaters 5 becomes more optimal, because it requires less electrical energy, which is 0.257 kWh.

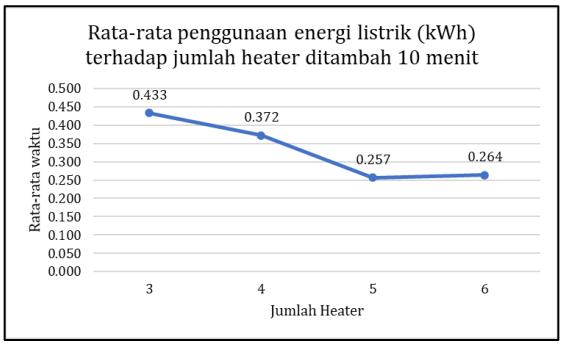

Fig 6. Graph of The Average Pattern of Electrical Energy Use (Kwh) When Used

Validity test

In every measurement, it is always expected to obtain accurate and objective measurement results. One of the efforts to achieve this is that the measuring instrument used must be valid. Validity test is used to obtain high validity of the research instrument so that it can meet the requirements.Validity test is done by manual calculation and compared with r table, if r count>r table, then the data obtained is valid. The number of samples is 4 with = 0.05 obtained r table = 0.95. The validity test formula is as follows:

$$r = \frac{n\,(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n(\sum X^2) - (\sum X)^2][n(\sum Y^2) - (\sum Y)^2]}}$$

Calculation of validity test for power variables:

$$r = \frac{4\,(\sum 6411906) - (2829.2)(8450.2)}{\sqrt{[4(2146898) - (2829.2)^2][4(19149910) - (8450.2)^2]}}$$

$$r = \frac{1740319}{1740432} = 0.999935$$

The results of the calculation and decision of the validity test on the power variable are shown in Table 3. below:

Table 3. Test The Validity Of The Power Variable

No. Replikasi	r_{hitung}	r_{tabel}	Keterangan
1	0.999935	0.95	Valid
2	0.999963	0.95	Valid
3	0.999902	0.95	Valid

Calculation of validity test for time variable:

$$r = \frac{4\,(\sum 6411906.16) - (2829.2)(8450.2)}{\sqrt{[4(2146898) - (2829.2)^2][4(19149910) - (8450.2)^2]}}$$

$$r = \frac{1740318.8}{1740432.407} = 0.99993$$

The results of the calculation and decision of the validity test on the time variable are shown in Table 4. below:

Table 4. Test the validity of the time variable

No. Replikasi	r_{hitung}	r_{tabel}	Keterangan
1	0.99993	0.95	Valid
2	0.99996	0.95	Valid
3	0.9999	0.95	Valid

Correlation Analysis and F test

Correlation analysis is used to determine the degree or strength of the correlation between the number of heaters and the power, the correlation between power versus time, and the correlation between heater and time. Calculation of correlation using the following formula:

$$rxy = \frac{n\,(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n(\sum X^2) - (\sum X)^2][n(\sum Y^2) - (\sum Y)^2]}}$$

Calculate the correlation value between the number of heaters and power.

$$rxy = \frac{4\,(13524.1) - (18)(2816.73)}{\sqrt{[4(86) - (18)^2][4(2127767.79) - (2816.73)^2]}}$$

$$rxy = \frac{3395.33}{3397.31} = 0.99942$$

The number 0.99942 indicates the level of the correlation between the number of heaters and the power is very strong. The calculation results are also reinforced by the results of processing using the following SPSS 26 software:

Table 5. The Correlation Between The Number of Heaters to Power Using SPSS 26

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.999	.998	9.15206

a. Predictors: (Constant), Number of Heater

In table 5. above, it is known that the value in column R (0.999) also shows a very strong correlation between the number of heaters and power.

Calculating the correlation value between power and time.

$$rxy = \frac{4\,(3082899.844) - (2816.73)(5375.33)}{\sqrt{[4(2127768) - (2816.73)^2][4(11011692.67) - (5375.33)^2]}}$$

$$rxy = \frac{-2809281.2}{2957077.729} = -0.95$$

The number -0.95 indicates the level of the correlation between power and time is very strong. The calculation results are also reinforced by the results of processing using the following SPSS 26 software:

Table 6. Analysis of The Correlation Between Power Over Time Using SPSS 26

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.950[a]	.903	.854	429.65097

a. Predictors: (Constant), Power

In Table 6. above, it is known that the value in column R (0.950) also shows a very strong correlation between power and time.

Calculate the correlation value between the number of heaters against time.

$$rxy = \frac{4\,(19513.7) - (18)(5275.33)}{\sqrt{[4(86) - 18^2][4(10904559) - (5275.33)^2]}}$$

$$rxy = \frac{-16901}{17770.3} = -0.9594$$

The number -0.9594 shows that the correlation between the number of heaters and time is very strong. The calculation results are also reinforced by the results of processing using the following SPSS 26 software:

Table 7. The Correlation Between the Number of Heaters to Time With SPSS

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.959[a]	.920	.881	388.23334

a. Predictors: (Constant), Number of Heaters

In Table 7. above, it is known that the value in column R (0.959) also shows a very strong correlation between the number of heaters and time.The F test aims to show whether an independent variable that is included will have a simultaneous and significant effect on the dependent variable or not [14].Then according to Gujarati [15], states that the degree of confidence commonly used in the F test is 5% (α = 0.05). Decision making on the hypothesis is based on the value of sig. The results of processing the F test are shown in tables 8. 9. and 10.

Based on Table 8. it is known that the value of sig. (0.001) 0.05, then the hypothesis Ha is accepted, or there is a significant effect between the number of heaters on the power used. Table 9. also shows that the value of sig. (0.05) 0.05, then Ha is accepted, or there is a significant effect between the power used and the time required to reach the optimal temperature. Likewise, with Table 10. where the value of sig. (0.041) 0.05, so Ha is also accepted, or there is a significant effect between the number of heaters on the time required to reach the optimal temperature.

Table 8. F Test Between the Number of Heaters and Power Using SPSS 26

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	144104.171	1	144104.171	1720.439	.001[b]
	Residual	167.520	2	83.760		
	Total	144271.692	3			

a. Dependent Variable: Power
b. Predictors: (Constant), Number of Heater

Table 9. F Test Between Power and Time Using SPSS 26

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3418984.931	1	3418984.931	18.521	.050[b]
	Residual	369199.904	2	184599.952		
	Total	3788184.836	3			

a. Dependent Variable: Time
b. Predictors: (Constant), Power

Table 10. F Test Between the Number of Heaters and Time Using SPSS 26

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3486734.577	1	3486734.577	23.133	.041[b]
	Residual	301450.259	2	150725.130		
	Total	3788184.836	3			

a. Dependent Variable: Time
b. Predictors: (Constant), Number of Heater

IV. CONCLUSION

Based on the analysis and discussion that has been carried out, it can be concluded that the three hypotheses made, all three accept Ha, that is, there is a significant influence between the number of heaters on the power used, there is a significant effect between the power used and the time required to reach the optimal temperature, and there is a significant effect between the number of heaters on the time required to reach the optimal temperature.

V. ACKNOWLEDGMENTS

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