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Analysis of the quality of the shredder plastic machine depend on variations in material plastic types and dimensions using the Taguchi Method

Hendra Hendra [a,1], ***Nur Qodri Wijayanto*** [a], ***Sidik Susilo*** [a], ***Adam Kamil*** [a], ***Erny Listijorini*** [a], ***Hernadewita Hernadewita*** [b]

[a]*Mechanical Engineering Department, Universitas Sultan Ageng Tirtayasa, Jl Jendral Sudirman km 3, Cilegon 42435, Banten, Indonesia*
[b]*Magister of Industrial Engineering, Universitas Mercubuana, Jakarta, Kampus Meruya, Jakarta, Indonesia*

[1]Corresponding author: hendra@untirta.ac.id

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ABSTRACT

The problem of plastic waste is critical things because everybody still often uses plastic for various daily needs. Therefore, recycling is considered very important to overcome these problems, including using a plastic chopping machine. The types of plastics used in this research are HDPE, PE, and PP plastics with experimental methods and the Taguchi method to determine the effect of plastic variations, the dimensions of the chopped results, and the percentage value of the contribution of the test variables to the plastic chopping machine. The results obtained in the study are that all types of plastics can be adequately chopped, with the optimum size for PP plastic being 6,8 x 4,5 mm with a processing time of 91,5 seconds. For PE, it is 16 x 10. 5 mm with a processing time of 170.6 seconds. While for HDPE, it is 68 x 34.5 mm with a processing time of 251.1 seconds. These results follow those obtained using the Taguchi method, with a contribution percentage of 77 % for the variable type of plastic followed by dimensions, weight, and thickness.

ABSTRAK

Permasalahan sampah plastik merupakan hal yang sangat penting karena setiap orang masih sering memanfaatkan plastik untuk berbagai kebutuhan sehari-hari. Oleh karena itu proses daur ulang dinilai sangat penting sebagai upaya mengatasi permasalahan tersebut, salah satunya dengan menggunakan mesin pencacah plastik. Jenis plastik yang digunakan dalam penelitian ini adalah plastik HDPE, PE, dan PP dengan metode eksperimen dan metode Taguchi untuk mengetahui pengaruh variasi plastik, dimensi hasil cacahan, dan nilai persentase kontribusi variabel uji terhadap performan mesin pemotong plastik. Hasil yang diperoleh pada penelitian adalah semua jenis plastik dapat dicacah dengan baik, dengan ukuran optimum untuk plastik PP adalah 6,8 x 4,5 mm dengan waktu pengerjaan 91,5 detik, untuk PE 16 x 10 ,5 mm dengan waktu pemrosesan 170,6 detik. Sedangkan untuk HDPE berukuran 68 x 34,5 mm dengan waktu pengerjaan 251,1 detik. Hasil tersebut sesuai dengan yang diperoleh menggunakan metode Taguchi yaitu persentase kontribusi sebesar 77% untuk variabel jenis plastik diikuti dimensi, berat, dan ketebalan plastik.

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1. Introduction

Plastic is a material that is widely used in everyday life because it can be used for various things, whether as plastic packaging or other items. Apart from its benefits, plastic also has disadvantages, one of which is that it is difficult to break down because it is long-lasting and not easily destroyed naturally, so it can become an environmental problem. Plastic bags or bags take 10 to 20 years to decompose completely, and plastic bottles even take 450 years to decompose. Meanwhile, with the increase in population, the volume of waste generated by human activities will also increase [1-4].

Therefore, a plastic shredding machine can be used as a method for processing plastic waste used daily. A chopping machine is a tool that functions to cut/crush materials into smaller shapes so that the recycling process can be carried out for various things, including new products.

The chopping machine used in this research is a series of plastic injection machines that will be used to process plastic waste using a chopping machine, the results of which are small pieces. The resulting shredded products will be channeled to a heating chamber using a screwdriver to make plastic waste into new products. There are several methods for recycling plastic waste, namely mechanical recycling, feedstock recycling, and energy recovery. Mechanical recycling, such as using a plastic shredder for the recycling process with flexibility, strength, and good resistance to chemical reactions [3-18].

2. Research Method

This study uses the main tool, namely a plastic chopping machine, to chop plastic waste into small sizes. This study used the experimental method and the Taguchi method, where the experimental method was used to carry out the direct testing process on plastic waste with the variables of plastic type, plastic dimensions, plastic thickness, and plastic weight, while the Taguchi method was carried out to find out the ranking optimization of each test variable and the percent contribution produced by each test variable [12-13], [19-21].

The variables used are as follows:

1. Control Variables: Plastic shredding machine
2. Independent variables
   a. Type of Plastic
   b. Plastic Dimensions
   c. Plastic Thickness
   d. Plastic Weight
3. Dependent variables: Results of chopped plastic

From the variables above, the levels can be determined to make it easier to apply the Taguchi method. The research-level variables are as follows at Table 1.

Table 1. Variable design of research

Variable Design	Variation		
	Level 1	Level 2	Level 3
Type of Plastic	HDPE	PE	PP
Dimension of Plastic	10cm	15cm	20cm
Thickness of Plastic	0,5mm	1mm	1,5mm
Weight of Plastic	30gr	50gr	70gr

2.1. Tools and Materials

The tools and materials used in this study include the following:

1. Plastic Chopping Machine
   Specifications:
   a. Machine type = Induction electric motor
   b. Machine material = steel
   c. Machine size = 95 x 60 x 96 cm
   d. Electric motor = 1100 W, 220 V, 9.8 A
2. Micrometer Screw
3. Digital Scales
4. Ruler
5. Stopwatch
6. HDPE, PE, PP Plastic Waste

2.2. Research Procedure

This research was conducted using experimental methods and the Taguchi method. The experimental method used is to carry out tests with predetermined variations according to the stages of the research process and observe phenomena that occur during the testing process. After this, the data obtained will be processed using the Taguchi method to get the best optimization variations and find out the percent contribution value of each test variable so that the variables that affect the quality of the chopped plastic are known.

2.3. Data Retrieval

Data collection can be done using the following procedure:

1. Prepare plastic waste to be used for the shredding process
2. Clean and dry plastic waste
3. Take measurements and adjust variation
4. Select and weigh the mass of plastic waste to be shredded.
5. Weigh each type of plastic
6. Turn on the counter
7. Record the time of the enumeration process
8. Sorting the results of the count according to classification
9. Measuring the dimensions of the results of the count

10. Collect data on the results of the enumeration
11. Repeat testing with different variations

3. Results and Discussion

3.1. Result Data of Experiment

The process carried out in this study used a plastic chopping machine to produce chopped plastic in the form of small pieces or flakes with various types of plastic and input dimensions of 20 cm, 15 cm, and 10 cm. Experimental test results were obtained for PP-type plastic with optimum results at a dimension of 20 cm, namely a processing time of 91.44 seconds with a chopped size of 6.83 x 4.32 mm.

For PE-type plastic, optimum results were obtained at dimensions of 20 cm, namely processing time for 170, 6 seconds with a chopped size of 15.9 x 10.5 mm. For plastic-type HDPE, optimum results were obtained at a dimension of 10 cm, namely a processing time of 251.1 seconds with a chopped size of 67.9 x 34.5 mm.

The Table 2 shows the optimum data of experiment results.

Table 2. Optimum chopping results

Variable/Type of Plastic	HDPE/10	PE/20	PP/20
Time	251 s	170,6 s	91,44 s
Dimension Length	67,9 mm	15,9 mm	6,83 mm
Dimension width	34,5 mm	10,5 mm	4,32 mm

The results above are the results of testing each chopping. Here are the chopped results for each type of plastic with different variations, as shown in Figure 1-3.

Figure 1. HDPE

Figure 2. PE

Figure 3. PP

For the chopping results according to the table, the chopping size results are according to the standard, namely 2 cm, which is in accordance with the standards of Minister of Public Works Regulation No. 3:2013 regarding the size of the chopped waste, which is 2 cm.

Figure 4. Size of plastic waste after cutting by shredder machine plastic

3.2. Analysis of Data

After obtaining the data from the experimental test results, the data will be processed using the Taguchi method to get the best optimization variations and find out the percentage contribution value of each test variable. Then, the variables that affect the quality of the chopped plastic results are known. From the calculation of the degrees of freedom, it is obtained that is 6, and the calculation using Minitab software determines the orthogonal matrix $L_9(3^4)$.

Table 3. Variable Design

	Variation		
Variable Design	**Level 1**	**Level 2**	**Level 3**
Type of Plastic	HDPE	PE	PP
Dimension of Plastic	10cm	15cm	20cm
Thickness of Plastic	0,5mm	1mm	1,5mm
Weight of Plastic	30gr	50gr	70gr

Table 4. Orthogonal Array $L_9(3^4)$

Type of Plastic	Dimension of Plastic	Thickness of Plastic	Weight of Plastic
HDPE	10 cm	0,5 mm	30 g
HDPE	15 cm	1 mm	50 g
HDPE	20 cm	1,5 mm	70 g
PE	10 cm	1 mm	70 g
PE	15 cm	1,5 mm	30 g
PE	20 cm	0,5 mm	50 g
PP	10 cm	1,5 mm	50 g
PP	15 cm	0,5 mm	70 g
PP	20 cm	1 mm	30 g

Figure 5 is the S/N Ratio value from Orthogonal Array data processing with nine trials and three repetitions. While the type of S/N Ratio used is smaller, the better.

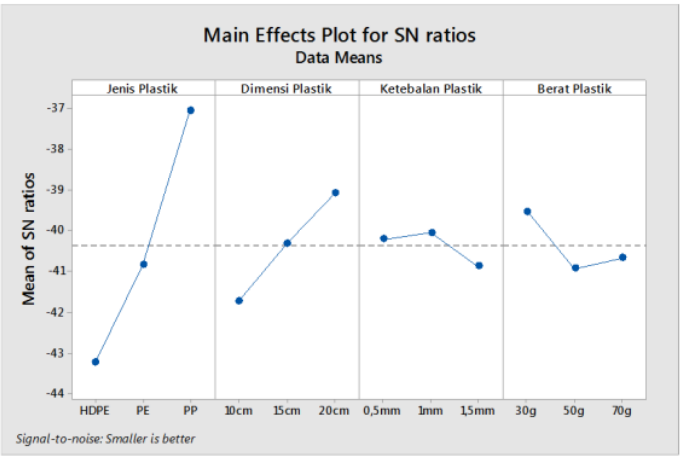

Figure 5. S/N Ratio Smaller is Better

Table 5. Analysis of Variance

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
Type of Plastic	2	58,002	58,002	29,000	*	79,5%
Dimension of Plastic	2	10,495	10,495	5,2478	*	14,4%
Thickness of Plastic	2	1,1452	1,1452	0,5726	*	1,5%
Weight of Plastic	2	3,3460	3,3460	1,6730	*	4,6%
Residual *Error*	0	-	-	-		
Total	8	72,9885				100%

From Figure 5, we can see that the smaller, the better optimization is used, where the more significant the signal, the better it is, and the smaller the noise, which indicates that the results we get are not good. It is known that the type of PP plastic is the most optimal plastic compared to PE and HDPE for a plastic dimension of 20 cm, which is the most recommended dimension compared to the others, and a thickness of 1 mm is the best variation with a plastic weight of 30 g. From the picture above, it can be seen that optimal results will be obtained with variations in the type of PP plastic, dimensions of 20 cm, plastic thickness of 1mm, and plastic weight of 30 grams. Meanwhile, the percentage value of the contribution can be known by Analysis of Variance (ANOVA) to find out which parameters have the most influence on knowing the magnitude of the contribution of these parameters. The results of the ANOVA calculation are shown in the following Table 5. As shown in Table 5, the type of plastic has a P value of 79.5%, and the thickness of plastic is 1.5%.

4. Conclusions

Based on the test results and analysis of the research that has been carried out, the following conclusions can be drawn: using the Taguchi method, the variable type of plastic has quite a significant influence with a contribution percentage of up to 77%, followed by the variables dimensions, weight, and thickness of plastic. Each variation of plastic type can be chopped by a plastic chopping machine, knowing that PP plastic is the most optimal plastic for the

chopping process because PP plastic can produce better chopping results compared to other types of plastic, and optimization is obtained for the most optimal chopping results, namely with PP plastic-type, input dimensions 20 cm, thickness 1 mm, and weight 30 gr. For the measurements of the chopped results for each type of plastic, obtained from the effects of tests that have been carried out, the smallest chopped dimensions are the PP type with an average size of 6.8 x 4.3 mm, then the PE type with an average length of 16 x 10 .5 mm, as well as HDPE type with an average size of 68 x 34.5 mm. The optimal chopping process time was obtained for each type of plastic, namely, PP plastic with a time of 91.4 seconds, PE plastic with a time of 170.6 seconds, and HDPE plastic with a time of 251.1 seconds.

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