Effect of Adhesive on Tensile Strength in Weld-Bonding of Mild Steel

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Abstract
Spot welding is the basic and weld bonding is the improvised manufacturing process for making components or assemblies in automobile, refrigeration industries, etc. due to high speed of process, ease of the operation and its adaptability for automation. Weld-bonding technology has widely been used in vehicle manufacturing to improve structural crashworthiness, fatigue performance, and corrosion resistance. In the present study efforts were made to improve the weld quality in weld-bonded mild steel sheets of 16 SWG (0.8-mm-thick) by using TEROKAL 5089 adhesive placements. To investigate the effect of the adhesive placement on the weld-bonding process, the results were compared with the simple spot welding process. In the present work, the effect of spot welding parameters (welding current, weld time, electrode force, thickness of the job) were analyzed on the failure load of sheets (0.8 mm) of mild steel. Results showed that the tensile strength between the steel sheets increased significantly by 75% due to the presence of the adhesive. Weld qualities of weld-bonded joints with adhesive layer at both faying interfaces between sheets produced better welds than without adhesive. This study provides the guidelines regarding the application of adhesive in weld-bonding of sheets for vehicle manufacturing.

Keywords: - spot welding, weld bonding, tensile strength, mild steel, adhesive placement

Introduction

The spot welding (RSW) process uses copper alloy electrodes to concentrate welding current into a small "spot" while simultaneously clamping the sheets together under pressure. Forcing a large current, for a very short time (approximately ten milliseconds) through the spot, will melt the metal and form the weld without excessive heating of the remainder sheet. This results in the formation of a nugget (fusion weld) surrounded by a forge weld between the sheets at the perimeter of the nugget. Weld-bonding technology wherein adhesive material layer is placed between metal sheets, has been widely used in vehicle manufacturing to improve structural fatigue performance, crashworthiness, and corrosion resistance. In weld-bonded lap joints, both the spot weld and the adhesive layer contribute to the joint strength. In the present study, the effects of bonding material on tensile strength of the joint in single layered sheet stocks was studied. An adhesive layer of appropriate thickness and elastic modulus is necessary to obtain reasonable distribution of stresses in the whole lap region of a weld-bonded joint. A thin adhesive layer of high elastic modulus is favorable to the fatigue properties of weld-bonded joints, and it is recommended on certain conditions.

2. Plan of investigation

The research work was carried out in the following steps:

- Identifying the important process control variables.
- Finding the upper and lower limits of the control variables.
- Conducting the experiments
- Recording the responses.
- Presenting the direct effects of different process parameters on tensile strength graphically.
- Analyzing the results.

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3. Identifying the important process control variables:

In spot welding

$$H = I^2Rt$$

Where H= heat generated, I= Current, R=resistance, t=time
Apart from this electrode pressure is also one of the most important factor which influence the spot welding.
In this study Cycle time, Current and the electrode pressure were considered as the parameters to study their effect on the tensile strength.
Upper and lower limits of these control variables have been fixed as under:
Cycle time- 10 to 14 ms
Current- 12 to 14 kA
Pressure- 35 to 75 psi

4. Experimental Procedure

0.8-mm-thick mild steel sheets were used in this study. The chemical composition of these steels was analyzed as listed in Table 1.

Table no.1 Chemical composition of mild steel

C	Si	Mn	P	Pb	S	Fe
0.14	0.05	1.01	0.09	0.25	0.25	98.21

Table 2. Properties of Terokal 5089

Property	Typical Results
Color	Purple
Odor	None
Consistency	Paste
Solids	> 98.5%
Specific Gravity	1.05 – 1.20
Tensile Strength	>30 MPa
Elongation at break	>10%
Young's Modulus	>1400 MPa
Curing Mechanism	Heat Cure
Viscosity (40 mm parallel plate, 50°C, shear rate 30 1/s)	30-50 Pa.s
Impact Peel Resistance ISO 11343 (2m/s), 0.8mm CRS	
Bake 20 minutes at 177°C	> 25 N/mm
Shear Strength at 23°C on CRS (0.8 mm)	
Bake 20 minutes at 177°C	> 20 MPa
Peel Resistance at 23°C on EG (0.8 mm)	
Bake 10 minutes at 155°C	> 100 N/ 25mm
Bake 20 minutes at 177°C	> 125 N/ 25mm
Bake 60 minutes at 190°C	> 100 N/ 25mm
Application Temperature	20° - 50°C

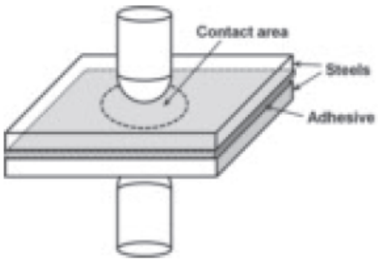


Fig. 1-Experimental Setup

An epoxy resin-based adhesive (Terokal 5089) manufactured by Henkel was used in this study. It is a one-component, hot-cured adhesive with low viscosity before curing and high performance after curing. The material properties of Terokal 5089, from the Henkel data sheet, are listed in Table 2.

A typical weld-bonding process contains the following three stages: squeeze cycle, weld cycle, and hold cycle. During the squeeze cycle, an electrode force is applied to squeeze out the excessive adhesive between the steel sheets. During weld cycle, weld current is passed through the steel sheets to form a weld nugget. A weld-bonding joint is finally completed after cooling of the nugget in the hold cycle. In this study, two sheets of 0.8 mm thick were used to spot weld with each other using adhesive material — Fig. 1. The adhesive layer of Terokal 5089 first was laid on the mild steel sheets, and then the joint was heat cured at 200 degree centigrade for 20 to 30 minutes. Thereafter, prescribed welding current was applied through the adhesive and mild steel to get a weld-bonding joint. The adhesive layer of Terokal 5089 first was laid on the mild steel sheets, and then the welding current was applied through the adhesive and mild steel sheets to get a weld-bonding joint. Copper alloy electrodes and the welding parameters according to the taguchi L9 method as listed in Table 3 were used in the experiment. In the whole experiment squeeze time and hold time were kept constant 90 and 20 ms respectively.

Table 3. Welding parameters according to taguchi L9

Sr. No.	Welding time (ms)	Current (kA)	Pressure (psi)
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

5. Recording the responses

Specimen pieces of 125 X 25mm were cut from a complete Mild Steel sheet of 0.8 mm thickness. Then the pieces were joined by spot welding in two groups; one without adhesive and another with adhesive coating, under pre-decided the range of parameter.

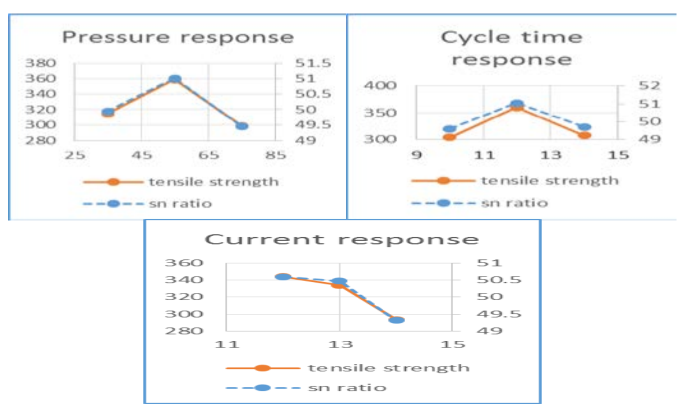
Table no. 4- Anova table without adhesive

Exp no.	Repetition 1	2	3	Mean	SN Ratio larger-the-Better)
1	313.33	311.64	310.82	311.93	49.881
2	340.233	341.6	342.42	341.42	50.666
3	259.236	257.886	259.33	258.82	48.260
4	424.55	426.47	423.5	424.84	52.565
5	342.1	343.1	341.8	342.33	50.689
6	311.55	312.43	313.73	312.57	49.899
7	294.544	295.478	296.34	295.45	49.410
8	318.25	319.66	317.44	318.45	50.061
9	310.23	309.34	308.75	309.44	49.812
SUM	2914.02	2917.60	2914.13		451.24
TOTAL SUM (T)			8745.76		
AVERAGE		323.92			

ANOVA S/N							
SOURCE	SS	DOF	V	P	F-Ratio	F-Ratio Table	% Contribution
Cycle time	3.79	2	1.89	35.19	27.30	19	35.65
Current	3.02	2	1.51	28.03	21.75	19	28.40
Pressure	3.82	2	1.91	35.48	27.53	19	35.94
ERROR	0.14	2	0.07	1.29			
T	10.76	8		100			

The calculated value of F shows that the parameter effect on tensile strength is significant as the calculated value of F is greater than F0.05 (2, 8)

Fig.2- Various responses of factors without using adhesive material



From the Anova table no 4 it was found that the percentage contribution of various variables influencing the tensile strength of the weld, when adhesive was not used, are as follows: cycle time 35.65%, current 28.40%, Pressure 35.94%.

The graphs at Fig. 2 show the effect of these variables on the variation of tensile strength and the maximum tensile strength is achieved at: cycle time- 12 ms, Current- 12 and pressure- 55 psi and maximum tensile strength achieved is 424.84 N/mm²

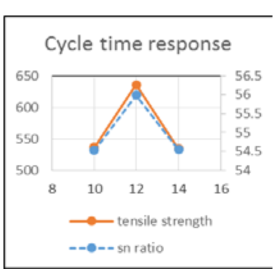
Table no. 5- Anova table with adhesive

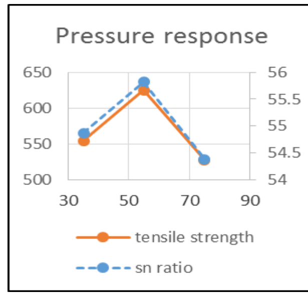
Expt. No.	Repetition 1	2	3	Mean	SN Ratio larger-the-Better)
1	550.42	551.23	553.22	551.62	54.83
2	600.21	601.42	603.20	601.61	55.59
3	455.69	455.71	455.63	455.68	53.17
4	750.43	751.56	752.22	751.40	57.52
5	604.32	603.65	605.33	604.43	55.63
6	550.76	551.20	553.20	551.72	54.83
7	520.76	521.77	522.43	521.65	54.35
8	558.74	558.71	558.76	558.74	54.94
9	520.54	521.44	523.22	521.73	54.35
SUM	5111.87	5116.69	5127.21		495.21
TOTAL SUM (T)			15355.77		
AVERAGE		568.73			

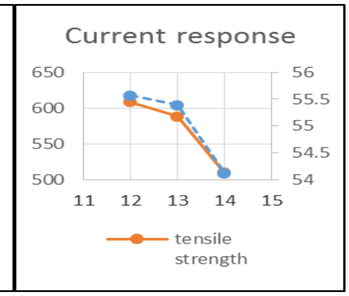
ANOVA S/N							
SOURCE	SS	DOF	V	P	F-Ratio	F-Ratio Table	% Contribution
Cycle time	4.229	2	2.1145	37.37	26.5320	19	37.9
current	3.732	2	1.8660	32.98	23.4132	19	33.4
Pressure	3.194	2	1.5971	28.23	20.0398	19	28.6
ERROR	0.159	2	0.0796	1.40			
T	11.314	8		100			

The calculated value of F shows that the parameter effect on tensile strength is significant as the calculated value of F is greater than F0.05 (2,8)

Fig 3 - Various responses of factors when using adhesive material







From the Anova table no. 5 it was found that the percentage contribution of various variables influencing the tensile strength of the weld, when adhesive was used, are as follows: cycle time 37.91%, current 33.45%, Pressure 28.63%

The graphs at Fig. 5 show the effect of these variables on the variation of tensile strength the maximum tensile strength is achieved at the cycle time- 12 ms, Current- 12 and pressure- 55 psi and the maximum tensile strength achieved is 751.40 N/mm²

There is a clear improvement in the tensile strength of the weld bonded joint over a simple spot weld joint. However the current, pressure and time also influence the weld strength apart from the application of bonding material.

6. **Conclusions**

Mild Steel is an extremely important commercial material due to its easy availability. The following conclusions are drawn from the present work:-

1. When adhesive was not used, the maximum tensile strength was obtained at Cycle 12, current 12 kA and pressure 55 psi.
2. When adhesive was used, the maximum tensile strength is obtained at Cycle 12, current 12 kA and pressure is 55 psi.
3. The best tensile strength obtained without using adhesive was 424.84 N/mm² but after using the adhesive the tensile strength is increased to 751.40 N/mm².
4. There was significant increase of 75% in the tensile strength of the weld joint when adhesive was used.
5. When adhesive was used the % contribution of Cycle time and current has increased where as it decreased in case of pressure.

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