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Optimization of Process Parameter for Electrode Tip Diameter in Resistance Spot Welding of Coated Steel

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Abstract — *A review of the resistance spot welding process is given, followed by a literature study of the known issues when welding galvanized coated steels and some of the methods explored to address those issues. This study presents a systematic approach to determine effect of process parameters on tip diameter as a primary & initial measure of weld quality and subsequently ultimate tensile strength. To achieve the objective an attempt has been made to select important welding parameters like weld current, weld cycle, hold time using quality tools, available literature and on scientific reasons. On the selected parameters, Experiment have been conducted as per Taguchi method and fixed the levels for the parameters. The experiment has three factors and all factors are at two levels. To have wide spectrum of analysis and variability with time experiments are conducted. Optimum welding parameters determined by Taguchi method improved electrode tip life. Taguchi Analysis has been used for determining most significant parameters affecting the spot weld parameters. Study of the degradation mechanisms of the uncoated electrode revealed that electrode tip life was due to more than the typical alloying and material loss as well as gross electrode deformation.*

Keywords-*resistance spot welding; coated steel; process parameters; taguchi analysis; electrode; tip life*

INTRODUCTION

Resistance Spot Welding is one of the oldest and main method of the electric welding processes in use by industry today for joining sheet steel components. In industries increased the use of zinc coated steels or galvanized coated steels because of their good corrosion resistance and low cost. The weld is made by a combination of heat, pressure, and time. However, the Galvanized coating has increased the difficulty of welding due to its lower electrical resistance and melting temperature. It has led to a drastic reduction in Weldability as well as electrode tip life. Poor Weldability requires more care to be taken when setting weld parameters. The purpose of this work is to explore the performance and behavior of the electrode.

I. WELDING TRIAL PARAMETERS

Table 1. Electrode Test Weld parameters

	Weldability Study		Electrode Life Study
	Current Tests	Time test	Uncoated
Weld Current (A)	10500 - 11300	10600	500
Weld Time (cycles)	10	5 - 45	25

Weld Current: Adjustments of the welding parameters to suit the galvanized coatings have been studied by various authors. The presence of the low resistance zinc coating at the faying interface requires a higher welding current to be used to form satisfactory weld nuggets. Orts [26] has reported that an increase in the welding current is needed due to the displaced molten zinc ring increasing the contact area. Other findings have put the amount of weld current increase need from 25-100% [10,35].

Weld Time: Weld time is normally set dependent on the thickness of the sheet being welded. Weld time must be increased to allow time for the molten zinc coating to be displaced from the weld area. Dickenson [28] reported that a 50-100% increase was needed over uncoated steels, and Kimchi and Gould [29] noted that too short a weld time will cause a severe heating cycle and too long a weld time will lead to higher overall electrode temperatures and longer diffusion times.

II. SHEET MATERIAL PROPERTIES

Sheet steel used was hot dip galvanized high strength low alloy steel as specified in Table 2. Two sheet thicknesses were used for experimentation. A 0.8 mm thick sheet was used for weldability testing, while 0.7mm thick steel was used for electrode life testing. Welding coupons were cut as per guidelines specified in the "Recommended

Practices for Test Methods for Evaluating the Resistance Spot Welding Behaviour of Automotive Sheet Steel Materials" [ASTM E-415-2014(SPECTRO)] [15]. Light wiping of all steel surfaces was conducted prior to welding to remove loose dirt and evenly distribute any machine oil. All of the steel sheets were of the same batch for their respective thickness. Details of the coupon dimensions for peel testing and life testing are shown in Figure 1.

Table 2. Steel Sheet Specification

Steel Type	HSLA
Coating Type and Thickness	Hot Dip - 60 G
Sheet Thickness	0.7mm/0.8mm
Tensile Strength	520-670 MPa

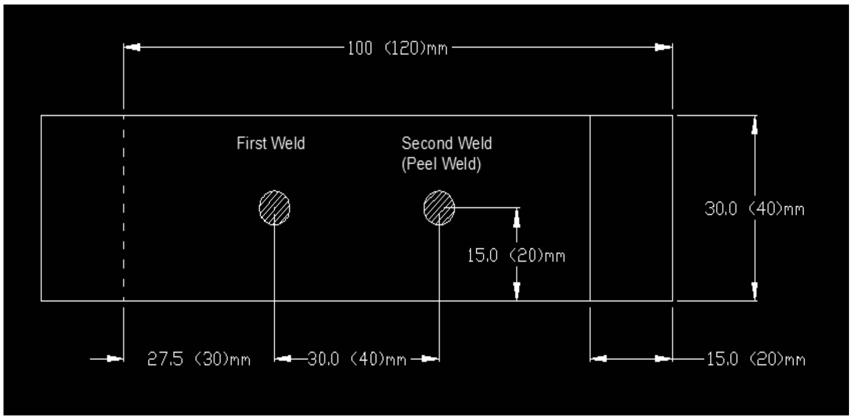

Figure 1. Dimensions for 0.8mm thick steel sheets

Table 3. Chemical Composition of Steel Sheet Material S460MC

Elements	Wt%
Carbon	0.044
Silicon	0.017
Sulphur	0.007
Phosphorus	0.015
Manganese	0.150
Nickel	0.015
Chromium	0.012
Moly	0.002
Vanadium	NIL
Copper	0.002
Aluminium	0.037

Table 4. Physical & Thermal Properties of S460MC

Property	Values
Density	7700 Kg/m3
Melting Point	1450°C
Thermal Conductivity	25 W/m-K
Specific Heat Capacity	460 J/Kg-K
Ultimate Tensile Strength	650 MPa

Tensile Yield Strength	350 MPa
Elongation	15 %
Modulus of Elasticity	200000 MPa
Poisson's Ratio	0.33
Fatigue Strength	275 MPa
Resistivity	0.55 Ohm.mm2/m

III. EXPERIMENT WORK AND RESULTS

Welding trials were conducted on hot-dip coated steels using uncoated electrodes. Weldability testing was carried out to investigate the ability of the coated electrode to make acceptable welds. Electrode life tests were conducted to study electrode degradation.

3.1. Base Metal Specification

Sheet was used for experimentation with 0.8 mm thick sheet was used for Weldability testing, while 0.8mm thick and 385mm x 60mm galvanized coated steel sheet was used for electrode life testing.

3.2. Welding Behaviour Study

Uncoated electrodes was tested to observe the difference in Weldability and tip life behaviour. Results are divided in two sections, the first dealing with the formation of the weld nugget, and the second dealing with the electrode life. Welding parameters and data collection procedures were used to characterize the electrodes.

3.3. Optimization of process parameters

In present study general full factorial method was adopted for the design of experiments to identify important factors affecting the response and to optimize the response using MINITAB 18 software. Three factors i.e Weld Current (kA), Weld Time (cycle) and Hold Time (cycle) are selected as variables and tip diameter are selected as response parameter.

3.3.1. Analysis of Tip Diameter after conducting experiment

Factor and Levels Information

Table 5. Factors and Levels values

Sr. No.	Factors	Low	High
1	Weld Current(kA)	10.8	11.0
2	Weld Time(cycle)	20	35
3	Hold Time(cycle)	45	50

3.3.2.Taguchi Analysis: Tip Diameter (mm) versus WC, WT HT

In order to correlate the process parameters and TD of welded joints, a taguchi model was developed to predict TD of RSW S460MC steel based on experimentally measured TD. Predicted values were calculated using statistical software, MINITAB 18. After determining significant values (at 95% confidence level), final model was developed using only these values to estimate TD.

Table 6. Response Table for Signal to Noise Ratios

Level	WC	WT	HT
1	30.55	30.92	30.80
2	32.18	31.81	31.93
Delta	1.63	0.88	1.13
Rank	1	3	2

Table 7. Response Table for Means

Level	WC	WT	HT
1	3.888	4.844	4.631
2	5.875	4.919	5.131
Delta	1.987	0.075	0.500
Rank	1	3	2

Table 8. Response Table for Standard Deviations

Level	WC	WT	HT
1	0.1246	0.1496	0.1358
2	0.1526	0.1277	0.1414
Delta	0.0280	0.0220	0.0056
Rank	1	2	3

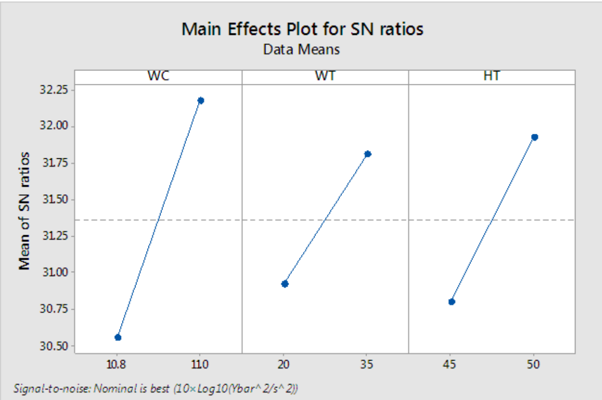

Fig. 2Main effects plot for tip diameter

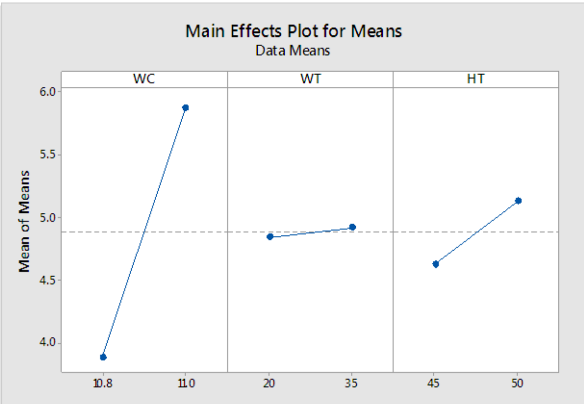

Fig. 3Main effects plot for tip diameter

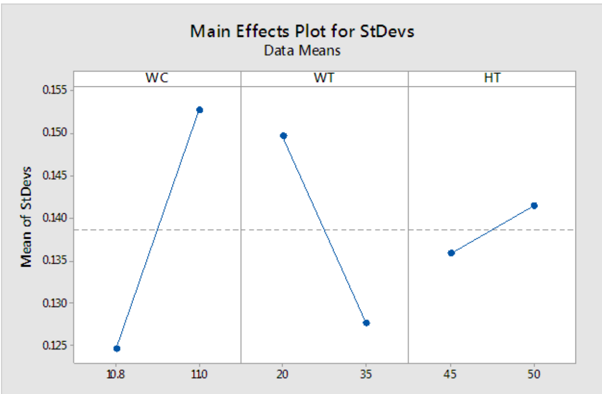

Fig. 4Main effects plot for tip diameter

Table 9. Table for Predicted Values for Prediction

S/N Ratio	Mean	StDev	Ln(StDev)
11.2229	3.6	0.132800	-2.10750

Table 18. Table for Predicted Values for settings

WC	WT	HT
10.8	20	45

IV. CONCLUSION

The level of importance of the welding parameters on tip diameter is determined by Taguchi Analysis (main effect plots). Based on Taguchi Analysis method, the highly effective parameters on tip diameter are found as weld current, interaction between weld current & weld time cycle and interaction between weld current, weld time cycle. The experimental results confirmed the validity of Taguchi method for optimizing the process parameter in resistance spot welding. By using optimized process parameters(Taguchi analysis), Electrode were shown to improve the robustness of the RSW system as well as improve electrode tip life.

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