IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 6, June 2020, ||Series -II|| PP 19-26

Effect of Temperature And Time of Heating Printing Hdpe Boards With Linear Regression Method

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Received 18 June 2020; Accepted 04 July 2020

Abstract:
Background: High-density polyethylene (HDPE) is the most abundant type of plastic waste in the city. The most effective way to manage HDPE waste is by recycling. The purpose of this study was to determine the effect of heating temperature and HDPE waste melting time on the tensile test of recycled plastic boards. The results of this study will be used to determine the optimum temperature and time of the smelting process of HDPE waste which will be used to produce plastic boards that will be used as raw material for creative products.
Materials and Methods: The material used in this research is the HDPE bottle cap which will be recycled chopped using a crusher machine to make it flake so it can be melted down and printed into a test sample. The research method used is multiple regression with 2 variables with the Independent Variable (X): Temperature and hot press time and the Bound Variable (Y) from the Modulus Young calculation of the Specimen,
Results: If an additional 1 degree of temperature occurs, the modulus of the young will increase by 41,708 N/m^2. And each additional time during a one minute hot press will increase the value of young modulus by = 779,714 N/m^2.
Conclusion:the higher the heating temperature of HDPE and the heating time the higher the tensile test value of the modulus young results of recycled HDPE specimens.
Key Word: Waste, HDPE, Temperature, Time, Modulus Young

I. INTRODUCTION

Plastic has become a very useful commodity in many aspects of human life because of its relatively inexpensive, easy to process and lightweight nature. Over the past few years, the world has tried to use renewable energy by using plastic waste to reduce environmental pollution. But this method has a big impact on climate change [1]. Burning of plastic waste will pollute the environment. In the research of Nnorom, I. C., & Osibanjo, O. in 2009 stated that burning plastic waste in open fields is the main source of air pollution. Most of the handling of municipal solid waste containing about 12% plastic is carried out by combustion, the result of combustion releases toxic gases such as Dioxin, Furan, Mercury and Polychlorinated Biphenyl into the environment [2]. To overcome the more severe environmental pollution is to recycle plastic waste. Recycling is the preferred solution for managing plastic waste, because it has a lower environmental impact on the specified impact categories, from the Global Warming Potential (GWP) and Human Toxicity Potentials (HTP) indicators [3].

High-density polyethylene (HDPE) is the third largest commodity plastic material in the world, after polyvinyl chloride and polypropylene[4]. HDPE is a type of plastic waste that is widely used as recycled material. Because the waste from these materials is easily processed and recycled as raw materials for use, one of them is electrical equipment such as low voltage insulation jacket, medium voltage cable insulation layer and various products, its application is useful to reduce the cost of imported materials, and their disposal[5] In addition, High-density polyethylene (HDPE) is one of the most widely used polymers, having many applications such as bottles, containers and consumer goods. Because post-consumer HDPE from bottles cannot be used anymore and has high melting viscosity, HDPE is an attractive source of recycled material [6, 7].

HDPE is included in the thermoplastic category, because it has bonds between linear molecules that can undergo softening or deformation, in other words melting, if subject to heat. Whereas in some other types of plastics (for example polyester and epoxy) bonds between molecules occur crosslinking (crosslink). This form of bonding has high temperature resistance, so that this type of plastic cannot melt if subjected to an increase in temperature. Such plastic is called thermosetting[8]. The test temperature plays a decisive role, because the tensile strength of PE80 thermoplastic materials is linearly dependent on it, in the temperature range at which the experimental test is carried out (the range is included in the field of viscoelastic behavior)[9].

In this study, tensile testing of plastic samples is carried out with ASTM D3039 tensile testing standard. ASTM D3039 is used because it is a tensile testing standard for composites with polymer matrices[10, 11, 12].

HDPE is obtained from used HDPE bottle caps on the market. The plastic bottle cap is chopped with flakes so that it can be melted down and pressed with pressure to become a tensile test sample, and finally to do tensile testing of this plastic sample so that the strength and tensile strain can be known.

The purpose of this study was to determine the effect of heating temperature and HDPE plastic waste melting time on the tensile test of recycled plastic boards. The results of this study will be used to determine the optimum temperature and time of the melting process from HDPE waste which will be used to produce plastic boards as shown in Figure 1. These HDPE boards are used as raw material for creative products.

Figure 1 HDPE Board Printing Results

II. MATERIAL AND METHODS

This study is intended to explore the problem of recyclable plastic waste, melting temperature, heating time and tensile strength of plastic products in the field of plastic molding based on theory and some references.**Study Experimental Design:**Data analysis in this study was carried out by multiple linear analysis. Where Linear / Multiple Linear Regression Model (LM) is a model that represents the relationship between one response variable and one predictor variable (Simplified Linear Regression) or more than one predictor variable (Multiple Linear Regression) using parameters entered linearly and estimated by the linear at least [13]. In this study focuses on 2 independent variables that affect one dependent variable, so the research method used is multiple regression method with 4 variables. Research Variables consist of:
Dependent Variable (X):
X1: Hot press temperature
X2: Time of hot press
Independent Variable (Y): Y: Result of calculation of Modulus Young on Specimen

The experiment was conducted with 2 variables, temperature hot press and hot press time. Where hot press Temperature: 140 ℃, 160 ℃, 180 ℃, 200 ℃ and hot press time: 1 minute and 2 minutes
Study Location: The research was conducted at the Mercu Buana University Production Process Laboratory
Study Duration: June 2019 to December 2019.
Sample size: 12specimen.

Procedure methodology
• The process of making a specimen

The HDPE bottle cap that will be recycled is chopped using a chruser machine to make it flake so it can be melted down and printed into a test sample. The results of HDPE counts from the plastic chopper process are then sorted, in order to get a material with a size of 5 to 10 mm so that the material can enter evenly in the mold and no air settles in the mold. Before the HDPE chopped material is put into the mold, the mold is given special treatment by giving a liquid spray silicone mold release. This release agent is a compound that is usually sprayed on the surface of the mold, forming a thin film that can act as a barrier preventing sticking and the product is easy to remove from the mold [14]. Then the temperature setting on the hot press machine before heating. Check the actual temperature on the hot press printing base using a digital infrared thermometer as a compare setting.

Figure 2 Process of Material Input into the Mold

Figure 3 Hot press process

After the temperature at the hot press machine is reached as desired, the mold that has been filled with chopped HDPE bottle cap material is placed on the hot press foundation and the jack is raised until the top mold sticks to the top heater. Wait until the mold reaches the desired temperature (according to settings), and press according to the experimental design. After passing the hot press stage, the mold is then taken and the aging and cooling process is carried out using ground water that is sprayed on the mold gradually, so that the mold temperature drops gradually and no deformation occurs in the mold due to the cooling process. The product is removed from the mold and then finished and given a sample number on the product as a description for product testing. After the temperature in the mold reaches ± 50°C, the mold is opened and the HDPE board product is removed from the mold and then cut into 3 specimens in each product using a saw with specimen dimensions in accordance with ASTM D3039 tensile test testing standards.
Experimental process

Table 1: Initial Experimental Design

Number.	Hot Press Temperature(℃)	Heating Time (minute)
1	140	1
2	140	2
3	160	1
4	160	2
5	180	1
6	180	2
7	200	1
8	200	2

Table 2 Results of the Experimental Process

Number	Hot Press Temperature(℃)	Results of the Production Process
1	140℃	Print results are not perfect (does not melt completely). So that the product NG (Not Good) & not continued for the testing process.
2	160	The product melts in the mold. Perfect print, OK product & testing process.
3	180	The product melts in a mold. Perfect print, OK product & testing process

4	200	Imperfect printing results, product defects due to overheat, so NG products & not continued for the testing process. Experimental design with a temperature exceeding 180ºC could not be continued because of over heat.

Table 2 it can be seen that a good production result is a production with temperatures of 160^{o}C and 180^{o}C while the results of production at 140^{o}C and 200^{o}C are obtained NG results. Based on the table, the experiments will only be performed at temperatures of 160^{o}C and 180^{o}C at temperatures of 1 minute and 2 minutes respectively. The specimen is cut into 3 parts. So that it is obtained into 12 tensile test specimens according to ASTM D3039 standard.

Figure 4 Tensile test specimen 160/1

The size of the 12 specimens has the following dimensions: Length 193 mm, Width = 25 mm and thickness = 5 mm. Then tensile strength testing is carried out according to ASTM D3039 standard, then the data collected has then been processed.
Example of Calculation of Modulus Y
Specimen tensile strength 160 / 1 :

Tension = F/A
= 1275.3 N/0.125 m^2
= 10202,4 N/m²

Strain = ΔL/ L0
= 0.195/0.193
= 1,010363

Modulus Young = Tension/Strain
= 10202,4 N/m^2/1,010363
= 10097,76 N/m²

Young's Modulus value, then used as a variable Y = Quality of printing products (Modulus Young).

Table 4 Data of test results

Number.	Hot Press Temperature(℃)	Heating Time (minute)	Modulus Young (N/m²)
1	160	1	10097.760
2	160	1	10097.760
3	160	1	10097.760
4	160	2	10875.086
5	160	2	10486.690
6	160	2	10486.690
7	180	1	10540.468
8	180	1	10540.468
9	180	1	10930.855
10	180	2	12102.018
11	180	2	11321.243
12	180	2	11711.631

Statistical analysis

The results of the calculation of multiple linear regression

Linear / Multiple Linear Regression Model (LM) is a model that represents the relationship between one response variable and one predictor variable (Simplified Linear Regression) or more than one predictor variable (Multiple Linear Regression) using parameters entered linearly and estimated by the most a little [14].

Table 5 Descriptive Statistics

	Mean	Std. Deviation	N
Modulus Young (Y)	10774.03575	648.295004	12
Temp. (X1)	170.00	10.445	12
Duration (X2)	1.50	.522	12

In Table 5 shows the average values of young modulus, temperature and duration of the hot press, Std. Deviation and total data (N).

Table 6 Correlations

		Modulus Young (Y)	Temp. (X1)	Duration (X2)
Pearson Correlation	Modulus Young (Y)	1.000	.672	.628
	Temp. (X1)	.672	1.000	.000
	Duration (X2)	.628	.000	1.000
Sig. (1-tailed)	Modulus Young (Y)	.	.008	.014
	Temp. (X1)	.008	.	.500
	Duration (X2)	.014	.500	.
N	Modulus Young (Y)	12	12	12
	Temp. (X1)	12	12	12
	Duration (X2)	12	12	12

In Table 6 the relationship between temperature variables and young modulus is 0.672, which means the relationship between the two variables is very strong. A positive correlation coefficient indicates a direct relationship, meaning that if there is an increase in temperature, it will increase the value of the young modulus. The relationship between the two variables is seen from the significance number (sig.) of 0.008 <0.05, which means that the relationship between temperature and modulus young is significant.

And the relationship between young modulus and duration is 0.628, which means the relationship between the two variables is very strong. A positive correlation coefficient indicates a direct relationship, meaning that if there is an increase in temperature, it will increase the value of the young modulus. The relationship between the two variables is seen from the significance number (sig.) of 0.014 <0.05, which means that the relationship between temperature and modulus of young is also significant.

Table 7 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.920a	.846	.812	281.234757

a. Predictors: (Constant), Duration (X2), Temp. (X1)

In Table 7 the Summary Model, the information presented is as follows:

- R value shows the value of correlation or relationship, which is equal to 0.920 or 92% and the magnitude of the influence of the independent variable on the dependent variable is called the coefficient of determination which is the result of squaring the R value.
- The value of R Square is called the coefficient of determination, the number 0.846 (squaring the R value) means that 84.6% of the young modulus can be explained using the temperature and duration variables. The remaining 15.4% (100-84.6%), due to other variables or other factors. The effect of other factors is referred to as error (e), which is calculated by the formula e = 1 - r2. R Square values range from 0 to 1, the smaller this number, the weaker the relationship between the two variables or vice versa.

- Std value. Error of the Estimate (SEE) of 248.923 was used to assess the feasibility of the independent variable (predictor) in relation to the dependent / dependent variable. The conditions are if the value of SEE <Std. Deviation, the predictor used to predict the dependent variable is feasible. The results of SEE 281.234757 <648.295004, so that the independent variables of temperature and duration are feasible as predictors for the dependent variable modulus young.

Table 8 ANOVA

Model	Sum of Squares	Df	Mean Square	F	Sig.
1 Regression	3911313.636	2	1955656.818	24.726	.000a
Residual	711836.896	9	79092.988		
Total	4623150.532	11			

a. Predictors: (Constant), Duration (X2), Temp. (X1)

b. Dependent Variable: Modulus Young (Y)

In Table 8 the ANOVA calculation of the calculated F value of 24.726 with a probability or significance (sig.) of 0.000. Based on probability, 0.000 <0.05 so that the regression model is feasible to predict the value of young modulus.

Table 10 Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (Constant)	2514.137	1403.828		1.791	.107		
Temp. (X1)	41.708	8.119	.672	5.137	.001	1.000	1.000
Duration (X2)	779.714	162.371	.628	4.802	.001	1.000	1.000

a. Dependent Variable: Modulus Young (Y)

Multiple Linear Regression

In Table 10 this illustrates the regression equation Y = a + b1X1 + b2X2, with the following explanation:

Y = Modulus Young

a = constant number of Unstandardized Coefficients, in this case 2514.137 which means young modulus when the values of X_1 (temperature) and X_2 (duration) = 0

X1 = temperature data

X2 = Data duration

b_1 = first regression coefficient number of 41.708 which means that each addition of 1 degree of temperature increases the value of young modulus by 41.708. Conversely, if the number is negative (-), the modulus young decline applies.

b_2 = the number of the second regression coefficient is 779,714 which means that each time addition (duration) at the time of the hot press increases the modulus young value = 779.714. Conversely, if the number is negative (-), the modulus young decline applies.

T test

The t-test was used to compare the average of two independent groups [15]. The basis of temperature using the significant probability figures as follows:Seeing the value of t table with the provisions α / 2 = 0.05 / 2 = 0.025, two-sided test because they want to know the significance of the regression coefficient rather than looking for bigger or smaller. The degree of freedom (df - degree of freedom) is calculated by the formula = amount of data - 2 = 12 -2 = 10 so the t table value is 2.222.

Determine the criteria as a basis for decision making:
If the calculated t value <table t value, H0 is accepted
If the value of t arithmetic> T value of table H0 is rejected
Decision: temperature variable, t value 5.137> 2.222 (t table value), H0 is rejected or H1 is accepted, which means the regression coefficient is accepted. The second variable, duration, t value 4.802> 2.222 (t table value), H0 is rejected or H1 is accepted, which means the regression coefficient is accepted.

F test

The F test was used to determine all variables, namely temperature and duration simultaneously influencing the printing quality (modulus young) of recycled HDPE products. A calculated F value of 24.726 with a probability or significance (sig.) of 0.000, with df1 = degree of numerator 2 and df2 = degree of denominator 9 with a level of 5%, then obtained an F table of 4.26 means F arithmetic> F table. Results 24.276> 4.26, then H_0 is rejected, H_1 is accepted.

III. RESULT AND DISCUSSIONS

In the F test results it can be concluded that the independent variables jointly or simultaneously affect the dependent variable significantly. Based on the analysis it can be concluded that the temperature and time (duration) variables have positive and significant effects simultaneously on the quality of HDPE recycle printing with hot press machines.From the results of the study found that the optimum temperature for printing HDPE boards ranged between 160^oC and 180^oC with a heating time of 1-2 minutes if less than that the NG results would be obtained. From the results of statistical analysis it was also found that temperature and heating time affected the strength of the tensile test (Modulus Young) on the printed HDPE board results. And of the four experimental variables found below a temperature of 180oc and a heating time of 2 minutes is the best time to do HDPE board printing

IV. CONCLUSION

From the results of the study it was concluded that the higher the heating temperature of HDPE and the heating time will increase the value of the tensile test value of the modulus young results of recycled HDPE specimens. If an additional 1 degree of temperature occurs, the modulus of the young will increase by 41.708 N / m2. And each additional time during a one minute hot press will increase the value of young modulus by = 779.714 N / m2. From the results of the above study it can be concluded that the higher the HDPE heating temperature and the heating time for temperatures between 160^oC and 180^oC and the heating time of 1 and 2 minutes, the optimum temperature is 180^oC with a heating time of 2 minutes. With the addition of 1 degree the temperature increases the modulus young value by 41.708 N / m2 and the addition of time (duration) at the time of the hot press, increasing the modulus young value by = 779,714 N / m2

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Silvi Ariyanti, et. al. "Effect of Temperature And Time of Heating Printing Hdpe Boards With Linear Regression Method." *IOSR Journal of Engineering (IOSRJEN),* 10(6), 2020, pp. 19-26.