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THE APPLICATION OF FUZZY LOGIC INTEGRATED WITH TAGUCHI METHOD IN OPTIMIZING PROCESS PARAMETER TO REDUCE THE TIME CYCLE

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Summary

Given the importance of quality and responsiveness of manufacturing companies to customers, the most important principle can be considered reducing the cycle time of the production process. Since preserving the quality standards in a disposable necessities manufacturer is important, the Fuzzy Taguchi method as a powerful design optimization tool is used to determine the quality and design of optimal control parameters. Because in the real world due to measurement errors and inaccuracies in information and uncertainty in processes, fuzzy concepts have been used. Therefore, in this study, the parameters for controlling the process of disposable essentials are optimized to reduce the time cycle. Also, $S\ /\ N$ and ANOVA methods have been used to study the characteristics of process performance. The four control parameters affecting the feed rate of the sheet, the machine wind pressure, and the mold temperature and sheet thickness affect the quality of the process. And Taguchi Fuzzy is a systematic and efficient method that reduces the cycle time. Experimental results have been reviewed and presented to evaluate the effectiveness of this approach in the Kach Company.

Keywords: Fuzzy Taguchi method; time cycle; optimization; control parameters

Zastosowanie logiki rozmytej i metody Taguchiego w optymalizacji parametrów procesu produkcyjnego

Streszczenie

Czas trwania cyklu procesu produkcyjnego jest jednym z podstawowych czynników zarówno zapewnienia wysokiej jakości produkcji jak również zmniejszenia czasu reakcji producentów na wymagania klienta. W pracy prowadzono optymalizację parametrów sterujących stosowanych w procesie produkcji wyrobów jednorazowego użytku dla skrócenia czasu cyklu produkcyjnego. Do badań przyjęto metodę Taguchiego z elementami logiki rozmytej. Uwzględniono w procesie optymalizacji wpływ błędów pomiarowych, niedokładność danych wejściowych oraz niepewność w ustaleniu prawidłowych wartości parametrów procesu. Stosowano w badaniach cztery parametry sterujące procesu: grubość arkusza tworzywa, prędkość podawania arkusza, ciśnienie robocze maszyny i temperaturę matrycy. Stosowano metodę S/N i analizę wariancji (ANOVA) dla oceny przebiegu procesu produkcyjnego. Wyniki analizy danych doświadczalnych były podstawą oceny efektywności optymalizacji procesu produkcyjnego w firmie Kach Company.

Słowa kluczowe: metoda Taguchiego, czas cyklu produkcyjnego, optymalizacja, parametry sterujące

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1. Introduction

Today, in the manufacturing industries, companies face increasing production challenges and product quality, which challenges quality requirements, cost intensification pressures, and short-term cycles. To maintain competitiveness and increase this, The Company's market is forced to simultaneously optimize its production in terms of cost efficiency, customer response speed, and product quality. Forming disposable supplies, Forming is one of the important processes used to achieve optimum quality and product dimensions. In the forming process, selection of control parameters such as feeding speed, mold temperature, wind pressure and sheet thickness to achieve high quality performance It is important in the minimum processing time that these parameters are based on the engineers' experience in Kach's company. Taguchi's method is an effective tool for designing an experiment that evaluates the effect of performing each process parameter on responses by performing a minimum number of experiments [1,2]. Signal-to-Noise Ratio the best level of each parameter for a particular response is based on a better quality characteristic such as a lower, better, and better name [3]. Regardless of the quality characteristics selected for a particular response, the S / N ratio levels are favorable to the different factors for this particular response. The Taguchi method is sufficient enough to address the problems of a target, but not suited to solving multi-objective problems. These types of problems are typically solved by assigning individual weight to a response based on priority. The beneficial theory, the theory of gray-matter analysis, the optimal performance approach, are a few examples. In all these theories, weight is determined by hypotheses, which may result in uncertainty as a result [4]. The fuzzy logical approach in this study is used to overcome all of these hypotheses and the uncertainty regime.

Fuzzy Logic A mathematical theory is a misconception that allows modeling the process of human reasoning in linguistic terms [5]. This is based on intuition and judgment, and it is not necessary to construct a mathematical model [6]. A fuzzy logic system consists of a fuzzy mechanism, membership functions, a fuzzy legal basis, an inference engine, and a freezer. To convert bulk values to values with the function of membership functions [7]. The membership function is a graphical representation of the contribution rate of each entry. The rules for using input values as weight factors to determine their effect on the fuzzy output set are the final output results. When the functions are obtained, scaled and combined, then, the fuzzy argumentation inference engine employs fuzzy rules to generate a fuzzy value [8]. Finally, with a de-fuzzification approach, the fuzzy predicted value is converted to a single index. The Taguchi Fuzzy optimization of the model can be introduced through the Taguchi design and ANOVA to the TFO. The results can help to prove the benefits of parameters related to economic and environmental factors in system benefits, total product quality and quality. (ii) Identifying the optimal parameters of the parameter to obtain the desired systemic benefits and simultaneously reducing the cycle time.

The organization of the study is as follows. In section two, the implementation of the Taguchi Fuzzy method in the third section is analyzed and in the final section of the conclusion is stated.

2. Implementation of Fuzzy Taguchi optimization method

Taguchi defines quality as a loss that is passed on to society from the moment the product is shipped. It includes social failures, failure to meet customer needs, failures in ideal performance and hazardous side-effects. The key role of Taguchi's philosophy of reducing Variability and emphasis on minimizing costs. The quality of the cost should be measured as a standard deviation function and the losses should be measured in the system. Quality should be designed during production, not during the manufacturing process. Quality minimizes the deviation from the characteristic value to the best will be. The product should be designed in such a way as to be safe against uncontrollable irregularities

Taguchi recommends recommending a loss function for measuring the percussive performance of a given value. The value of the loss-response function is converted to signal-to-noise ratio (S / N). The S / N ratio for each level of the process parameters is calculated based on the S / N analysis. Regardless of the classification of the performance feature, the larger S / N ratio matches the performance feature. Therefore, the optimal level of process parameters is the surface with the highest ratio of S / N. In addition, statistical analysis of variance (ANOVA) is performed to determine that the process parameters are statistically significant. By analyzing S / N and ANOVA, an optimal combination of process parameters can be predicted. Finally, an approval test is performed to examine the parameters of the optimal process resulting from the design of the parameter. The fuzzy Taguchi model is designed as follows.

2.1. The assumptions of the Forming salon

Forming machines have a setup time to get started. When to prepare the machine for the start of the production process must be considered. The materials of the forming salon are polystyrene sheets produced by the extrusion salon, and the final product of the forming salon is the plates produced during thermoforming operations in this salon. Each forming machine is individually a line and each machine is switched on or off, regardless of whether other forming machines are turned on or off. The actual production volume of the forming salon depends on the request of the printing salon. In other words, since the final product of the forming salon should be used as a raw material in the printing salon, white glasses should be printed, so the shutting down or turning on of the forming machines depends on the demand for the printing salon. In addition to item 2, if the extruder room was not able to provide the sheet needed for any reason, and the warehouse sheet does not meet the needs of the salon, forging machines will be turned off due to lack of sheets.

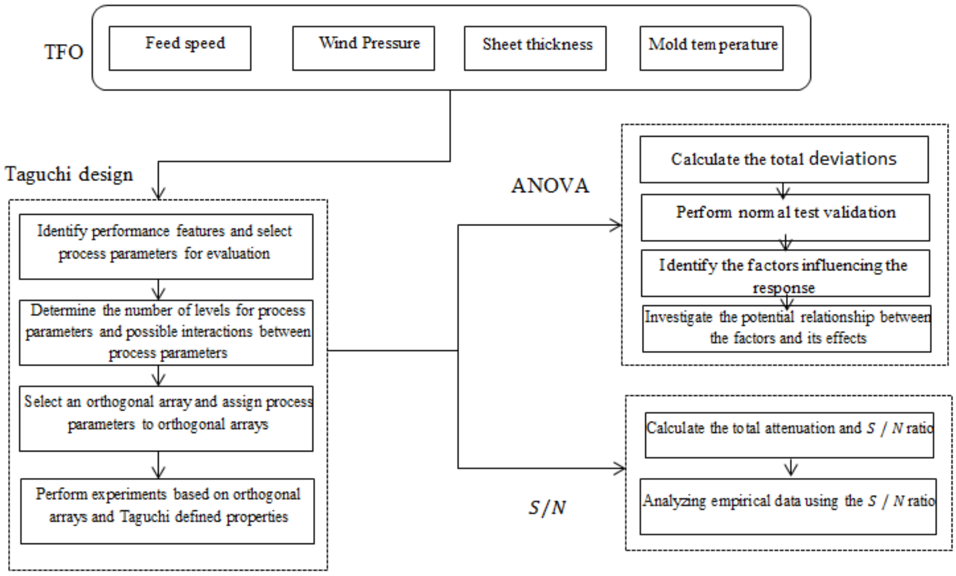

Fig. 1. Fuzzy Taguchi Model Diagram

In other words, the turning or turning off of the forming machines depends on the supply of the sheet by the extruder salon. Forming machines have a multiplying process and each machine has the ability to produce different glasses. But it cannot produce all the glasses. To change the product produced by each machine, the time to change the template should be considered. If a particular glass can be manufactured by two machines, the capacity of the machines to produce this particular glass may vary. And it is possible at any moment to stop the production of A glass and, by changing the mold, began to make the glass$B$. How does the planning unit arrange forging machines to produce products, so that the minimum number of switching forms to machines is allocated to the time allocated to change the templates, and at the same time, each machine will produce a product that It has the highest capacity to produce that product, with this method of producing the salon production, Max, depending on its planning ability and creativity in the planning process. In the process of manufacturing polystyrene glass in the forming salon, the production process is punch. Therefore, during the production of each product, the percentage of the sheet used is turned into sheet and another percentage as a Punch sheet is transferred to the mill hall and after the mill, it returns to the cycle of the extruder. The ratio of the weight of the manufactured glass to the weight of the Punch is different from product to product and from device to device. The lower the ratio, the more efficient the sheet is, the less the cost of rework and energy dissipation.

Selection of control parameters and their levels a typical forging cycle described in the previous section is therefore the selected control parameters as follows:

- Feed rate: The advance speed of the extruder plate production plate into the forging machine, which is characterized by R14
- Wind pressure: The amount of wind pressure in the sheet produced from the extruder in the forging machine, which is characterized by R15.
- Sheet thickness: The plate fluctuation generated from the extruder housings in the forging machine, which is characterized by R16.
- Molding temperature: Molding temperature in the forming machine, which is characterized by R17.

The control parameters are variable in the range and their number is shown in Table 1.

Table 1. Control parameters in the domain

S.No	**Symbol**	**Control parameters**	**Range**	**Level 1**	**Level 2**	**Level 3**
1	R14	Feed speed	30-18	18	22	30
2	R15	Wind pressure	350-250	250	270	350
3	R16	Sheet thickness	16-8	8	12	16
4	R17	Mold temperature	220-150	150	220	-

Changes in the size of the quality and the time of the process the forming process is the two output parameters that are measured after the processing of the forging. Cycle time changes were measured based on the user interface of the forwarding device. Basic measurements were performed on overall production, and then the output parameters before and after the tests were compared to analyze the stability of the forwarding process and the effects of different parameters on the quality change moment and the time of the heating cycle process.

Using an orthogonal array to reduce the number of experiments is described to optimize design control parameters. The results of the experiments were analyzed using S/N and ANOVA. Based on the results, optimal control parameters have been obtained and approved for reducing the changes in the quality and cycle time of both. Basic measurements were performed to determine the stability of the Forming process during the overall production. The Forming process is based on the I-MR chart (Individual Movement Range), which indicates that the measurement is within the limits of steady control. Changes, the cycle time measured and the average cycle time of 36.3 seconds are shown in Fig. 2. The basic control parameters are given in Table 2.

Table 2. Control parameters for the production of disposable supplies

S.NO	R14	R15	R16	R17
1	18	270	12	180

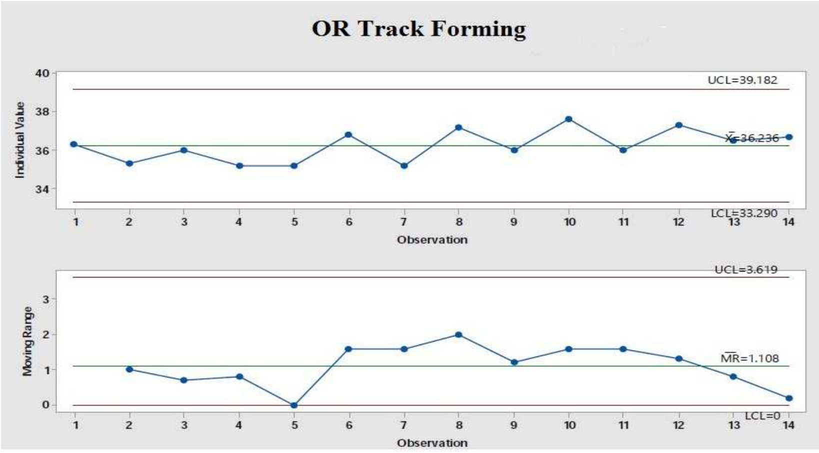

Fig. 2. Shows the I-MR diagram for the forming process time cycle

To select an orthogonal array suitable for testing, Design-Expert MINITAB software was used for the Taguchi method. Based on the number of control parameters and their levels, an orange L9 array was selected. Experiments have been conducted based on Taguchi's design. The horizontal array L9 is shown in Table 3.

Table 3. Orthogonal Array L9

S.NO	**R14**	**R15**	**R16**	**R17**
1	18	250	8	150
2	18	250	8	220
3	18	250	8	150
4	22	270	12	220
5	22	270	12	150
6	22	270	12	220
7	30	350	16	150
8	30	350	16	220
9	30	350	16	150

Dual Fuzzy Logic Bold Values In this study, the S / N ratio is related to the parameters. These values are then converted to the membership function. Input values are shown under the triangular membership function of three small subsets (S), medium (M) and large (L). Similarly, the output value (COM) was divided into three parts. These five sub-sets are called very small (VS), small (S), medium (M), large (L) and very large (VL). The fuzzy rule base contains a group of control rules [9,7] with three inputs, y_1 ، y_2 and y_3, and an output z. These rules are as follows:

Rule 1: If y_1 is A_1 and y_2 is B_1 and y_3 is C_1 and Z is D_1
Rule 2: If y_1 is A_2 and y_2 is B_2 and y_3 is C_2 and Z is D_2
Rule n: If y_1 is A_n and y_2 is B_n and y_3 is C_n and Z is D_n

Table 4. Expression of fuzzy terms

S.No	R14	con	R15	con	R16	con	R17	con	com
1	S	And	S	And	S	And	S	And	VS
2	S	And	S	And	S	And	M	And	S
3	S	And	S	And	M	And	L	And	S
4	M	And	M	And	M	And	S	And	M
5	M	And	M	And	L	And	M	And	M
6	M	And	M	And	L	And	L	And	L
7	L	And	L	And	S	And	S	And	S
8	L	And	L	And	S	And	M	And	L
9	L	And	L	And	M	And	L	And	L
10	S	And	S	And	M	And	S	And	S
11	S	And	S	And	L	And	M	And	S
12	S	And	S	And	L	And	L	And	S

where A_i, B_i, C_i are fuzzy subsets of the input variables and D_i is the fuzzy subset of the output value defined by the corresponding member functions. Table 4, shows the proposed fuzzy rules. Based on the results of the experiment, the degrees of membership in the fuzzy sets are calculated. The inference system performs fuzzy argumentation in fuzzy rules to produce a fuzzy value [10]. Using the max-min combination, fuzzy logic generates these fuzzy output rules. Assuming that y_1, y_2 and y_3 are three inputs of the fuzzy logic unit, the fuzzy argument output membership function can be expressed as [8, 10, 11]:

$$\mu_{Co}(z) = [\mu_{A_1}(y_1) \wedge \mu_{B_1}(y_2) \wedge \mu_{C_1}(y_3) \wedge \mu_{D_1}(z)]$$

$$\vee [\mu_{A_2}(y_1) \wedge \mu_{B_2}(y_2) \wedge \mu_{C_2}(y_3) \wedge \mu_{D_2}(z)] \vee$$

$$\dots \vee [\mu_{A_n}(y_1) \wedge \mu_{B_n}(y_2) \wedge \mu_{C_n}(y_3) \wedge \mu_{D_n}(z)] \quad (1)$$

Where μ_{A_i}, μ_{B_i} and μ_{C_i} are the membership functions of the input values and μ_{D_i} is the membership function of the output value. Here, it shows the maximum number of operations and shows the minimum operation. The Centroid method of defuzzification is used to convert the output of the fuzzy inference to the non-fuzzy value of COM using the equation below [12]

$$Z_0 = \frac{\sum z\mu_{C_0}(z)}{\sum \mu_{C_0}(z)} \tag{2}$$

In this study, based on the purpose chosen, only two types of first features are used. The S / N ratio with higher, better and lower qualities are best described by Equations (3) and (4) respectively [13]

$$\eta = -10\log\left[\frac{1}{n}\sum_{i=1}\frac{1}{y_i^2}\right] \tag{3}$$

$$\eta = -10\log\left[\frac{1}{n}\sum_{i=1} y_i^2\right] \tag{4}$$

Where η represents the ratio S / N of experimental values $y_i$represents the experimental value of i and n is the number of experiments.

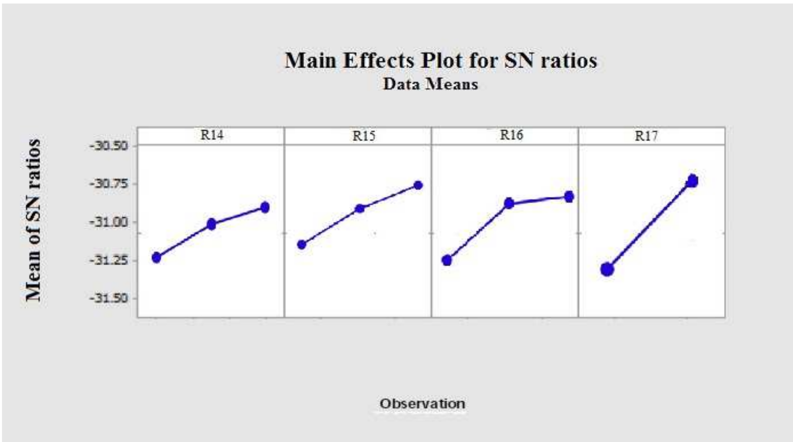

Fig. 3. S / N Ratio diagram for time cycle

Figure 3 shows the following important parameters for the time cycle based on the S / N ratio: R14, R15, R16 and R17.

The values of the control parameters must be selected on the levels corresponding to the higher S / N ratio for obtaining optimal output results.

In Table 5, the response parameters are shown with relation to the corresponding S / N and COM.

Table 5. The response parameters are shown with relation to the corresponding $S\ /\ N$ and COM

S.NO	R14	S/N	R15	S/N	R16	S/N	R17	S/N	com
1	18.2	-29.352	250.123	-306	8.01	-10.01	150.18	-198.002	0.537731
2	20.23	-21.033	270	-312.01	9.01	-9.32	170.08	-152.032	0.518618
3	22.22	-20.123	290.140	-348.06	8.50	-10.41	190.15	-196.123	0.835476
4	24.02	-28.214	310.021	-330.12	10.65	-8.03	210.09	-167.025	0.778468
5	26.01	-19.365	330.003	-296.05	12.45	-11.45	220.10	-180.351	0.139245
6	28.14	-19.547	350.120	-324.45	11.06	-14.36	160.05	-202.152	0.567603
7	30.03	-25.321	260.056	-304.25	14.01	-12.03	180.06	-210.032	0.168623
8	19.15	-22.412	280.352	-262.03	13.21	-12.47	200.07	-186.001	0.065381
9	21.5	-27.033	300.452	-264.62	15.30	-9.95	220.06	-187.062	0.215181
10	23.4	-19.020	310.065	-278.13	16.02	-9.08	150.05	-173.123	0.81396
11	25.08	-21.260	320.751	-307.18	14.11	-8.09	180.03	-172.014	0.142974
12	27.36	-19.111	340.009	-252.20	9.012	-9.12	210.02	-186.020	0.782626

3. Analysis of variance (ANOVA)

Although the Taguchi design allows the results to be achieved using less experience than other techniques, it cannot evaluate individual effects on modeling responses. ANOVA is a statistical method that is typically used to test the results for identifying the factors affecting the output of the model. The purpose of ANOVA is to examine which process parameters significantly affect performance characteristics. This is done by separating the total variations of the $S\ /\ N$ ratios, which is measured by summing the square deviations from the total average $S\ /\ N$ ratio to the contribution of each of the process parameters and the error. First, the total square deviations $SS_T$are calculated from the mean total $S\ /\ N$ ratio. The sum of the total deviations depleted SS_T is divided into two sources: the sum of the square deviations SS_d due to each design parameter and the total square errorSS_e.

The analysis of variance (ANOVA) was performed using MINITAB software to determine the percentage of process parameters on the output responses, the cycle time of the process. Statistically, a tool the F-test called Fisher [2] is called to determine that the process parameters have a significant impact on the performance attribute. Usually, the larger value of F-value has a greater effect on the performance attribute due to the change in the process parameter. Table 6 shows the ANOVA results for the processing cycle. It can be seen that the control parameters R14, R15, R16 and R17 are significant and contribute to 86% of the total cycle time of the formation process.

Table 6. Analysis of variance for time cycle

sources	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**%**
R14	1	0.3388	0.3388	0.3388	3.02	0.012	2
R15	1	0.6574	0.6574	0.6574	5.86	0.042	6
R16	1	0.8832	0.8832	0.8832	7.87	0.023	8
R17	1	0.3165	0.3165	0.3165	2.82	0.132	2
Residual Error	3	0.8974	0.8974	0.1122	-	-	-
Total	12	9.3771	-	-	-	-	-

Therefore, based on the S / N ratio and ANOVA analysis, optimal control parameters for reducing the time cycle while maintaining quality are presented in Table 7.

Table 7. Optimization of control parameter

S.No	R14	R15	R16	R17
1	22	300	14	220

3.1. Verification test

Once the optimal level of process parameters has been selected, the final stage is the forecast and improvement check functionality using the desired level of process parameters. The estimated S / N ratio can be obtained using the MINITAB software, and the corresponding cycle time can also be calculated using equations (3 and 4).

Table 8. Results of validation tests

S.No	**Output function specification**	**The amount**	
1	Time cycle	Entrance	36.3
		Predicted	31.3
		Real	34.5

Table 8 compares the initial and actual results of the confirmation test for the output function, resizing the diameter of the path and the time of the cycle of the grinding process. A change in the diameter of the song decreased by 39.12% and the cycle time was reduced by about 3 seconds. This led to improvements in flow and overall time. Therefore, the experimental results show that the previous design and analysis to optimize the process control parameters improved the performance of the output function.

4. Conclusion

This paper describes a Taguchi method for optimizing control parameters in the process of producing disposable essentials. This study shows that the design of the Taguchi method parameter is a simple, systematic and efficient method for optimizing process control parameters. Experimental results show that the cycle time for a forwarding process can be reduced simultaneously. Verification experiments were performed to confirm the optimal parameters. This research shows how the Taguchi parameter design can be used to optimize process performance with minimal cost and time for industrial readers. A further study can take into account more factors to see how it affects the output characteristics of a process. And also for optimization, the ideal planning and its combination with the Taguchi method can be paid.

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