An Analysis Of Optimum Process Parameters Using Fuzzy Logic And Regression Analysis

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ABSTRACT-

Complex systems can be effectively solved by Fuzzy models. Taguchi design of experiments will trace the optimum parameters for process with a smaller number of experimentations. Regression analysis will be useful in modelling and analyzing the various influenced variables having the relationship between a dependent variable. In the present paper, we mainly focused on traditional Taguchi approach, Fuzzy logic and Regression analysis methods to obtain the optimum process parameters. We also compare the results of these three methods. From the results we observed that the Fuzzy rule-based models are closer values to experimental data than the other traditional approaches.

Keywords: Fuzzy logic, Regression analysis, Taguchi approach, Tensile strength, ANOVA.

1. INTRODUCTION:

Taguchihas proposed a very powerful tool to carry out the experimental designs to improve the quality of products. Recently these methods are playing a vital role in the field of engineering and sciences.Generally, we are controlling the process either manual or automatic process. Fuzzy logic is used as a modern process control method to determine the solutionsof the complex process. Zadeh has initially laid foundation of Fuzzy logic concept. Based on the ideas of Fuzzy logic Mamdani and Assilian and several authors laid foundation to develop the Linguistic and membership functions to the selected process parameters.Aengchuan and phruksaphanrat (2013) studied fuzzy logic models in inventory system design.Sudha Hatagar (2015) studied the fuzzy logic model of washing machine for three input parameters and one output variable. Pratap Singh et al (2016) determined the optimum process parameters of friction stir welding joints by Taguchi method. They have made an interesting study by considering Tool rotation speed, Welding speed and Tool geometry as input parameters. Generated test data of all possible combinations of input parameters and their levels to observe the output response test data Tensile strength. Buddi et al. (2018) derived optimum process parameters using soya meal adhesive. Venkata Ratnam et al (2017) studied forecasting model using fuzzy logic. Ganguly and Patil (2019) developed X bar control chart for multi-objective economic-statistical design. Since tensile strength leads to the product life, manufacturers would like to provide higher grades of Tensile strength at low cost. An experimental work done by PratapSingh et al. (2016) help us in identifying the optimum process parameters of the tensile strength of Friction stir welded AA7075-10%wt. SiC composite joints.They have selected ‘3’ input parameters, viz., Tool rotation speed, Welding speed and Tool geometry and specified ‘3’ levels to each parameter. For all possible combinations of ‘3’ input parameters with ‘3’ levels, the number of required test runs are 27. They have repeated each test run 3 times and reported the mean value of the output response, namely, the Tensile strength.Rajyalakshmi and Nageswara Rao (2019a) trace the optimum parameters of weld dilution for ST-37 plates using Modified Taguchi approach. Rajyalakshmi and Nageswara Rao (2019b) determined expected range using Modified Taguchi approach. The objective of this study is to compare the fuzzy logic control with other traditional approaches such as Taguchi and Regression modelling and want to show that the experimental results are much closer to Fuzzy logic than other approaches by considering the experimental data of Pratap Singh et al. (2016).

2. Methodology:

The complete description of Friction Stir welded AA7075-SIC composite joints and its process has been explained by Pratap Singh et al. (2016). To carry out this study, we consider the three input parameters, Tool rotation speed (A), Welding speed (B) and Tool geometry (C) were taken as the input parameters of the proposed models. The output variable Tensile strength (MPa). Fuzzy logic toolbox of MATLAB was used to the process control fuzzy inference system model to calculate Tensile strength. Following the work of Sudha and Halase (2015),we determine the values of process parameters to apply the fuzzy logic controller. Define the simple set of rules for doing the process of fuzzification. The following rules were set to carry out the analysis by using MATLAB (2020a).

Rule1: If (Rotational speed is low) and (Welding speed is slow) and (Tool Geometry is Square) then Tensile strength is Medium.

Rule 2: If (Rotational speed is low) and (Welding speed is slow) and (Tool Geometry is Hexagonal) then Tensile strength is Weak.

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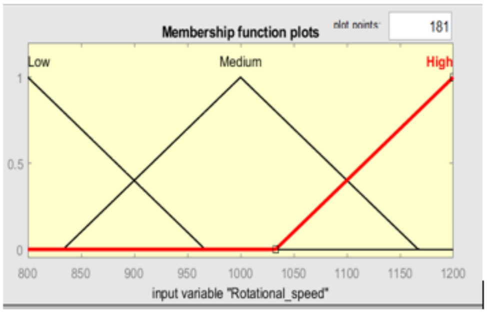
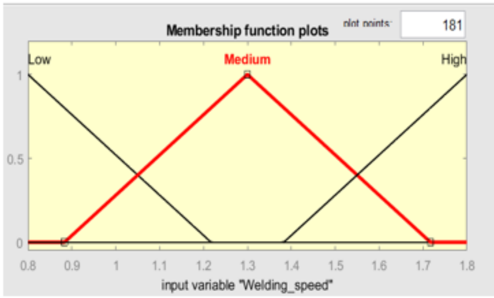
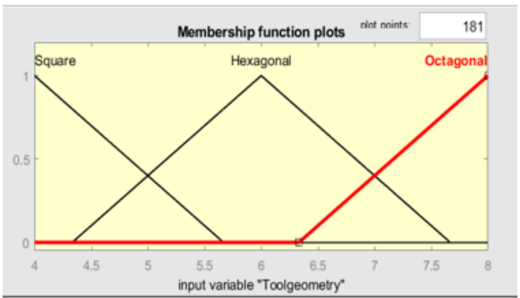
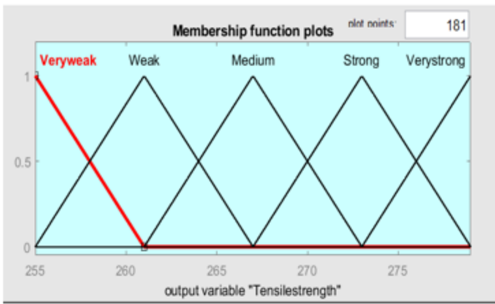
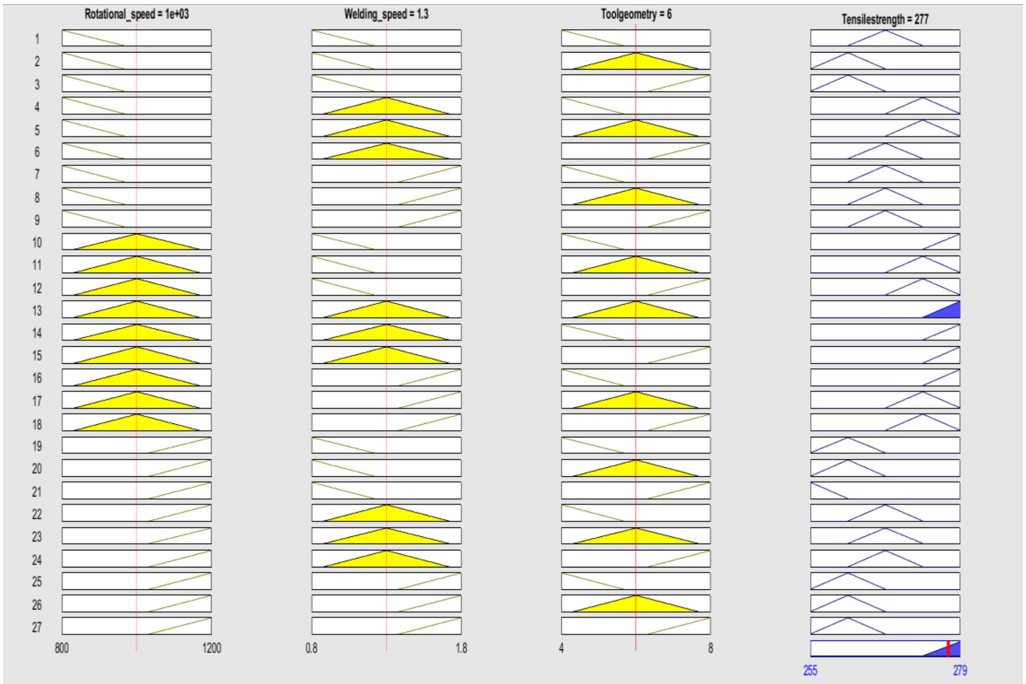
A membership for input and output variables of tensile strength have clearly shown in the following figure(s), At last the crisp value of tensile strength have been obtained as an answer.











Defuzzification provides the maximum Tensile strength with the value of 277 Mpa for thegiven input parameters $A_2B_2C_1$

Taguchi approachhelp us to predict the output response of '3' input parameters each at three levels using L_9 Orthogonal array. Using the experimental data of Pratap Singh et al. (2016), we determine the means for each factor and obtain the estimated output response with different combination of factors at different levels are presented in Table (2).From the results of analysis of variance (ANOVA), the significant factors are determined and used to produce regression prediction model. ANOVA showing that A, B, C are the main factors affecting the tensile strength. Here we follow the assumption of Pratap Singh et al (2016) and not considering the interaction factors. As per Taguchi design, the number of experiments (N) for the number of process parameters (v) and the number of levels (r) assigned to each process parameter can be found from

$$N = 1 + v(r - 1) \quad (1)$$

The regression model of experiment is given in (2) is used to predict the output results to compare with the Fuzzy logic and Taguchi approaches indicated in Table (4).

$$Y=278.537-00.64A+0.56B-1.25C \quad (2)$$

The Fuzzy logic control model of the Friction stir weld joints has been modelled systematically as well as with Taguchi and Regression techniques. The prediction of Tensile strengthfor these three models compared to actual values represented in Table IV.

3. **Result and Discussion**

To predict the output response Tensile strength (MPa), Tool rotation speed (A), Welding speed (B) and Tool geometry (C) were taken as the input parameters of the proposed models. The output variable. Fuzzy logic has provided the optimum solution of tensile strength $A_2B_2C_1$ withthe value of 277. From the test data given in Table (1) the maximum tensile strength observed is 294 at the same combination of factors and levels. Comparative analysis of the three methods and the results are represented in Table (1). By following the Taguchi approach we got the value of 257, whereasthe regression method indicating the value of '268'. From the results we can clearly identified that fuzzy logic is very closer to the maximum value of the given data.ANOVA results presented in Table-3 indicate that Tool rotation speed (A), Welding speed (B) and Tool geometry (C) have 72%, 22% and 6% contributions on the Tensile strength. Predicted values of the three methods are given in Table IV. The test results are much closer to Fuzzy logic than other approaches by considering the experimental data of Pratap Singh et al. (2016) and we also observed that the error% is also very low when compared with other approaches.

4. **Conclusion**

This paper provides the comparative analysis of Optimum output response using Fuzzy logic, Taguchi approach and Regression analysis for various input parameters. The results indicated in Table (1) and Table (4) are concluding that the predicted values are much closer to Fuzzy logic when compared with other traditional approaches.

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Table-1:Input parameters and their levels (Pratap Singh et al. (2016))

Process parameters	Designation	Level-1	Level-2	Level-3

Tool Rotational speed (rpm)	A	800	1000	1200
Welding speed(mm/sec)	B	0.8	1.3	1.8
Tool geometry	C	Square	Hexagonal	Octagonal

Table-2: Output response as per L9 Orthogonal array

	Output response: Tensile strength, MPa			%Contribution
	Mean-1	Mean-2	Mean-3	
A	258	288	250	72
B	258	278	260	22
C	272	267	257	6

Table-3: ANOVA

Table-4: Predicted Response for all the combinations of various process parameters and their levels

S. No	X1	X2	X3	Tensile strength Taguchi L9	Predicted (2)	Predicted (3)	Error(%)
1	800	0.8	4	263	267	268.87	-5.87
2	800	0.8	6	261	261	266.37	-5.37
3	800	0.8	8	258	261	263.87	-5.87
4	800	1.3	4	269	273	269.15	-0.15
5	800	1.3	6	268	273	266.65	1.35
6	800	1.3	8	264	267	264.15	-0.15
7	800	1.8	4	263	267	269.43	-6.43
8	800	1.8	6	262	267	266.93	-4.93
9	800	1.8	8	258	267	264.43	-6.43
10	1000	0.8	4	273	277	267.59	5.41

Test run				**Tensile Strength**			
	A	B	C	Test Data [1]	Predicted Taguchi [1]	Predicted Fuzzy [2]	Predicted Regression [3]
1	1	1	1	258	274	267	269
2	1	2	2	272	267	273	267
3	1	3	3	243	261	267	264
4	2	1	3	281	264	273	263
5	**2**	**2**	**1**	**294**	**257**	**277**	**268**
6	2	3	2	289	274	277	266
7	3	1	2	234	254	257	264
8	3	2	3	268	270	267	262
9	3	3	1	248	264	261	267

11	1000	0.8	6	271	273	265.09	5.91
12	1000	0.8	8	268	273	262.59	5.41
13	**1000**	**1.3**	**4**	**279**	**277**	**267.87**	**11.13**
14	1000	1.3	6	278	277	265.37	12.63
15	**1000**	**1.3**	**8**	274	**277**	262.87	11.13
16	1000	1.8	4	273	273	268.15	4.85

17	1000	1.8	6	272	273	265.65	6.35
18	1000	1.8	8	268	273	263.15	4.85
19	1200	0.8	4	260	261	266.31	-6.31
20	1200	0.8	6	258	261	263.81	-5.81
21	1200	0.8	8	255	257	261.31	-6.31
22	1200	1.3	4	267	267	266.59	0.41
23	1200	1.3	6	265	267	264.09	0.91
24	1200	1.3	8	262	267	261.59	0.41
25	1200	1.8	4	261	261	266.87	-5.87
26	1200	1.8	6	259	261	264.37	-5.37
27	1200	1.8	8	256	261	261.87	-5.87