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Reducing Waste In Plastic Seed Cleaning Process in Injection Machine with Design of Experiment Method

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ABSTRACT : *This research was conducted at plastic industry companies in Indonesia. The object in this study is the color waste resulting from the Cleaning process on injection molding machines. The purpose of the research is to reduce the color waste produced in the Cleaning process. Obtained data on the most color waste produced in the process, namely red and black waste. Both color wastes were sampled in this study. Reducing color waste is done by Design of Experiment Method.There were 2 experiments conducted, the first mixing the main material of PP MAF 5402 plastic with Compounding resin PP EL-Pro P700J and PP HI10HO, the second way of mixing the main material PP MAF 5402 with a new product mixture called MasterbatchCleant, testing new products using Design Factorial calculations. Both experiments were conducted with the calculation of OFAT (one factor at the time), for the first experiment did not reduce a lot of waste there were even results that had absolutely no waste reduction effect. While the second experiment there was a significant reduction. The second experiment obtained the best composition in reducing color waste by mixing MasterbatchCleant as little as 50% into the main material PP MAF 5402.*

KEYWORDS:*Design of Experiment, Factorial Design, Injection Molding Machine, OFAT, Waste.*

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I. INTRODUCTION

The global economy is increasingly competitive, in each sector industry challenged to produce quality products and, to achieve these goals companies need to optimize the production process. The Production system is one of the very roles to the efficiency of the production system, the form of efficiency can be by reducing waste on the production system [1-3]

Injection Molding machine process that is used as material, is a method in the process of melting plastic material done in a barrel so that the plastic melts due to friction and hot temperature in the barrel, then after the plastic melts then injected into the mold or mold [4]. Injection molding is the most traditional plastic component manufacturing procedure using molds [5]. This research was conducted on plastic printing manufacturing companies and the purpose of this research is to reduce color waste in the cleaning process

The problems arising from the cleaning process injection molding machine are: occurs in the process of color change using Masterbatch. Masterbatch is a plastic seed dye that has gone through the process of dispersing and pelleting. Maserbatch consists of carriers, pigments, fillers, and additives. Where every change of color using resin is quite a lot, increase resulting in the use of resin in the process of cleaning t he machine every time a change of color. The resin itself is granules that are usually white clear, usually used as the main material of making plastic products at the same time can be used for the cleaning process of the machine

There are seven types of plastics including Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS), Other or commonly referred to as Polycarbonate (PC) and multilayer plastic [6]. For plastic materials used in this Injection molding machine, using 2 types of materials namely PP and HDPE. Of the two types of materials, the most widely produced type of color waste plastic from PP material is polypropylene plastic-type produces an average waste of 267 kg every month. To reduce the waste, a repair experiment was conducted using Design of Experiment (DOE). This methodology allows making conclusions with a high level of trust, where DOE is a powerful tool for managing inputs and processes to generate and optimize outputs [7].

II. RESEARCH METHODS

Aform of systematic stages in the design of this study are:

1. Conduct field observation (Gemba) to see the cleaning process on the injectionmachine. This field observation is complemented by findings of how much color waste is produced. Gemba is one of the methods that achieve success, one of the many methods used in Lean Manufacturing [8]. The Results of kaizen depend on human effort as an effort to increase results and things that require process improvement [9]
2. Analyze and conduct experiments for the repair process using the Design of Experimentmethod
3. Research design is divided into several forms of *Design Experimen*t namely *Pre Experimental Design, True Experimental Design, Factorial Design, and Quasi-ExperimentalDesign*. The factorial analysis is used for several interaction assessments of some treatments performed, with the design of factorial in can assess the magnitude of the effect of the interaction [10]

2.1. Research Experiment

The research trial was conducted using The Design of Experiment method.*Design of Experiments*(DOE) is a mathematical methodology used for the planning and execution of experiments to analyze and interpret data obtained from an experiment [11]. Theexperiment was conducted with 2 trials of color waste reduction, namely:

1. Conducting trials mixing the main plastic material PP MAF 5402 with Compounding resin PP EL-Pro P700J and PP HI10HO,
2. Conducting trials mixing the main ingredient PP MAF 5402 with a new product mixture called MasterbatchCleant.

2.1.1. Factorial Design

Before conducting research trials of the 2 experiments above, researchers conducted experiments on the manufacture of MasterbatchCleant products first as an application of experiments for the second point trial. A trial using Factorial Design, this experiment is a combination of all possibilities from various levels of experimentation. Using the f factor is followed by level 1 for each factor. The Factorial design has been proven as a suitable method for determining optimum conditions [12]

2.1.2. One Factor At a Time (OFAT)

OFAT is an experiment that uses one treatment factor between one variable and another variable similar to One Factor At a*Time* (OFAT) using independent variables with ≥ 2 levels at which samples randomly into groups. Each group received one level of independent variables with samples treated identically in every other respect. *The experiments*of the two groups considered earlier are specific cases of this type of design. The OFAT method is a model of insert changes to a single overall modified design variable, experiments are conducted by studying the influence of process parameters on process performance [9,10]. This OFAT experiment was used to identify a range of formulation factors to produce the best composition [15]

In one-factor experiments with existing levels (a - 1) / 2 paired comparisons. The confidence interval for one of the two size groups of effects. This experiment is to see the main effect obtained, the main effect is to see the difference in results between certain variables and other level variables [10].

$$\text{JK (effect)} = \left(\frac{A-B}{A}\right) x\ 100\% \ldots\ldots (1)$$

Keterangan :

Jk (effect) :Number of Errors (experiment)
A : The main Ingredient Factor
B : Subtitute Material Factor

2.1.3. ANOVA

Testing is conducted with One Way ANOVA testing to determine if there is an increase in waste and its significance. Hypothesis Testing conducted is to look at the magnitude of the reduction in the results of color plastic waste processed by adding additional mixing materials to the Cleaningprocess. ANOVA can be used in estimating the main effects of each variable as well as the interaction between them [10]. Analysis of Variance is a possible method to explore the relationship between controlled factors in experiments [16].

III. DATA COLLECTION AND PROCESSING

Waste data collected from injection molding machines is seen from the activity of the injection machine cleaning process, each use of resin (plastic seeds) in the cleaning process for each color change is shown in Table 1

Table 1

Amount of Waste *Cleaning* Process Per Day

No	Color Cleaning	Waste Produced (kg)
1	White	0,80
2	Yellow	0,80
3	Orange	0,84
4	Green	1,20
5	Blue	1,04
6	Red	1,55
7	Black	2,68
Total		**8,91**

From the table data above the largest amount of waste in the cleaning process is produced at the turn of black and red colors, then the 2 wastes that will be used as sampling for waste reduction research data. Raw Material used in this process, namely: **PP MAF 5402,** with *Polypropylene* type or PP Plastic, this plastic is crystalline that is thermoplastic and hard. PP MAF 5402 is a raw material that has a *melt flow* rate or high melting rate of plastic seeds.

3.1.Factorial Design Composition Making MasterbatchCleant

To make the manufacture of cleantmasterbatch products, three components will be tested, namely:

1. Resin/: as the main material in the manufacture of masterbatch
2. Lubricant: lubricant that serves to facilitate the process of making masterbatch
3. Soda line borosilicate Glass: additives used to speed up the cleaning process of residual products (waste) left in the Injection Molding machine

Sample test results were conducted as many as 5 experiments with a percentage measure mixing with the level of additive addition tiered, which can be seen in table 2.

Table 2. Trial Experiment mixing composition makes MasterbatchCleant products

No	Formula	Trial				
		X1	X2	X3	X4	X5
1	Resin	85	75	65	55	45
2	*Lubricant*	5	5	5	5	5
3	*Soda line borosilicate glass*	10	20	30	40	50
Total		100	100	100	100	100

The above testing process is a formulation used in the process of making new products masterbatchCleant to get the maximum dose, so that the maximum dose results, will be the basis of mixed materials in the cleaning process in injection molding machines to reduce the amount of waste produced to the maximum. From the mixing percentage table above get the test results that can be seen in table 3.

Table 3. Mixing composition test results

No	Trial	Hasil	Keterangan
1	X1		X1 formulation with the use of 10%Soda line borosilicate glass,smooth process no constraints.
2	X2		X2 formulation with the use of 20% *Soda line borosilicate glass*, smooth process no constraints.

3.	X3		X2 formulation with the use of 20% *Soda line borosilicate glass*, smooth process no constraints.
4	X4		In the formulation to X4 with the use of 40% *Soda line borosilicate glass*, there is a problem in the *material extrude* process, the material can't be processed and resulted in a jam on the *screw*.
5	X5	None	In the fourth test, there has been a problem screw jam then X5 trials are not done because it will risk damaging the machine

From the results of the above experiments, the maximum limit of formulations in X3 trial testing, for mixing the manufacture of Masterbatchcleant is by mixing additives by 30%. More than that there is a problem in the material extrude process, the material can't be processed because there is a bottleneck in the *screw*. Due to the X4 experiment, there was already a problem so testing was not continued until X5, due to the possibility of engine damage later. Factorial *Design* test results for the completion of the manufacture of *Masterbatch*Cleant products using X3 trial composition by mixing 65% resin, 5% lubricant, and 40% *Additive Soda Line Borosilicate glass*

3.2. OFAT (*one factor at the time*)

OFAT testing is conducted with 2 types of trials, the trials will be described below

A. Trial mixing plastic main material PP MAF 5402 with Compounding resin PP EL-Pro P700J and PP HI10HO

Testing was conducted with the addition of replacement materials with PP EL-Pro P700 and PP HI10HO resins from each color sampled by the experiment. The experiment was conducted with the composition of 50% of the main ingredients with 50% substitute material. Black and red waste results and their effects can be seen in table 4

Table 4. Amount of Waste color mixing resin

Trial	Additional Materials	Color Cleaning Process	Waste Produced (kg)	Effect %
1	(Resin) PP EL-Pro P700J	Red	1.60	0
2	(Resin) PP HI10HO	Red	1.48	4,51
3	(Resin) PP EL-Pro P700J	Black	2.79	0
4	(Resin) PP HI10HO	Black	2.54	5,22

The results of the calculation of securities were obtained using the formula (1), with the main material waste PP MAF 5402 red color of 1.55 kg and black color of 2.68 Kg (Table 1).

B. Trial mixing the main ingredient PP MAF 5402 with a new product mixture called MasterbatchCleant

Testing conducted mixing of the main material PP MAF 540 with cleantmasterbatch products with a test composition level of 10% to 50%, conducted testing with each sample color

1. Red Color Sample

The test results of red color samples can be seen in table 5 using formulas (1)

Table 5. Waste results and effects of use *masterbatchcleant* red color

Testing	Composition of MasterbatchCleant Replacement Material	Amount of Waste produced (kg)	The effect (%)
1	*MasterbatchCleant* 10%	1,42	8,39
2	*MasterbatchCleant* 20%	1,30	16,13
3	*MasterbatchCleant* 30%	1,18	23,8
4	*MasterbatchCleant* 40%	1,10	29,03
5	*MasterbatchCleant* 50%	0,93	40

2. Black Color Sample

The test results of the red color sample can be seen in table 6 using the formula (1)

Table 6. Waste results and effects of using *black MasterbatchCleant*

Testing	Composition of MasterbatchCleant Replacement Material	Amount of Waste produced (kg)	The effect (%)
1	*MasterbatchCleant* 10%	2,48	7,46
2	*MasterbatchCleant* 20%	2,27	15,30
3	*MasterbatchCleant* 30%	2,08	22,38
4	*MasterbatchCleant* 40%	1,87	30,22
5	*MasterbatchCleant* 50%	1,60	40,30

Efek from tables 5 and 6 can be seen the larger the replacement material *masterbatchcleant* added to the main material then the resulting waste will be less.

From the above tests, the composition of the addition of cleantmasterbatch into PP MAF 5402 as the main material is done only on the addition of Cleant*Masterbatch* 10%, 20%, 30%, 40%, and 50%, this is because of the addition of additional materials above 50% is very risky because it exceeds the threshold of use of additional materials and if forced then the risk also to *injection molding* machines used in the company.

3.3 Analysis of Variant (ANOVA)

Based on the data obtained from the tests conducted, further ANOVA testing is used to find out whether there is a significant increase in waste in the cleaning process and how much significance. This analysis process compares two factors between PP MAF 5402 waste and PP MAF 5402 waste mixed with Masterbatchcleant. In this test, H_0 and H_1 are determined as follows

Ho/: No addition of waste to the cleaning process by mixing products
$H_{1/}$: There is the addition of waste to the cleaning process by mixing products

Testing Criteria
- if F count < F table then H_o is accepted
- if F count > F table then H_0 is rejected

By Significance:
- If significance > 0.05, then H_0 is accepted
- If significance < 0.05 then H_0 is rejected

A. ANOVA Resin PP EL-Pro P700J and PP HI10HO Resin Results

To see how big the significance value is, then tested using one way ANOVA can be seen in table 7

Table 7. ANOVA Resin Addition Testing

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
hasil limbah penambahan resin PP EL-Pro P 700J	Between Groups	1,346	1	1,346	368,658	,003
	Within Groups	,007	2	,004		
	Total	1,353	3			
hasil limbah warna penambahan resin PP HI10HO	Between Groups	1,199	1	1,199	195,759	,005
	Within Groups	,012	2	,006		
	Total	1,211	3			

The ANOVA test applied to the PP EL-Pro P700J Resin sample showed that the calculated F of 368,658 and F table were obtained from df1 = 1 and df2 (n-3) = (4-3) = 1, then obtained the result of table F is 161,488 means F count > F table, then H_0 rejected and means H_1 received With significance value of 0.003 (0.003< 0.05) means H_0 rejected

In the ANOVA test applied to the resin sample, PP HI10HO shows that F count of 195.759 and F table obtained from df1 = 1 and df2 (n-3) = (4-3) = 1, then the result of table F is 161,488 means F count > F table, then H_0 is rejected and means H_1 is accepted. With a significance value of 0.005 (0.005< 0.05) means H_0 is rejected.

From the two ANOVA tests above, obtained the results of mixing materials PP MAF 5402 with resin PP EL-Pro P700J and resin PP HI10HO does not reduce color waste, but rather the addition of color waste and has no significant effect on waste reduction

B. ANOVA MasterbatchCleant Results

To see how big the significance value is, then tested using one-way ANOVA can be seen below.

1. Anova Red Color Testing

The ANOVA test applied to the red color sample shows that F count of 0.219 and F table obtained from df1 = 4 and df2 (n-3) = (10-3) = 7, then obtained the result of table F is 4,120 means F count ≤ F table, then H_0 received means that there is no addition of waste to the *cleaning* process by mixing Masterbatchcleantproducts. With a significance value of 0.917 (0.901>0.05), it means H_0 is accepted. Mixing PP MAF 5402 material with MasterbatchCleant significantly affects waste. Table 8

Table 8. ANOVA Testing The Addition of Red CleantMasterbatch Material

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,070	4	,018	,219	,917
Within Groups	,402	5	,080		
Total	,472	9			

2.Anova Black Color Testing

ANOVA testing applied to the black sample shows that F count of 0.245 and F table obtained from df1 = 4 and df2 (n-3) = (10-3) = 7, then obtained the result from table F is 4,120 means F count ≤ F table, then H_0 received means that there is no addition of waste to the *cleaning* process by mixing CleantMasterbatchproducts. With a significance value of 0.901 (0.901>0.05), it means H_0 is accepted. Mixing PP MAF 5402 material with MasterbatchCleant has a significant effect on waste reduction. Table 9

Table 9. ANOVA Testing The Addition of Black CleantMasterbatch Material

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	,234	4	,059	,245	,901
Within Groups	1,195	5	,239		
Total	1,430	9			

IV. RESULT

The process of waste reduction in the *cleaning* process is done with two testing experiments using OFAT*(one factor at a time).* Firstly using compounding, mixing with plastic seed resin to the main plastic material (PP MAF 5402), the second by mixing masterbatchcleant with the main plastic material PP MAF 5402, from the 2 experiments the most significant reduction in color waste reduces waste is to use the addition of *masterbatch*cleant products with the maximum composition mixing of 50% of the products. While the test results that can be by using the addition of *compounding* does not significantly affect the reduction of waste in the *Cleaning* process

This result is also supported by ANOVA test results that stated the great significance of the additional use of cleantmasterbatch products on average of 0.909 = 90.9% success, while the average significance of adding compounding material is 0.004% = 0.4%

Table 10. Color Waste Reduction Results In *Cleaning* Process with Cleantmasterbatch

NO	Waste Color	Waste Reduction Composition Mixing MasterbatchCleant				
		10%	20%	30%	40%	50%
1	Red (Kg)	1,55	1,55	1,55	1,55	1,55
		1,42	1,30	1,18	1,10	0,93
Waste Reduction (kg)		**0,13**	**0,25**	**0,37**	**0,45**	**0,62**
2	Black (Kg)	2,68	2,68	2,68	2,68	2,68
		2,48	2,27	2,08	1,87	1,60
Waste Reduction (kg)		**0,2**	**0,41**	**0,6**	**0,81**	**1,08**
Total Waste Reduction (kg)		**0,33**	**0,66**	**0,97**	**1,26**	**1,7**
Averange Reduction (%)		**16,5**	**33**	**48,5**	**63**	**85**

Based on the table above, the correct composition in using mixing is: by mixing 50% of the main ingredients PP MAF 5402 with 50% replacement material from MasterbatchCleant can on average reduce waste red and black color by 85%, so it is very effective. Mixing is only done a maximum of 50% because if it passes 50% then it will or has entered the threshold value allowed for mixing additional materials, more than that the effect caused is damage to the *Injection Molding* machine

V. CONCLUSION

The results of the tests conducted in this study, waste reduction can be done by using MasterbatchCleant products can reduce waste significantly, the success of waste reduction with the product has an average significance of 90.9%.

The best composition mixing is to mix 50% of the main ingredient PP MAF 5402 with 50% of MasterbatchCleant. Mixing in can reduce waste on average by 85%. It is very good to be used to improve the cleaning process so that when doing the process of changing colors does not produce a lot of waste and reduce the color contamination of plastic products with other colors

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