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Predictions of Weld Strength of Resistance Spot Welding using Fuzzy Logic MATLAB toolbox and comparison With Experimental Results

B.D. Parmar[1], N.G.Parmar[2]

[1]*Mechanical Engg Deptt. Govt.Ployechnic,Junagadh*
[2] *Mechanical Engg Deptt. Govt.Ployechnic, Kheda*

Abstract*-Spot welding is a resistance welding process for joining metal sheets by directly applying opposite forces with pointed tips. The current and the heat generation are localized by the form of electrode. The amount of heat produced is a function of current, time and resistance between the work pieces. The present work attempts experimental investigations to study influence of important process parameters of resistance spot welding on weld strength, current and cycle time are varied at three different levels for different thickness and manufactured specimens are tested for weld strength. Prediction of weld strength is done by using fuzzy logic tool box of MATLAB,and compared with experimental results.*

Keywords*- Spot welding, Weld strength, Cycle time, Fuzzy logic, DOE,FIS*

I. INTRODUCTION

Resistance spot welding is a process that is being widely used in the industry for sheet metal fabrication purposes, as the name applies spot welding is a resistance welding process for joining metal sheets by directly applying opposing forces with electrodes with potential tips, the current and the heat generation are localized by electrodes. Resistance spot welding is a process in which faying surfaces are joined in one or more spots by resistance to the flow of electric current through work pieces that are held together under force by electrodes. The contacting surfaces in the region of current concentration are heated by a short-time pulse of low-voltage, high-amperage current to form a fused nugget of weld metal. When the flow of current ceases, the electrode force is maintained while the weld metal rapidly cools and solidifies. The electrodes are retracted after each weld, which usually is completed in a fraction of a second.[1]

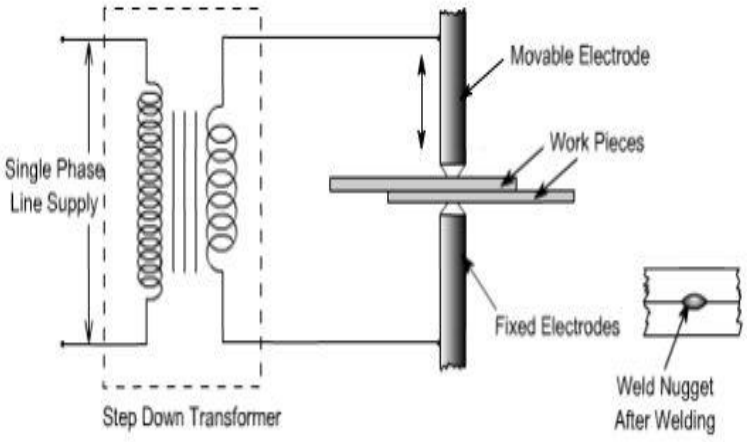


Figure1. Working principle of resistance spot welding

Figure 2 .Resistance spot welding Machine

II.EXPERIMENTAL SETUP

In Resistance spot welding machine, the magnitude of current and the welding time are two important process parameters which affect the strength of welds.[2]. The change of current will be made through the change of percentage of preset maximum current and length of time through number of cycles. Other process parameters in welding schedule, such as electrode force, hold time and off time, etc are kept constant during the test.[3,4]. 27 Specimen of galvanized sheets are manufactured on resistance spot welding Machine at manufacturing laboratory, Government Polytechnic, Junagadh with different combinations of current(1000amp to 3000amp) and welding

time(2 to 6 Seconds) and for different thickness (0.35mm to 1.5mm).Weld strength is tested on Universal Testing Machine (Enkay) at applied mechanics department ,Government Polytechnic, Junagadh. Prediction of weld strength is done by using fuzzy logic tool box of MATLAB.

Table 1, Process parameters to be controlled

Factors	Symbol	Level			Unit
		1	2	3	
Current	I	1	2	3	KAmp
Cycle Time	T	2	4	6	sec

Figure 3 Manufactured test specimen(sample)

Figure 4 weld strength Test set-up

III. METHODOLOGY

A design of experiment (DOE) is used to study the effect of process parameters on responses.[5] There are number of techniques available for predicting responses using input parameters e.g. genetic algorithm, artificial neural network, fuzzy inference system (FIS) etc. But present work uses Fuzzy Inference System (Mamdani Fuzzy logic) to predict the weld strength of joints by changing different parameters of spot welding machine. The model uses all input and output variables in linguistic terms enabling it convenient for practitioners. The inference engine in Mamdani type FIS uses rules which are obtained with help of design of experiment technique (DOE).

*3.1*fuzzy inference system

In general two most popular fuzzy inference systems are available: Mamdani fuzzy model and Sugeno fuzzy model. The selection depends on the fuzzy reasoning and formulation of fuzzy IF-THEN rules Mamdani fuzzy model is based on the collections of IF-THEN rules with both fuzzy antecedent and consequent predicts. The benefit of this model is that the rule base is generally provided by an expert and hence to a certain degree it is translucent to explanation and study.Because of its ease, Mamdani model is still most commonly used technique for solving many real world problems.[6]The methodology for development of fuzzy prediction model in MATLAB involved the following steps:

3.1. 1 Selection of input and output variables

Inputs and the output were taken in the form of linguistic format which displayed an important role in

the application of fuzzy logic. For example, current ={low,Medium,high}, cycle time = { low,Medium,high }, The output variable is similarly divided into Welding strength = { Very low, low, Medium, high, Very high },A linguistic variable is a variable whose values are words or sentences in a natural or man-made language.

3.1.2 Selection of membership functions for input and output variables

Linguistic values were expressed in the form of fuzzy sets. A fuzzy set is usually defined by its membership functions [7]. In general, triangular and trapezoidal membership functions were used to normalize the crisp inputs because of their simplicity and computational efficiency .As shown in figure, the triangular membership function is used to convert the linguistic values in the range of 0 to 1.

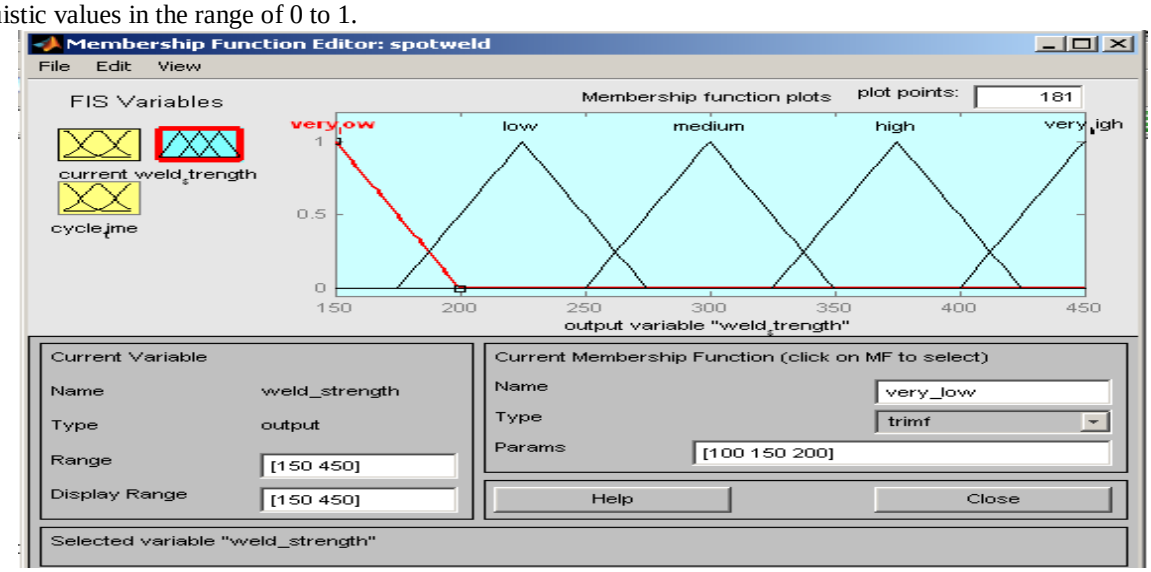


Figure 5 Member ship function editor

3.1.3 Formation of linguistic rule base

The fuzzy rule-based system uses IF–THEN rule-based system, given by, IF antecedent, THEN consequent. The rules are formed according to problem statement and the work is carried out in Fuzzy logic toolbox of MATLAB. [8]with two inputs, and one output five fuzzy subsets are assigned to inputs and outputs as shown in Fig. 2, Nine fuzzy rules are derived directly based on the fact that smaller is the S/N ratio, the better is the performance characteristics.

3.1. 4 Defuzzification

Defuzzification means the fuzzy to crisp conversions. The fuzzy results generated cannot be used as such to the applications, hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing. This can be achieved by using defuzzification process.

IV RESULT ANALYSIS

Table 2, Experimental and predicted weld strength

Sr. No	Factors symbol		Weld strength (N/mm2)								
			t=0.35mm			t=1.0mm			t=1.5mm		
	I	T	Exp.	Prediction	% Error	Exp.	Prediction	% Error	Exp.	Prediction	% Error
1	1	2	170	166	2.35	156	150	3.85	148	155	4.73
2	1	4	228	225	1.32	224	235	4.91	218	200	13.79
3	1	6	310	300	3.23	294	305	3.74	200	192	4.00
4	2	2	215	209	2.79	207	218	5.31	215	232	7.91
5	2	4	270	262	2.96	255	264	8.64	221	210	4.98

6	2	6	305	320	4.92	300	292	2.67	248	245	1.21
7	3	2	220	225	2.27	228	210	7.89	257	255	0.78
8	3	4	290	300	3.45	305	290	4.92	265	278	4.91
9	3	6	335	340	1.49	342	355	3.80	278	296	6.47

Error = Modulus of [(Experimental results – Predicted results (FIS))/Experimental results]

From the experimental work, the maximum weld strength 342 N/mm^2, was obtained at current value 3 Kamp and cycle time 6 seconds for 1mm thickness sheet, but at the same value of current and cycle time weld strength was obtained 278 N/mm^2 for 1.5 mm thickness, which means there is decrease in weld strength as thickness increases for same value of processing Parameters. Minimum experimental weld strength 148 N/mm^2, was obtained at current value 1 Kamp and cycle time 2 seconds for 1.5 mm thickness sheet.

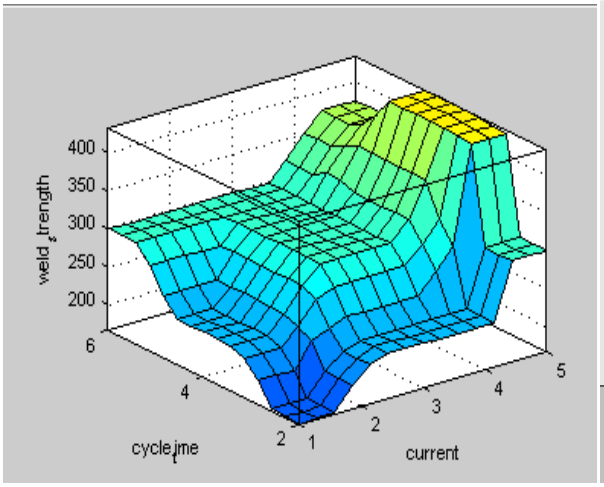


Figure 6 Surface plot

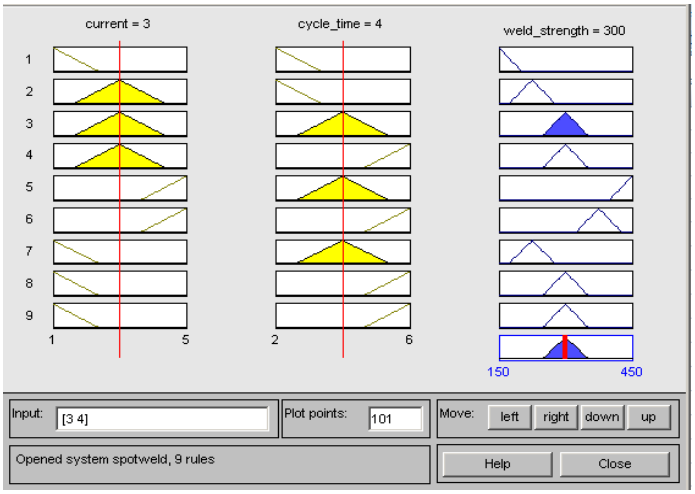
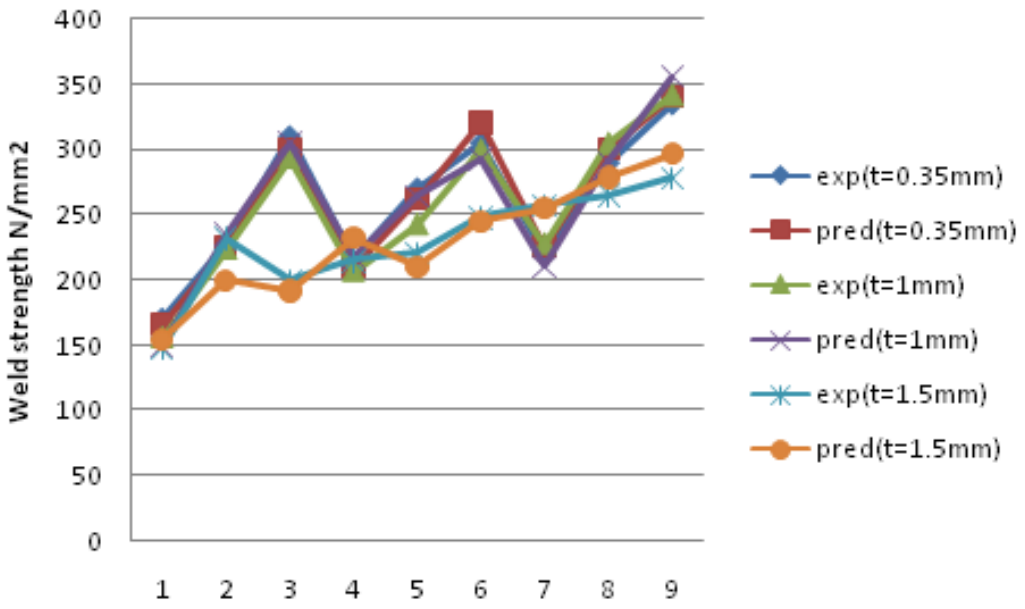


Figure 7 Output prediction by FIS

Predicted weld strength by Fuzzy logic tool box is also shown in the result table. Maximum predicted weld strength 355 N/mm2 was obtained at current value 3 Kamp and cycle time 6 seconds for 1mm thickness sheet. Minimum predicted weld strength 150 N/mm^2, was obtained at current value 1 Kamp and cycle time 2 seconds for 1mm thickness sheet.



Experiment No.

Figure 8 Weld strength vs Predicted and experimental weld strength

Minimum percentage change of error is 0.78 and maximum percentage change of error is 13.79 and comparison of experimental results with predicted results is shown in a graph for different experiments. It is clear from the graph that the Predicted results are within tolerance limits except few readings because of some manual as well as machine error involved. The low percentage error shows that the results predicted by fuzzy logic were highly accurate and precise.

V.CONCLUSION

In this paper, it was shown that a Fuzzy Inference System is a versatile tool for weld strength Prediction of resistance spot welding. A model was constructed that successfully predicted the weld strength for selected spot welding parameters. Following facts were derived from prediction by Fuzzy Inference System and Experiment results.

1. Prediction of experimental work using FIS the results obtained are within tolerance limit, except few readings because of some manual as well as machine error.
2. Weld strength increases as welding current increases.
3.In addition to cycle time the thickness of material has a significant impact on welding strength, as thickness increases weld strength decreases for the same processing parameters of spot welding machine,

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