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Application of statistical software analysis for optimization of resistance spot welding in carbon steel JIS SS400

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***Abstract*— This work describes an application of statistical software analysis for optimization in resistance spot welding. JIS SS400 is a carbon steel for resistance spot welding processes. The following resistance spot welding variables were examined: welding current, welding time and electrode force. The research studied and optimized the application of the full factorial design. The resulting materials were examined using the macrostructure (nugget size) according to JIS Z 3139: 1978 and tensile shear test according to JIS Z 3136: 1999 The results show that a welding current, welding time and electrode force interaction on nugget size and tensile shear test had a 95% confidence level. The resistance spot welding variables affecting the tensile shear and nugget size are the optimize welding current at 10,500 amp., welding time at 10 cycle and electrode force at 2 kN. were tensile shear of 7.18 kN. and nugget size maximum of 6.72 mm. The research described here can be used as material data on welding variable for carbon steel JIS SS400 weld in resistance spot welding.**

Keywords*— *Resistance spot welding; Tensile shear; Nugget size; Full factorial design; soft computing techniques

I. INTRODUCTION

Resistance spot welding is a type of welding process in use by automotive, building construction and electrical-electronics industry. There is the most common application because it can weld the work pieces speedily with high quality and less thermal effect, strong enough to use and easy method for operating. The operating systems of resistance spot welding were: 1) Electrode set-down 2) Squeeze 3) Current Flow 4) Forging 5) Hold Time and 6) Lift-off). Resistance spot welding has three mainly components: 1) Heat 2) Pressure and 3) Time. The quality problems which occur after welding are the indicators that being the complete welds or not. Due to the present checking process via the nondestructive cannot respond to the requirements for checking but using checking process via the destructive. From these reason, it may occur troubles on the cost of production, lose checking time and lose time in producing new work pieces according to incomplete welds. [1-2]

The factorial design is particularly useful in the early stages of experimental work, when there are likely to be many factors to be investigated. It provides the smallest number of runs with which k factors can be studied in a complete factorial design. Because there are only two levels for each factor, we must assume that the response is approximately linear over the range of the factor levels chosen. [3]

This work focuses on application of statistical software analysis in for optimization in resistance spot welding on the nugget size and tensile shear for a carbon steel JIS SS400. The optimum values for the variables in the resistance spot welding were determined by a full factorial design of experiments. The results of this research can be used as carbon steel data on resistance spot welding variables.

II. METHODOLOGY

A. Materials and Methods

The carbon steel SS400 was used for the test specimen. The specimens were 1.00 mm thick with dimension 30x100 mm in length and width. [4] The details on the chemical composition of the material are provided in Table 1. The electrode was used truncated radius electrodes (TR) following JIS C 9304:1999 with electrode 6 mm in diameter. After process of experiment , specimen were tested the strength of a weld by tensile shear testing following JIS Z 3136:1999 In addition specimen was measured on macrostructure for the weld nugget size following JIS Z 3139:1978 [5] with Coordinate Measurement Machine (CMM).

TABLE I CHEMICAL COMPOSITION OF MILD BY WEIGHT (%)

Alloy element								
Fe	C	Si	Mn	P	S	Ni	Cr	Al
Base	0.17	0.0014	1.201	0.009	0.007	0.012	0.018	0.043

B. Experimental Design

The experimental design is widely used to control the effects of the variables in many resistance spot welding processes. Its use decreases the number of necessary experiments, which consume time and material resources. Furthermore, the analysis that is performed on the results is easily implemented, and the experimental errors are minimised. The full factorial design measures the effect of changes in the operating variables and their mutual interactions on the process through an experimental design. The hypothesis test was level confidence of 95 %(P-value<0.05) [6]. The factors were used the excremental treatment of 3 replicated.

Factor study

Welding current at 8,500, 9,000 and 10,500 amp Fix factor

Welding time at 8, 9 and 10 cycle Fix factor

Electrode force at 2.00, 2.50 and 3 kN Fix factor

Squeeze time at 50 cycle Blocking factor

Hold time at 50 cycle Blocking factor

Tensile shear Response factor

Nugget size Response factor

Hypothesis of experimental.

H_0 ;$(\tau\beta)ij$ =0 is Welding current, Welding time and Electrode force no interaction Tensile shear

H_1; $(\tau\beta)ij \neq 0$ is Welding current, Welding time and Electrode force interaction Tensile shear

H_0 ;$(\tau\beta)ij$ =0 is Welding current, Welding time and Electrode force no interaction Nugget Size

H_1; $(\tau\beta)ij \neq 0$ is Welding current, Welding time flow and Electrode force interaction Nugget Size

III. EXPERIMENTAL RESULT

A. Results of Tensile Shear testing

The tensile shear testing was the test on mechanical property. The weld sample was measured tensile shear which using of 81 sample in according to JIS Z 3136:1999.

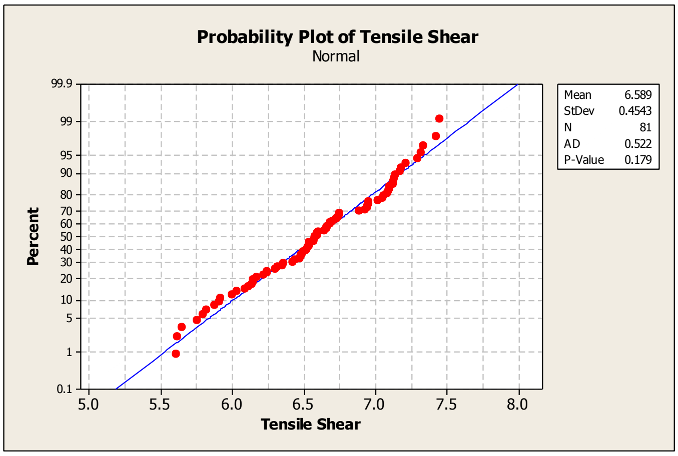

Fig.1 Probability plot of tensile shear

As shown Fig.1, A probability plot of tensile shear the data has normal distribution P value > 0.05.

TABLE II GENERAL LINEAR MODEL: TENSILE SHEAR VERSUS WELDING CURRENT, WELDING TIME AND ELECTRODE FORCE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	9.15	9.15	4.57	3332.32	0.00
B	2	1.02	1.02	0.51	371.82	0.00
C	2	1.04	1.04	0.52	381.39	0.00
A*B	4	2.70	2.70	0.67	491.48	0.00
A*C	4	0.79	0.79	0.19	143.85	0.00
B*C	4	0.78	0.78	0.19	143.18	0.00
A*B*C	8	0.93	0.93	0.11	84.89	0.00
Error	54	0.07	0.07	0.00		
Total	80	16.51				
S = 0.03	R^2 = 99.55%		R^2(adj) = 99.33%			

Note. Welding current = A, Welding time = B, Electrode force = C

Table II shows the analysis of variance for the tensile shear. The analysis of variance shows the p-value = 0.00 of the interaction. At least, the variable regression welding current, welding time and electrode force option would be significant in tensile shear. The experimental coefficient of determination is R^2 = 99.55%, and R^2adj = 99.33% as the desirable coefficient of determination.

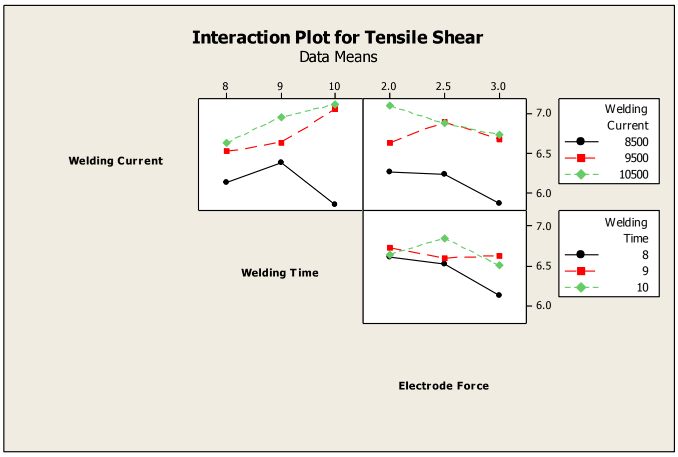

Fig.2 Interaction plot for tensile shear

Figure 2 shows the, effects of the welding current, welding tine and electrode force on the tensile shear. An interaction between these variables is seen when the lines in the plot are not parallel. The results show that the highest tensile shear achieved during the tensile shear was 7.18 kN for a welding current of 10,500 amp, welding time 10 cycle and an electrode force.

B. Results of nugget size

The macrostructure was tested in nugget size, diameter of nugget size was tested with coordinate measurement machine (CMM) from ROI Instrument which using in macrostructure measuring regarding to the measuring of nugget size

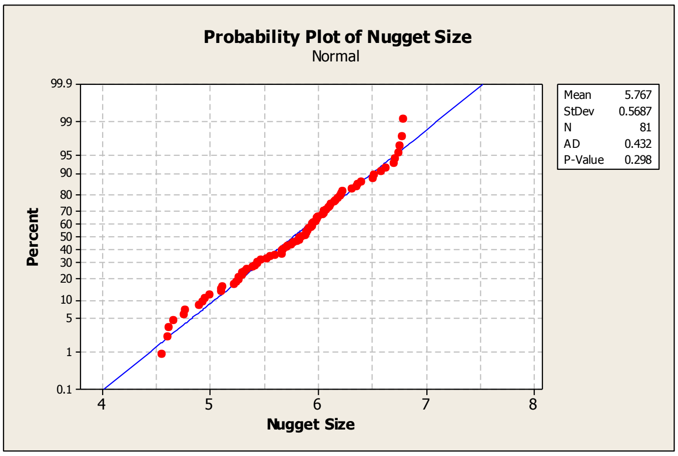

Fig. 3 Probability plot of nugget size

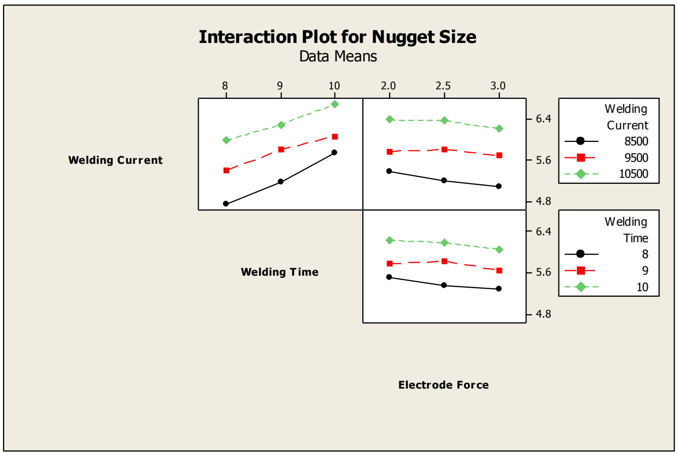

Fig. 4 Interaction plot for nugget size

As shown Fig.3, Probability plot of nugget size the data has normal distribution P value > 0.05.

TABLE III GENERAL LINEAR MODEL: NUGGET SIZE VERSUS WELDING CURRENT, WELDING TIME AND ELECTRODE FORCE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	16.79	16.79	8.39	3552.43	0.00
B	2	8.34	8.34	4.17	1765.20	0.00
C	2	0.47	0.47	0.23	101.12	0.00
A*B	4	0.38	0.38	0.09	40.58	0.00
A*C	4	0.12	0.12	0.03	13.68	0.00
B*C	4	0.07	0.07	0.01	8.40	0.00
A*B*C	8	0.05	0.05	0.00	3.17	0.00
Error	54	0.12	0.12	0.00		
Total	80	26.40				
S = 0.04	R^2 = 99.52%		R^2(adj) = 99.28%			

Note. Welding current = A, Welding time = B, Electrode force = C

Table III shows the analysis of variance for the tensile shear. The analysis of variance shows the p-value = 0.00 of the interaction. At least, the variable regression welding current, welding time and electrode force option would be significant in tensile shear. The experimental coefficient of determination is R^2 = 99.52%, and R^2adj = 99.28% as the desirable coefficient of determination.

Figure 4 shows the, effects of the welding current, welding tine and electrode force on the nugget size. An interaction between these variables is seen when the lines in the plot are not parallel. The results show that the highest nugget size achieved during the nugget size was 6.72 mm. for a welding current of 10,500 amp, welding time 10 cycle and an electrode force.

IV. CONCLUSIONS

In this work, the application of integrated soft computing techniques for optimization with full factorial design to the tensile shear and nugget size was discussed. The result showed that both of welding current, welding time and electrode force had interaction on tensile shear and nugget size at 95% confidential (P value < 0.05). The resistance spot welding variables was affected the tensile shear and nugget size are the most welding current 10,500 amp., welding time 10 cycle and electrode force 2 kN. When the shear force pulling the basis of accepted standards [7] all specimens of acceptable follow standards. The determining of integrity of nugget size also be based on acceptance criteria [7] must be determined by considering the suitable melting rate at 20 -80% [8]. With the result that the specimens appeared in the acceptance criteria [9]. This research can bring information to the foundation in choosing the appropriate parameters to resistance spot welding process.

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