The Effect of Injection Parameter on Acrylonitrile Butadiene Styrene (ABS) Products Using Fuzzy Logic System

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Abstract*—This research presents the effect of injection parameter such as nozzle temperature, charging stroke, injection pressure and injection speed on acrylonitrile butadiene styrene (ABS) LG Chem HI 100 on ID Card products using fuzzy logic system. The defects analyzed were in the form of short shot, flash and burn mark. In this study, 2 types of fuzzy, Mamdani FIS and Sugeno ANFIS were used. By combining these 2 types of fuzzy the error system value of 0.387 was obtained. The tuning process was carried out by matching the results of the fuzzy output and the injection results of 305 products with an accuracy of 94%.

***Keywords*—mamdani FIS, sugeno ANFIS, injection parameter, ABS material**

I. INTRODUCTION

One of the most widely used treatments for the process of forming products is the injection molding, it has 3 stages namely injection, holding and cooling [1] by using pressure to inject the melting material into the mold. There are four factors that must be considered to get good quality of injection products namely mold design, product design, type of material and injection parameters [2]. In order to get the right parts before manufacturing, this stage needs not only high-level technological knowledge, but also testing. At Polman Astra, trial error one new molds can take 1-2 months with a trial process on average 2-3 times a week and one trial are about 30-50 shoots. The duration of the trial error process for a new mold is greatly influenced by the difficulty of finding the best parameter combination for the product.

This research is focused on finding the best parameter combination to minimize the occurrence of defects in injection products with Acrylonitrile Butadiene Styrene (ABS) material type LG Chem HI 100 without trial error so that it can speed up the process and save material costs. In this study, the method to be used is Fuzzy Logic to establish the best setting for the injection parameter by developing an adaptive membership function which is closely related to the injection process.

The Objectives of this work are:

1. To find out the best parameter combination that minimizes defects and optimizes process variables in a smaller number of injection cycles with minimum trial error.
2. To design a fuzzy logic system to detect defects in Plastic Injection Products.

II. LITERATURE REVIEW & RESEARCH METHODOLOGY

A. *Injection Molding*

Injection molding process consists of three main stages namely: filling, packing/holding, and cooling [3]. The equipment of injection molding is divided into three main unit: injection unit, clamping unit and mold system [4]. Injection parameters consists of charging stroke, suck back, back pressure, injection and holding pressure, injection and holding speed and injection, holding and cooling time [5]. The three primary demands of this method are injection molding machine, raw plastic material and mold [6]. Understanding what potential flaws may be and what causes them is the first step in ensuring that appropriate specifications are consistently achieved by the products produced in the process [7].

B. *Acrylonitrile Butadiene Styrene*

The ABS is common thermoplastic polymer consisting of three monomer units: Acrylonitrile, Butadiene and Styrene [8]. The proportions of ABS is by polymerizing styrene and acrylonitrile in the presence of polybutadiene [9]. The most important mechanical properties ABS impact resistance and toughness [10]. The mechanical properties of the ABS material made by injection molding are far superior in various tests because the material is denser than the one made by using 3-D printing [10].

C. ID Card Product Simulation

ID card product was simulated using Autodesk Moldflow Adviser software to analyze the product condition as shown in Fig.1. It shows that this product is possible to have a weld line defect in position along with the material flow because the product design has a flow breaker profile. Weld line defects are always present in every product. For molds with complex geometries like in this one which has more than one gate, the weld line defects can be optimized by changing the thickness of the mold [11]. Although the weld line cannot be eliminated, the shape and position of the weld line can be controlled by optimizing the process parameters [12].

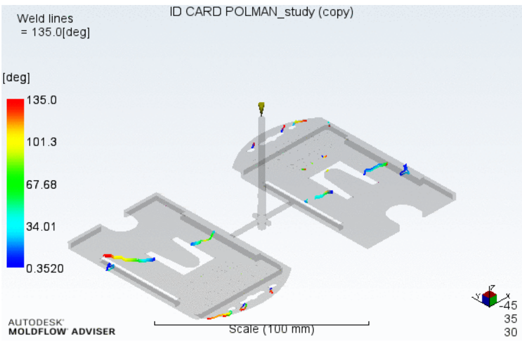

Fig. 1 Product simulation

D. Fuzzy Logic Control

The fuzzy control rules bind the fuzzy input variables to a fuzzy output variable called Fuzzy Associative Memory (FAM) and then defuzzify the system (defuzzifier) to get crisp values [13], as shown in Fig. 2.

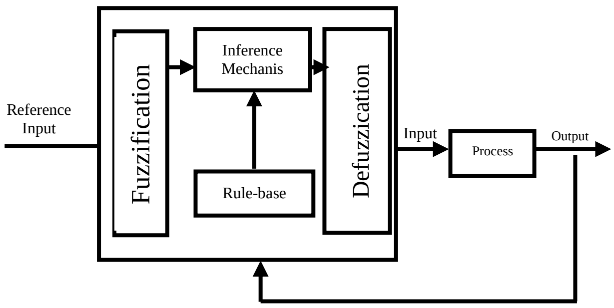

Fig.2 Fuzzy control system

A fuzzy rule in the form of If-Then is sometimes expressed. Before being used to construct If-Then rule, all of these fuzzy sets must be described by membership functions. [14]. Triangular membership functions gives minimum error and requires minimum computation time [13] as shown in Table 1 .

TABLE I
THE PERFORMANCE OF FUZZY LOGIC FAULT DETECTOR WITH DIFFERENT MEMBERSHIP FUNCTION

Response	Membership Function Type		
	Triangular	Trapezoidal	Gaussian
Computation time (sec)	12.41	14.11	24.06
Error (%)	0.13	0.13	3.44

E. Adaptive Neuro Fuzzy Inference System (ANFIS)

The control system used will use a system that combines a fuzzy system and an artificial neural network system. This system is known as the neuro fuzzy system or ANFIS. The combination of the two will be able to complement the advantages and disadvantages of each system [15]. And based on historical data entered into it, it can function and can forecast future events based on those data. So that ANFIS has the strength of both [16]. There are five layers in the framework of the ANFIS process, namely the fuzzification layer, the rule layer, the normalization layer, the defuzzification layer and a single neuro result [17] .

F. Research Methodology

The research design is one of the guidelines used in the research process in determining data collection instruments, determining samples, collecting data, and analyzing data. This research begins by determining the initial value of the parameters that will be used to collect initial data. From this data, the priority defects and their causes were analyzed. The next stage is to make the fuzzy design. Then the tuning will be carried out by making the product according to the parameters recommended by the fuzzy and re-analyzing it to find out whether the fuzzy is suitable or not [18]. This research flow process is shown in Fig.3

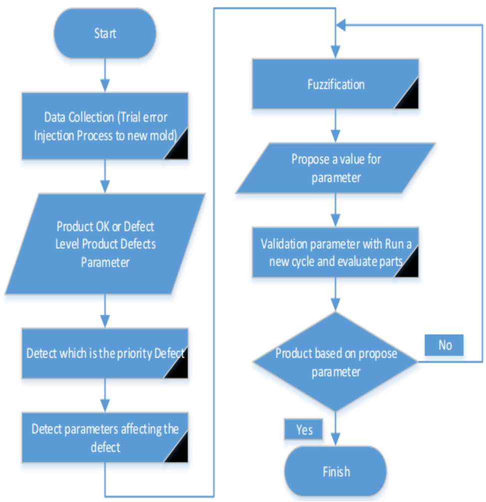

Fig.3 Research flow process

G. *Knowledge Based*

From several trial errors, it can be seen that the priority defects are: short shot, flash and burn mark all of which have a weld line. A set of tables has been created for collecting information about the cause of defects based on injection parameters and its levels as show in Table 2.

TABLE II
KNOWLEDFE BASED OF INJECTION DEFECT CAUSES

No	Defect	Defect Levels	Causes			
			Nozzle Temp.	Charging Stroke	Injection Pressure	Injection Speed
1	Short Shot	Major	L	L	L	L
2	Flash	Minor	H	H	H	H
3	Burn Mark	Major	H		H	H

H. *Fuzzification*

Fuzzification is achieved by taking a crisp input, transforming its crisp value into an appropriate fuzzy value, applying it to a membership function, and thereby receiving fuzzy inputs in terms of linguistic variables with a corresponding degree of membership [13]. Linguistic variables in the antecedents of fuzzy control rules form a fuzzy input in accordance with the discourse universe, whereas in the universe the consequences of these rules form a fuzzy output space. Table 3 explains the inputs and outputs variable, linguistics and labels and range in the fuzzy model.

TABLE III
INPUT AND OUTPUT VARIABLES

Fuzzy Variable		Labels	Linguistic	Labels
Input	Nozzle Temperature (^{0}C)	NT	Low	L
			Middle	M
			High	H
	Charging Stoke (mm)	CS	Low	L
			Middle	M
			High	H
	Injection Pressure (Bar)	IP	Low	L
			Middle	M
			High	H
	Injection Speed (%)	IS	Low	L
			Middle	M
			High	H
Output	Product Dimension	PD	Short Shot	SS
			OK	OK
			Flash	FL
			Burn Mark	BM

Fuzzy set of input variable was set by Sugeno ANFIS with a grid partition with 3 levels of trapezoid membership function according to the Equation 1.

$$(x) = \begin{cases} 0\,; & x \leq a \text{ atau } x \geq d \\ (x-a)/(b-a); & a \leq x \leq b \\ 1\,; & b \leq x \leq c \\ (d-x)/(d-c); & c \leq x \leq d \end{cases} \tag{1}$$

The input variable using ANFIS is shown in Table 4. The error value of 0.078 was obtained. Fuzzy set of output variables was created using triangle membership function using Mamdani and then convert to Sugeno ANFIS as shown in Table 5.

TABLE IV
INPUT VARIABLE USING ANFIS

Fuzzy Variable		Linguistic	Membership Range			
Input	Nozzle Temp.	Low	199.50	205.50	214.50	220.50
		Medium	214.50	220.50	229.50	235.50
		High	229.50	235.50	244.50	250.50
	Charging Stroke	Low	15.55	16.95	19.05	20.45
		Medium	19.05	20.45	22.55	23.95
		High	22.55	23.95	26.05	27.45
	Injection Pressure	Low	19.00	31.00	49.00	61.00
		Medium	49.00	61.00	81.00	91.00
		High	81.01	91.00	109.00	121.00
	Injection Speed	Low	22.50	32.50	47.50	57.50
		Medium	47.50	57.50	72.50	82.50
		High	72.50	82.50	97.50	107.50

TABLE V
OUTPUT VARIABLE FROM MAMDANI CONVERT TO ANFIS

Fuzzy Variable		Linguistic	Label	Parameters
Output	Product Level	Short Shot	SS	1
		OK	OK	2
		Flash	FL	3
		Burn Mark	BM	4

I. *Rules Based*

A fuzzy logic rule is called a fuzzy association. A fuzzy associative memory (FAM) is created by dividing the discourse universe of each condition variable into a grid of FAM elements according to the degree of fuzzy resolution chosen for these precedents. A FAM of a fuzzy logic controller for the motor speed is shown in the FAM diagram in Table 6.

TABLE VI
FUZZY ASSOCIATION MAP

		NT				
		L	M	H		
	L	SS	OK	FL	L	
CS	M	SS	OK	BM	M	SI
	H	SS	FL	BM	H	
		L	M	H		
		PI				

J. Defuzzification

The defuzzification used weighted average which means that the output is weighted average of all rule outputs according to the Equation 2. This method is the default for Sugeno systems.

$$z^* = \frac{\sum \mu_x(\bar{z}).\bar{z}}{\sum \mu_x(\bar{z})} \qquad (2)$$

where Σ denotes an algebraic sum define $\bar{z}$. The weighted average method is formed by giving weight to each membership function in the output with the maximum membership value. Since the method limited to symmetric membership function, the values "a" and "b" are the means of their respective shapes. This method is shown graphically in Fig.4.

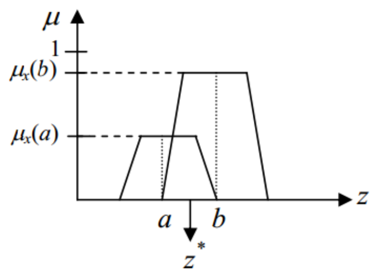

Fig. 4. Weighted average defuzzification method

III. RESULTS

A. Fuzzy Tuning

This test is carried out to determine the error value of fuzzy that has been made with 62 rules using ANFIS, because ANFIS can construct an input-output mapping in the form of fuzzy if-then rules with appropriate membership functions. The only type of rule that can be served is Sugeno type. Mamdani type cannot be applied to Anfis [15]. From the process, the error system value of 0.679 was obtained as shown in Fig.5.

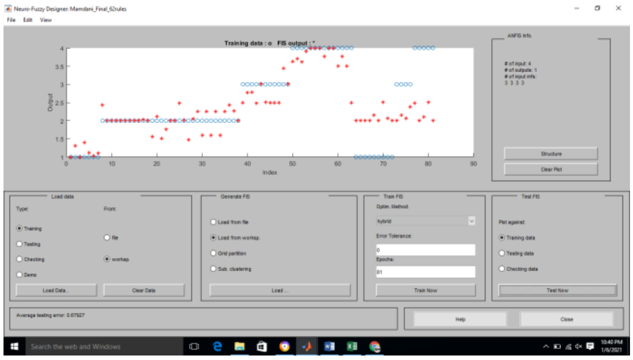

Fig. 5. Test result of initial fuzzy set

In the process of finding an even smaller error value, the rules based will be tuned to 81 rules according to the entered data then re-check it. From the process, the error system value of 0.573 was obtained as shown in Fig.6.

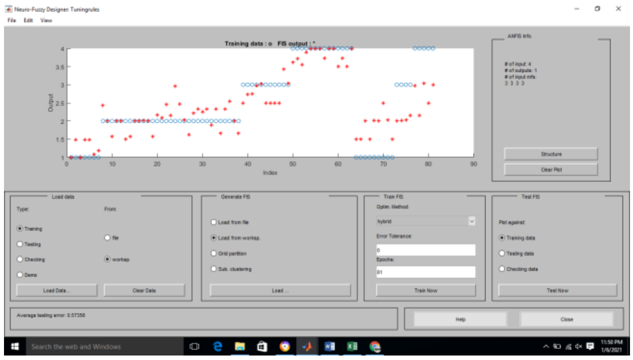

Fig. 6. Test result of first tuning

In this second tuning the data were re-checked directly using ANFIS to find out the parameter of input variable with the smaller error value. This process obtained 0.556 of error value as shown in Fig.7.

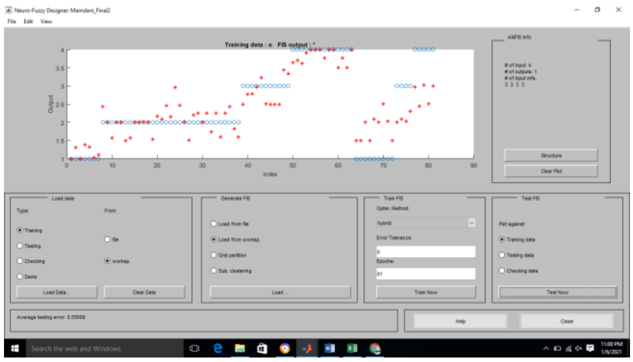

Fig. 7. Test result of second tuning

B. Validations

After the fuzzy system was formed, it will be validated by comparing the fuzzy output with the real plastic injection output results. Based on Fig. 8 it is known that the created fuzzy system has an error value of 0.387 when it is used to test 305 data, which is plastic injection molding product in real.

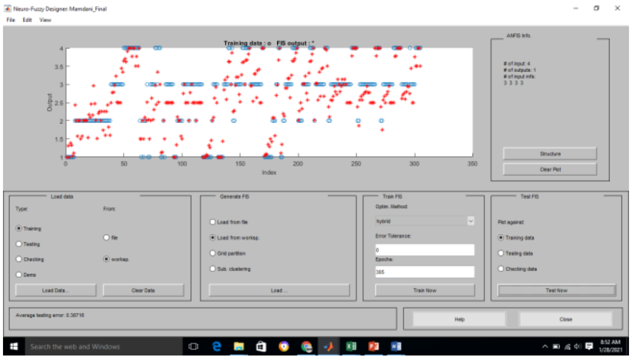

Fig. 8. Test result of validation data

The validation will be continued by comparing the fuzzy output with the real product results. The condition of the product will be converted into a number according to its variable output parameters, namely 1 for short shot defect, 2 for OK products, 3 for flash defects, and 4 for burn mark defects. Meanwhile, the fuzzy output will be rounded so the result will always be a whole number.

TABLE VII
THE RESULTS COMPARISON BETWEEN MATCHED AND UNMATCHED DATA

	Unmatched Data	Matched Data	Total
Total	18	287	305
Percentage	6	94	100

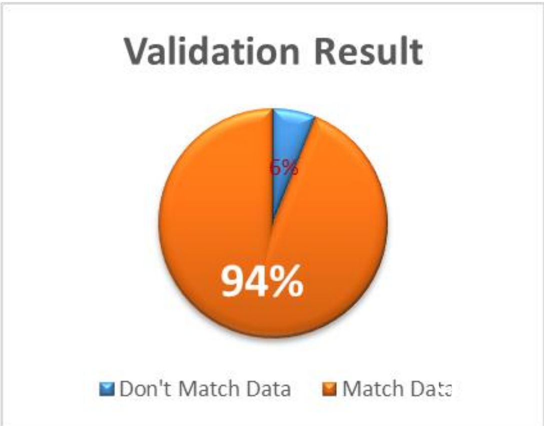

Fig. 9 Validation result

Based on the Table 7 and Fig.9 it is known that by using this fuzzy system we can predict accurately 94% of 305 variants data. The difference between the error value in the system and the accuracy value occurs due to the rounding system that we use for the fuzzy output. We have to apply the rounding system because what we compare is the condition of the product which has a definite value for each condition.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. *Conclusions*

- By combining Mamdani FIS and Sugeno ANFIS, the error system value of 0.387 was obtained.
- With such an error in the fuzzy system, the validation process resulted in a match of 94% between the fuzzy output and the real output from 305 data plastic injection products.

B. *Recommendations*

Referring to the mismatch between the fuzzy output and the actual output of plastic injection molding, it is highly recommended that further research could be carried out in this case. Here are some recommendations:

- To study fuzzy sets with different membership function types.
- To use other method such as Taguchi or ANN.
- To study fuzzy system using other product with different geometry.
- To study fuzzy system using other material such as polypropylene, polycarbonate or polystyrene.

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