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Optimization of small-scale projection lap-joint welding of Nickel and Nickel plated Mild Steel using Taguchi Method

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ABSTRACT: *The present work was carried out to study the feasibility of incorporating projection on the Nickel tab and optimization of welding parameters for the projection welding of Nickel tab to the Mild steel coated with Nickel (18650 Li- ion cell case material) using Taguchi method. Resistance welding is a group of joining processes in which coalescence is produced by the heat obtained from resistance of work pieces to current in a circuit of which the work piece is a part and by the application of pressure. Resistance welding is extensively used in the manufacturing industries for joining metal sheets. Resistance welding methods include spot welding; seam welding, projection welding, flash welding, upset welding, percussion welding, and high-frequency resistance welding. Projection welding is primarily used to join a stamped or machined part to another part. The purpose of projection is to localize the heat and pressure at a specific location on the work piece to be welded. Projection must be designed to support the electrode force to obtain a high contact resistance at the faying surface. Current flow through the faying surface between the two work pieces creates a rapid temperature increase. Electrode force then causes the collapse of the heated projections, and the work pieces can be fastened together.*

Keywords: *Nickel tab,Optimization,Projection, Resistance welding,Taguchi method.*

I. INTRODUCTION

In recent years, small-scale resistance welding has been widely used in the fabrication and assembly of electronic and medical components. Note that the difference between 'small-scale' and 'large-scale' resistance welding depends not only on the workpiece scale, but also on the weld current and electrode force used. Small scale resistance welding is associated with thin metal sheets (about 0.1–0.5 mm), generates a relatively smaller nugget size, and thus requires a lower weld current and electrode force. Previous studies have investigated both small-scale spot and large-scale projection welding. However, there remains a lack of understanding of small-scale projection welding (SSPW) despite the increasing demand. Detailed experiments for this study were to optimize and study the effects of the welding parameters like electrode force, weld current, weld time and upslope & downslope time for a constant projection height and diameter. The application of the SSPW is in the fabrication of small capacities batteries where battery tab attachment to batteries is carried out using a parallel gap welding technique in which the weld area is accessed from the same direction with both electrodes.

II. SAMPLE PREPARATION FOR PROJECTION WELDING

a. MildSteel (MS):

- Before preparing the samples , chemical composition of positive and negative tab materials were analysed using portable optical microscope @ CMTI. The tab material found to be Mild Steel(MS) coated with Nickel.
- To simulate the tab material with Li-ion cell case, Mild Steel (MS) was procured and chemical composition was carried out @ CMTI forconfirmation and then it was subjected to Nickel coating @LPSC.

TABLE 1: Chemical Composition Result

Sample ID	C	Mn	Si	P	S	Cr	Ni	Mo	Al
-Ve tab material	0.12	0.31	<0.006	0.020	0.028	0.020	<0.008	<0.003	0.022
+V tab material	0.09	0.096	<0.006	0.017	0.022	<0.008	<0.008	<0.003	0.057
Weld Sample material	0.10	0.18	<0.006	0.019	0.025	0.055	<0.008	<0.003	0.047

Weld sample chemical composition matches with the cell terminal material and the above values conforms to the specification of Cold Rolled Low Carbon Steel sheets and strips- IS 513: 1994

b. Nickel 200/201:

- A central slit as per the design was cut on the nickel strips.
- A Projection as per design was incorporated on the nickel strips at 4 locations using punch and die

PUNCH

DIE

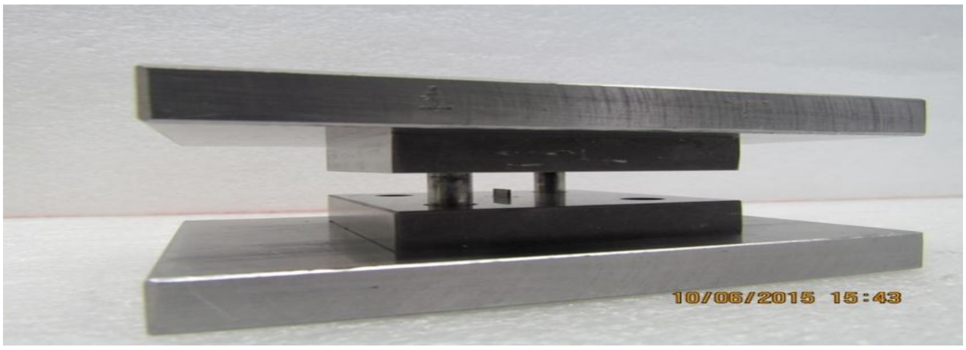

Fig1: FIXTURES FOR INCORPORATING PROJECTIONS ON NICKEL TAB

c. Dimensions of Weld Samples:

TABLE 2: Weld Attributes Dimensions

Attributes	MS coated with Nickel	Nickel 200/201
Thickness	0.24	0.12
Width	10	7.2
Length	50	50
Electrode material	Glidcop	
Electrode Diameter	1.5	

Note: All the dimensions are in mm

Based on AWS standards, interaction with experience persons, electrode geometry and keeping the projection rules in mind, a projection with 0.8 mm diameter and 0.12 mm height was proposed.

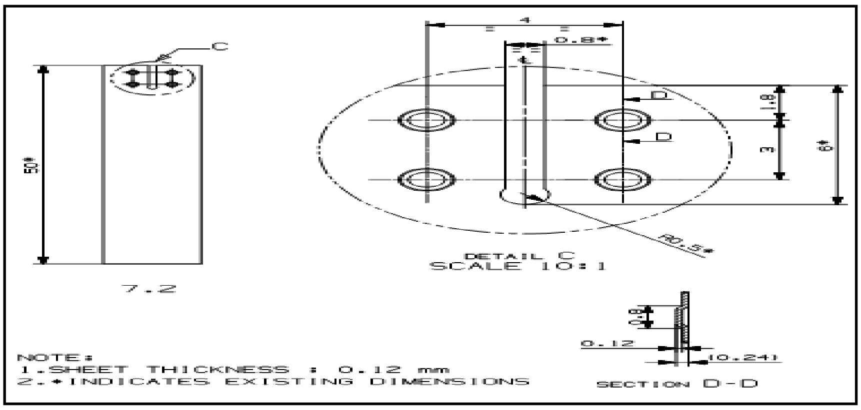

Fig 2: Dimensions of Nickel Tab with Projection

III. EXPERIMENTAL STUDY PLAN

The welding parameters and their levels planned to study is tabulated below:

TABLE 3: Welding Parameters & their levels

PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3
A) Welding Current (Amps)	900	800	1000
B) Weld force (N)	12	13	14
C) Weld time (msec)	16	17	15
D) Up slope& down slope time (msec)	5	7	6

IV. EXPERIMENTATION AND S/N RATIO

- Under Taguchi, system having four parameters with three levels can be performed with 18 experiments. Therefore L18 orthogonal array was selected.
- Parameters (welding current (A), weld force (B), weld time (C) and Up slope & Down slope) were varied as per the values for each level. Three responses were taken for each setting.
- Mean value of tensile strength and S/N ratio were found out.
- As strength should have larger value for better performance, S/N ratio was calculated as

$$SN_i = -10\log\left[\frac{1}{N_i}\sum_{u=1}^{N_i}\frac{1}{y_u^2}\right]$$

TABLE 4: EXPERIMENTAL PLAN USING AN L18 ORTHOGONAL ARRAY

Expt No	Column No. and Factor Assigned			
	1	2	3	4
	Current(Amps)	Weld Force(N)	Weld Time(Sec)	Up/ down slope Time(Sec)
	(A)	(B)	(C)	(D)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	1	2
5	2	2	2	3

6	2	3	3	1
7	3	1	2	1
8	3	2	3	2
9	3	3	1	3
10	1	1	3	3
11	1	2	1	1
12	1	3	2	2
13	2	1	2	3
14	2	2	3	1
15	2	3	1	2
16	3	1	3	2
17	3	2	1	3
18	3	3	2	1

TABLE 5: EXPERIMENTAL RESULT FOR TENSILE SHEAR (TS) STRENGTH AND S/N RATIO

	Tensile shear strength			**Mean Tensile shear Strength (Spec: >200 N)**	**S/N ratio**
	Trial 1	**Trial 2**	**Trial 3**		
1	369	356	360.5	361.83	51.17
2	374.5	373.5	370	372.67	51.43
3	368.5	363	371.5	367.67	51.31
4	351	368	370	363.00	51.19
5	362	371	362	365.00	51.24
6	368	360	360	362.67	51.19
7	363	366.5	324	351.17	50.87
8	368.5	369	367.5	368.33	51.32
9	366	358	368	364.00	51.22
10	361	370.5	365	365.50	51.26
11	372.5	369	371.5	371.00	51.39
12	368	361	363	364.00	51.22
13	354	361	359	358.00	51.08
14	366	371	367	368.00	51.32
15	358	366	363	362.33	51.18
16	362.5	358	361	360.50	51.14
17	363	367	365	365.00	51.25
18	356.5	368	363	362.50	51.18
				Mean	**51.22**

TABLE 6: THE S/N RESPONSE TABLE FOR TENSILE SHEAR (TS) STRENGTH

Factor	Level			Difference	Rank
	1	2	3		
Current	51.30	51.20	51.16	0.13	2
Weld Force	51.12	51.33	51.22	0.21	1
Weld Time	51.23	51.17	51.26	0.09	3
Up/ Down slope Time	51.19	51.25	51.23	0.02	4

a. PLOTS DUE TO MAIN EFFECTS:

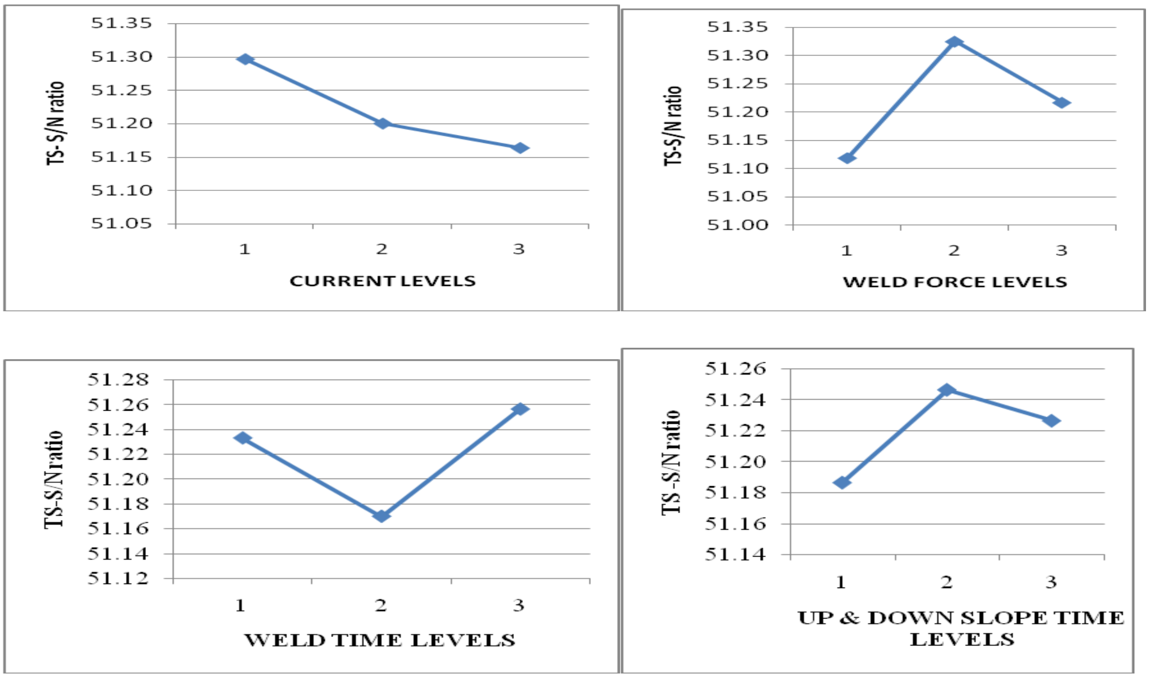

FIGURE 3. GRAPH SHOWING THE EFFECTS OF WELDING PARAMETERS ON TENSILE SHEAR (TS) STRENGTH BASED ON S/N RATIO

TABLE 7: ANOVA RESULT

Factors	Degree of freedom	Sum of Squares	Mean Sum of Squares	F	P	% contribu tion
Welding Current (Amps)	2	0.075144	0.03757222	2.718903	0.098271	26.61
Weld Force(N)	2	0.138678	0.06933889	7.235362	0.006313	49.10
Weld Time(Sec)	2	0.019811	0.00990556	0.56578	0.579578	7.01
Up/ Down slope Time(sec)	2	0.011411	0.00570556	0.315786	0.733947	4.04
Error	9	0.037383	-	-	-	13.24
Total	17	0.282428				100

b. METALLURGICAL EXAMINATION RESULT

Micro sectioning of the welded samples with optimized parameters was carried out to know the nugget diameter and fusion quality.

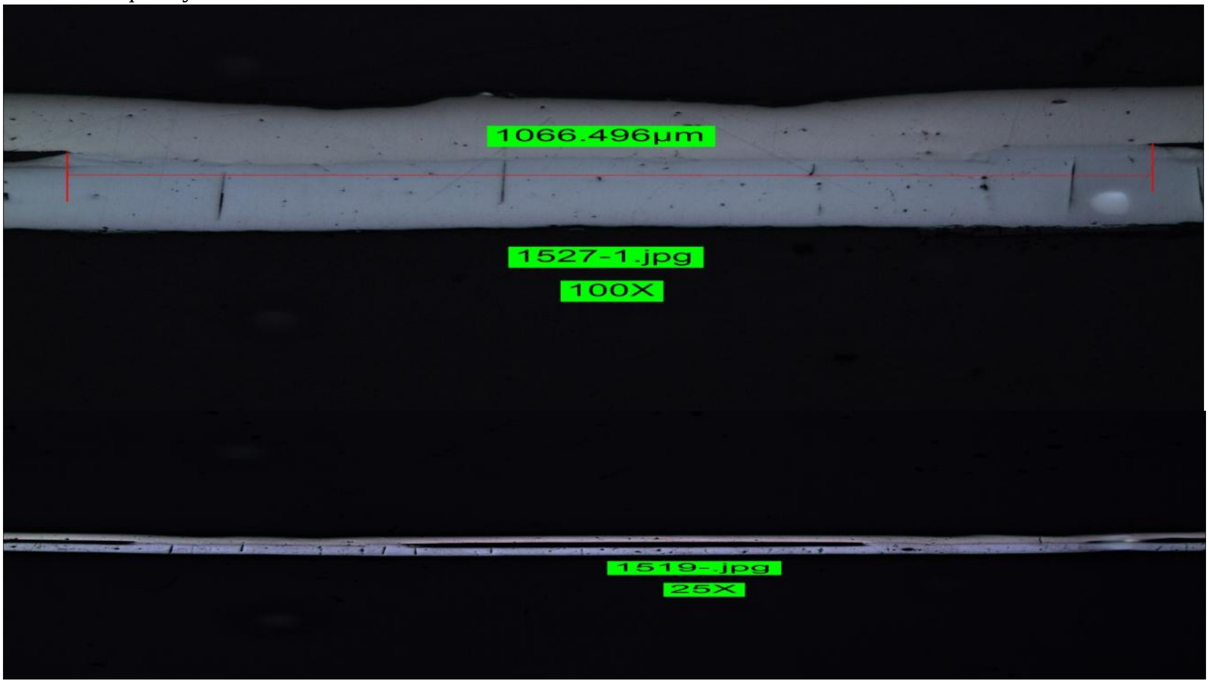

Fig 4: MICRO SECTIONING RESULT

V. RESULT AND DISCUSSIONS

- **S/N ratio analysis**

In order to quantify influence of each level of parameters, mean of S/N ratio for experiments were calculated.Our goal in this study is to maximize the weld strength i.e. to get maximum value for tensile shear strength. The optimum level for a factor is the level that gives the highest value of S/N ratio in the experimental region. From *Table 6*, it is observed that the optimum settings of current, weld force, weld time and up & down slope time are A1, B2, C3 and D2. Hence we can conclude that the settings A1B2C3D2 can give the highest tensile shear strength.

- **Analysis of Variance (ANOVA)**

A better understanding for the relative effect of the different welding parameters on the tensile shear strength (TS) was obtained by decomposition of variance, which is called analysis of variance (ANOVA). The relative importance of the welding parameters with respect to the TS was investigated to determine more accurately the optimum combinations of the welding parameters by using ANOVA.

The results of ANOVA for the welding outputs are presented in Table 7. Statistically, *F*-test provides a decision at some confidence level as to whether these estimates are significantly different. Larger *F*-value indicates that the variation of the process parameter makes a big change on the performance.

According to this analysis, the most effective parameters with respect to tensile shear strength is weld force, welding current, welding time and up& down slope time. P value (0.006313) of parameter indicates that weld force is significantly contributing towards Tensile Shear strength of the weld.

VI. CONCLUSIONS

- The percentage contribution of weld force(49.10 %) and weld current (26.61 %) were significant as compared to weld time and up & down slope time. Less percentage of error indicated that other factors did not have much effect on tensile strength.

- The optimized weld parameters can be successfully used for welding of small cell batteries.(Series and Parallel configuration)

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