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SMAW Process Parameters Optimization using Taguchi & Fuzzy Logic

Piyush Kumar Gupta[1], Dr. Abhishek Kamboj[2]

[1]Student, M.Tech (Industrial & Production Engineering), HEC, Jagadhri,
[2]HOD, Mechanical Department, HEC, Jagadhri

Abstract - *Taguchi method is used to optimize welding process parameter for single welding response. In order to optimize welding process parameters for multiple response various approaches is still an area of research. In this paper, Fuzzy Logic is used to optimize welding process parameter of SMAW having multiple response using Fuzzy Logic. The response parameters (i.e. Hardness & UTS) are fed as input to Fuzzy Inference System and Multi Response Performance Index (MRPI) is obtained as output. The optimal value is calculated based on the value of MRPI.*

Key Words*: *Taguchi Method, Fuzzy Logic, Hardness, UTS, MRPI, FIS

1. INTRODUCTION

With welding technique is it possible to join or weld different metal or alloys. Welding, a manufacturing process creates a permanent joint, the joint obtained by the fusion of the surface of the parts to be joined or welded together, with or without the application of pressure and a filler material. But variety of problem may arise after welding is done. Problem may be comprehensive and tensile stresses, stress corrosion cracking etc.

Taguchi Method, developed by Genichi Taguchi. The objective of Taguchi method is to produce high quality product at low cost for the manufacturers. Experimental design proposed by Taguchi uses orthogonal arrays that organize the parameters affecting the process and also the levels at which they should be varied. Instead of having to test all possible combinations the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect the product quality with a minimum amount of experimentation, thus saving resources and time. Taguchi method is basically used to optimize welding parameters for single weld property, it don't work well in case of multiple weld property. For optimizing welding parameters for multiple weld property Fuzzy method is used[1].

For multi-objective optimization, a Fuzzy Logic model was proposed and optimal levels of NiO, MnO and MgO was obtained using a single multi-response performance index (MRPI)[2]. The experimental studies were conducted under varying electrode forces, welding currents, and welding times. The settings of welding parameters were determined by using the Taguchi experimental design of L_{18} Orthogonal array method. The combination of the optimum welding parameters have determined by using the analysis of Signal-to-Noise (S/N) ratio[3]. It is found that control factors had varying effects on tensile strength, welding voltage having the highest effects[4]. Fuzzy logic created a relationship between input and output data so that mechanical properties for an untested rotational speed can be estimated[5]. An orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are used to investigate the welding characteristics of MC C20 material and optimize the welding parameters[6]. The study also shows that the use of the Taguchi Method has successfully improved on the existing process parameters, giving the industrial firm a more efficient signature welding protocol[7]. The Taguchi method is also used to predict the optimal setting for each welding parameter[8].

2. FUZZY LOGIC

Fuzzy logic is one of the fastest growing technologies in the world since the beginning of computer era. Because of its simplicity and wide range of applicability, there is an increasing need of education about fuzzy logic, especially for novice practitioners. The word design refers to almost any kind of creation in arts and sciences. In the artistic sense, design involves imagination, fiction, belief and taste. Whereas, in scientific terms, design applies theoretical principles in an appropriate and optimal manner. Designing a fuzzy system has both scientific and artistic elements that make it hard to learn.

The scientific elements are based on mathematics such as fuzzy set theory. The artistic element comes from the intuition, interpretation, insight, expectation etc, which we call heuristics. Fuzzy system theory has progressed in two directions; Fuzzy inference and the application of the fuzzy set theory to problem formulated strictly in mathematics. In fuzzy inference approach, the solution of a problem comes from human interpretation. The design challenge is to reproduce a specific solution by translating it from original domain of knowledge to calculate fuzzy IF-THEN rules. In second approach, the original solution of problem in hand is expressed purely by crisp mathematics with very little involvement of heuristics. The design challenge is to apply the fuzzy set theory to crisply defined concepts and formulas to improve their generality, robustness and expressive power. Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems and complex industrial processes, as well as for household and entertainment electronics, as well as for other expert systems[9].

A fuzzy set F is generalization of crisp set. It is defined on a universe of discourse X and is characterized by membership function $\mu_F(x)$ that takes on values in interval [0,1][10]. A membership function provides measure of degree of similarity of an element in X to fuzzy set. Fuzzy logic was proposed by Zadeh in 196[11].

3. Work using Taguchi and Fuzzy Method

Three process parameter of welding i.e. current, voltage and speed is chosen for this work at three different level named as 1, 2, 3. According to Taguchi method for three process parameters at three different levels L_9 orthogonal array is formed as shown in table 1.

Table 1. Orthogonal Array L_9

EXP NO.	LEVELS		
	CURRENT	VOLTAGE	SPEED
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The value of Hardness and UTS is noted for the table. The S/N value of Hardness and UTS is calculated according to equation i.e. Higher is best.

$$\frac{S}{N} = -10\log_{10}\left\{\frac{\sum 1/(y_i)^2}{n}\right\}$$

Table 2. Experimental Hardness & UTS value

EXPERIMENT NUMBER	LEVELS			HARDNESS (HRB)	UTS (N/mm²)
	CURRENT	VOLTAGE	SPEED		
1	1	1	1	66	450
2	1	2	2	69	461
3	1	3	3	72	455
4	2	1	2	64	434
5	2	2	3	66	430
6	2	3	1	67	435
7	3	1	3	66	426
8	3	2	1	64	430
9	3	3	2	70	435

The S/N value calculated is substituted in the Fuzzy Inference System (FIS) as input.

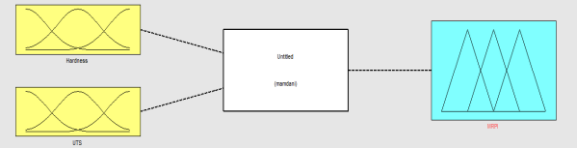

Figure 1. FIS Editor with two inputs and one output

Based on the rules as shown in table 3, the value of Multi Response Performance Index (MRPI) is calculated.

Table 3. Fuzzy Rules for MRPI

MRPI	UTS		
HARDNESS	Small	Medium	Large
Small	Small	Medium	Large
Medium	Small	Medium	Large
Large	Small	Medium	Large

The output obtained through FIS i.e. Multi Response Performance Index (MRPI), its values lies between the range of 0 and 1.

Table 4. MRPI value for S/N value of Hardness & UTS

EXP. NO.	CURRENT	VOLTAGE	SPEED	MRPI
1	1	1	1	0.548
2	1	2	2	0.858
3	1	3	3	0.71
4	2	1	2	0.38

5	2	2	3	0.218
6	2	3	1	0.425
7	3	1	3	0.16
8	3	2	1	0.185
9	3	3	2	0.423

4. Optimization of SMAW Process Parameters

The average of the value is calculated at the different value of current, voltage and speed at the three different levels and rank is calculated as shown in table 5.

Table 5. Optimal level of Current, Voltage and Speed

	Current	Voltage	Speed
Level 1	**0.705**	0.362	0.386
Level 2	0.341	0.420	**0.553**
Level 3	0.256	**0.519**	0.362
Delta	**0.449**	**0.157**	**0.191**
Rank	**1**	**3**	**2**
Optimal value is A1B3C2			

As per the above table the optimized value of current, voltage and speed is obtained at the level 1,3,2 i.e. A1B3C2.

5. Conclusion

By applying Taguchi along method along with Fuzzy Logic method, optimization of welding process parameter for SMAW is achieved. Taguchi method and fuzzy logic also helped in reducing the number of experiments to be performed.

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