

Investigating the Dissimilar Weld Joints of AISI 302 Austenitic Stainless Steel and Low Carbon Steel

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Abstract- A good weld from spot welding mechanism is what most of the manufacturers preferred and desired for mechanical assemblies in their systems. The robustness is mainly relies on the joining mechanism of mechanical parts; especially when combining two different materials and therefore this paper analyzes the spot weld growth on 302 austenitic stainless steel and low carbon steel of 1mm of thickness. In this experiment we have welded sixty three (63) samples; especially for tensile strength test (45); for hardness test (9) and the rest for metallurgical studies. The basic controlling parameters that varied throughout the experiments were welding current and the welding time while electrode force and tips were kept unchanged. The weldment was developed from lower range of controlling parameters to higher range. However this experiment was limited to the basic parametric variation to find optimum parametric set up for 1mm base metals. The test result shows close relationship in the parametric changes with respect to its strength as how other researchers found in mixed steel spot welds.

Index Terms- Dissimilar weld joints, low carbon and stainless steel welds, mixed weld.

I. INTRODUCTION

A statistical report shows that one mechanical assembly out of five is, to date, welded using resistance spot welding technology in manufacturing industry; especially the automotive industry that mainly anticipating this technology for its body assemblies. This experiment was carried out to analyze the dissimilar joints as the current advanced systems of mechanical assemblies uses mixed materials' parts in manufacturing industry. Technically considered, the spot weld growths are mainly have to be happened due to its basic controlling parameters such as current, welding time, electrode force and electrode tips[1]. However the force and tip increment cause drop in strength because of the drop of heat ($Q=I^2Rt$) that melts the concerned areas. So we have only increased the current and weld time in this experiment to determine the weld growth using 302 austenitic stainless steel and low carbon steel.

II. EXPERIMENTAL

The rectangular specimens are equally prepared with a size of 200mm (length) x 25mm (width) x 1mm (thickness) as shown in the figure 1. It was welded as lap joint and the weld nugget was

developed in the middle of overlap which was centered at 30mm from one edge of the sample. Low carbon steel and stainless steel are the two common materials that found in many industries. In these experiments low carbon steels (0.20%) and 302 austenitic stainless steels were used to complete the welding process. Table 1 shows the material properties of both types of steels.

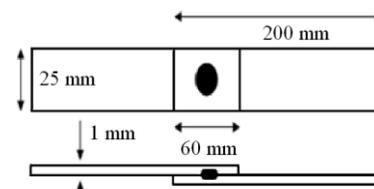


Figure 1. Test sample

Table 1. Chemical properties

304 (2B)Austenitic stainless steel	
Element	Weight %
C	0.15
Cr	18.14
Ni	8.13
Mn	2.000
Si	0.75
S	0.030
N	0.051
P	0.045
Low carbon steel	
C	0.15
Mn	0.30
Si	0.006
S	0.050
P	0.040

A pair of water cooled copper electrodes with tip diameters of 5 mm was used to join these base metals on a spot welder of 75kVA capacity. The welder was pneumatics driven force producer with sophisticated current controller which is up to 25kA. Initially the welded samples were placed on the top of down electrode tip as lap joint (30mm space from one edge). Once the sample is properly placed then the electrode was initiated with 40 squeeze cycles. During this squeezing time the electrode presses the base metals together firmly and reduces the contact resistance. Immediately the welding current was released

according to parametric set up at the current controller and therefore weldment takes place. Thereafter there will be a small amount of time is given for solidification. Eventually the upper electrode moves back to homing position of the machine resulting weldment happened. The tensile-shear test was carried out using 100kN (max capacity) tensile testing machine to determine the strength of spot welded specimens. The crosshead speed was maintained at 70 mm/min. The ultimate tensile strength (UTS) as shown in Figure 2 was taken as the maximum weld strength after which the weld will fracture. An average strength value of the 5 samples for each schedule was taken.

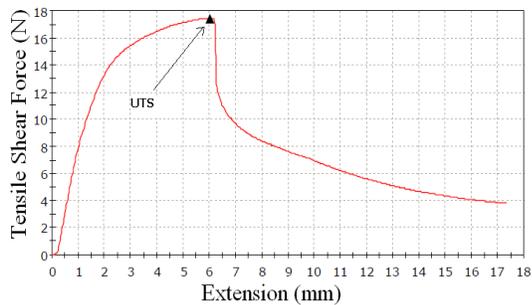


Figure 2. Tensile tests (Ultimate Tensile Strength)

The hardness test was conducted using Rockwell Hardness Tester using HRB scale. The hardness was measured from unwelded area through heat affected zone and ended with fusion zone for both, left and right sides. It was conducted for both side as one side occupied by low carbon steel and the other side by stainless steel. Metallographic samples were produced using standard metallographic procedures. Optical microscopy was used to examine the microstructures and to measure the weld diameters of both (low carbon steel [CS] and stainless steel [SS]) sides. A typical macrostructure for dissimilar joint shows three fundamental structural zones (figure 5). A fusion zone undergoes complete melting and solidification during welding process with a coarsened grain. The width of the zone is equivalent to the weld nugget diameter. The heat affected zone (HAZ) undergoes micro structural alteration due to heat existed at fusion zone but not complete melting. So the grains seemed to be finer compared to the FZ. The base metal is not affected and remained unchanged.

Table 2: The material properties of test samples

Weld Schedule	Sample No	Force (kN)	Current (kA)	Time (cycle)
1	1-5	3	6	10
2	6-10	3	7	10
3	11-15	3	8	10
4	16-20	3	6	15
5	21-25	3	7	15
6	26-30	3	8	15
7	31-35	3	6	20

8	36-40	3	7	20
9	41-45	3	8	20

A weld schedule was developed to weld 63 samples as 45 pairs of mixed steel. It was summarized in table 2 as shown below. The table shows three level of current increment (6,7,8 kA) and three level of time increment (10,15,20 Cycle) with constant force (3kN) and constant electrode tip (5mm). Total of nine weld level were listed and each weld level made of five samples pair. The average value of five samples for tensile and hardness were taken as final values for that particular weld schedule.

III. RESULTS AND DISCUSSION

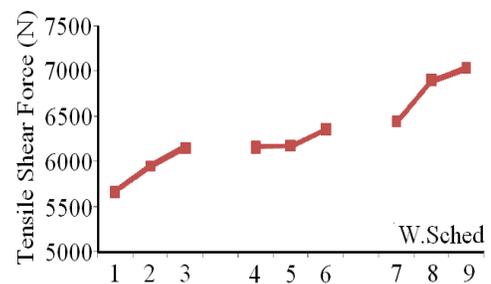


Figure 3. Tensile tests results

The tensile tests results have shown close relationship between parametric variations [2] and the strength. When the current and weld time were increased with constant force and constant electrode tips; the tensile strength increased and vice versa. As for an instance, from weld schedule 1 to 2 shows increment in strength due to current increment. Further increase from 2 to 3 also shows another increment as how other authors witnessed in their experiments [3]. This happened because of the current increment from 6 to 7 and 7 to 8 kA have caused the diameter of weld areas to be increased on both sides. Moreover the weld time increment also shows similar result as how current behaved. As for another instance, from weld schedule 1 to 4 and from 4 to 7 there were increases in tensile strength too. The first 3 weld schedules was done with 10 cycles of time and the followings 3 are with 15 and 20 cycles, respectively[4]. As such, by increasing weld cycles, sufficient time was given for the fusion to take place. However these experiments were not conducted for extreme (expulsion) case or beyond limits. The result was graphically shown in figure 3.

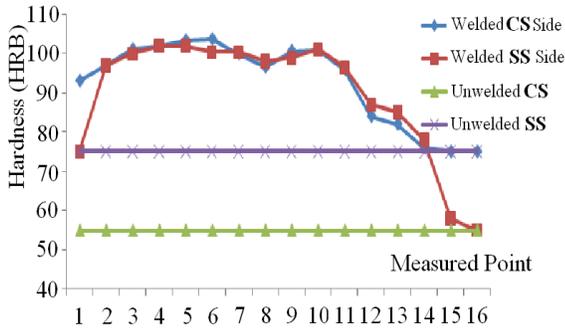


Figure 4. Hardness tests results

The hardness tests results (figure 4) have shown that the welded areas were increased in hardness due to the nature of the materials properties. The hardness of both sides was increased and the values were seemed very close to carbon steel values as the fusion process combines these materials. Besides, the hardness increments or decrements are never once being proportional in the distribution as it fluctuated up and down [5].

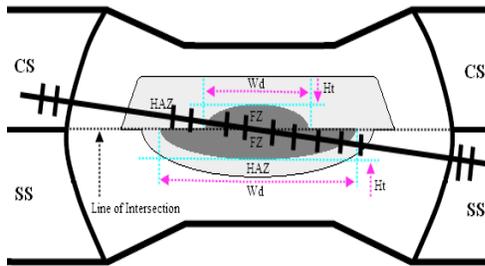


Figure 5. Structural zones

Having considered the macrograph of weld nugget (figure 5), three fundamental zones (Fusion zone [FZ]; Heat Affected Zone [HAZ]; and Base Metal [CS/SS]) were noticed in this experiment. The thermal conductivity coefficients are higher in carbon steels ($51.9 \text{ Wm}^{-1}\text{K}^{-1}$) as compared to stainless steels; therefore wider ranges of heat affected zones (HAZ) are noticed. But the thermal expansion coefficient ($11.9 \times 10^{-6} \text{ K}^{-1}$) rate is lower which alters the chemical properties during welding; so the width and height of fusion zone is shorter in carbon steel side [6]. On the other side, the stainless steel seemed to have higher thermal expansion coefficient ($17.2 \times 10^{-6} \text{ K}^{-1}$) but lower thermal conductivity ($16.2 \text{ Wm}^{-1}\text{K}^{-1}$). So the heat affected zones (HAZ) is smaller but the fusion zone is wider as compare to carbon steels. Technically this phenomenon is called as heat imbalance[7]. The heat imbalance happens mainly on both thermal coefficients and electrical resistivity of carbon and stainless steels. The electrical resistivity of carbon steel is $1.59 \times 10^{-7} \Omega\cdot\text{m}$ whereas the stainless steel value is $6.89 \times 10^{-7} \Omega\cdot\text{m}$. The resultant macrograph (Optical SEM) of current increment is shown in figure 6(a,b and c).

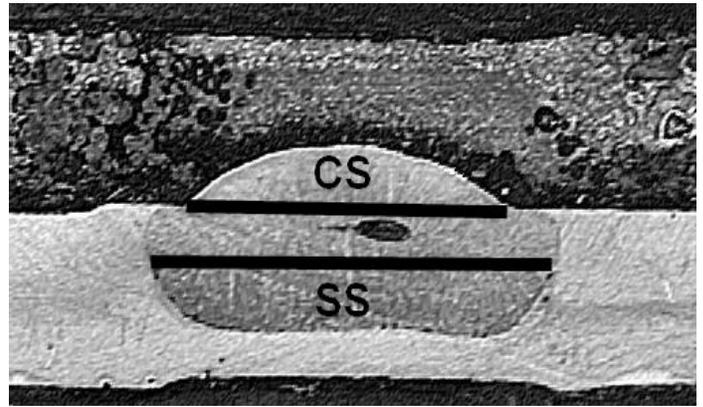


Fig. 6(a) Welded at 6 kA and 20 Cycle
 (SS-4.446 mm & CS -3.690 mm)

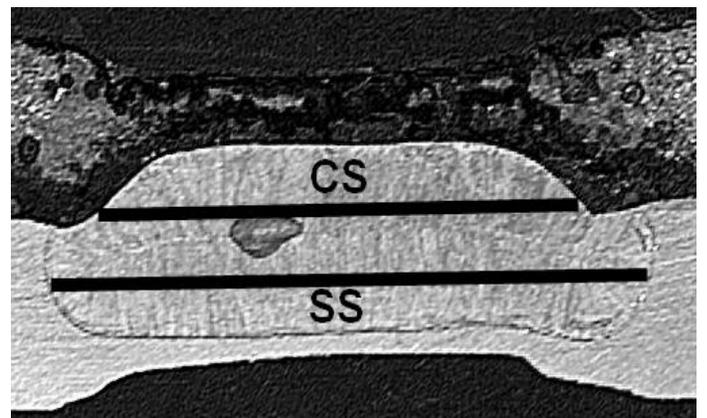


Fig. 6(b) Welded at 7 kA and 20 Cycle
 (SS-4.671 mm & CS -3.813 mm)

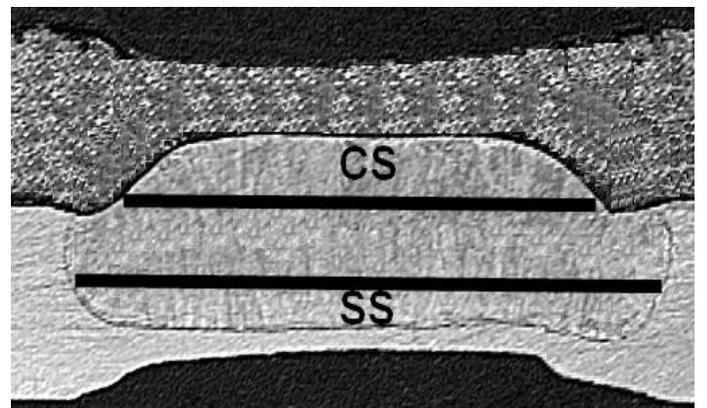


Fig. 6(c) Welded at 8 kA and 20 Cycle
 (SS- 5.023 mm & CS - 4.695 mm)

However the carbon steel alone or stainless steel alone; welded areas are shown in figure 7 (a and b) for comparison purpose. It shows the heat balance on both sides of the base metals whereas the figure 6 (a,b&c) show heat imbalances.

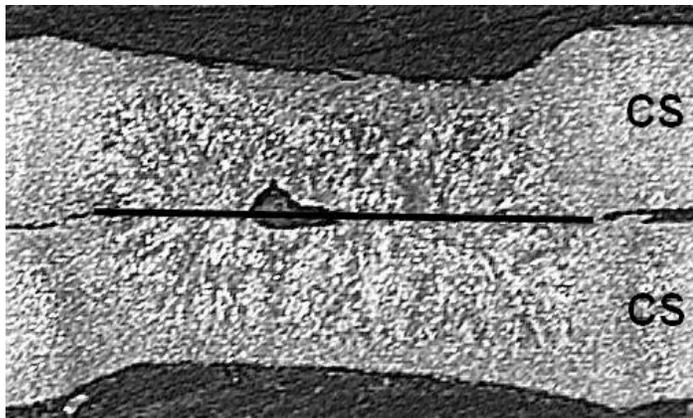


Fig. 7(a) Welded at 8 kA and 20 Cycle (CS ONLY)

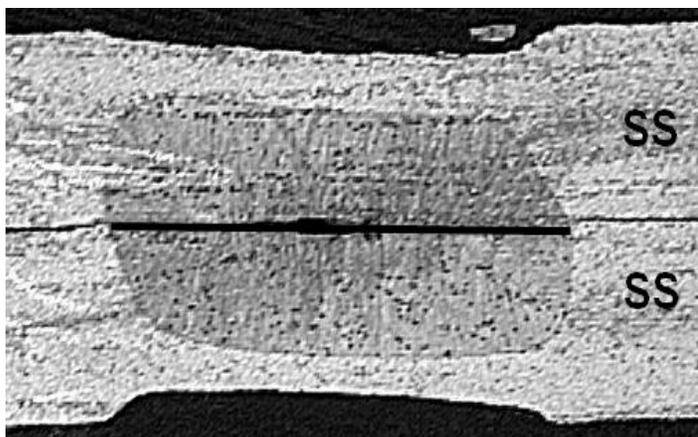


Fig. 7(b) Welded at 8 kA and 20 Cycle (SS ONLY)

The chemical properties of these zones are the root cause for the micro views [8]. It has been noticed from the energy disperse x-ray test (EDX detection) that the carbon content is significantly increased at the fusion zones although the carbon content at carbon steel (14.19%) and stainless steel (18.41) were lower. The heating process dissipates some of the chemical compositions during welding and therefore carbon content was increased in percentage [9]. Besides the chromium content from stainless steel side (15.12%) is also reduced to 6.97% and the nickel content is from 6.52% to 2.47%. However the primary content (Iron -Fe) occupies the zones with major percentage [10]. The results have been tabulated in table 3.

Table 3: Chemical distributive list of dissimilar welded joint

Carbon Steel (BM-CS)		
Element (K)	Weight%	Atomic%
C	14.19	38.43
O	8.00	16.26
Al		
Cr		
Fe	77.81	45.31
Ni		
Si		
Mn		
Totals	100.00	100.00
Fusion Zone (Weld Area)		
Element (K)	Weight%	Atomic%
C	28.48	64.58
O		
Al	0.66	0.67
Cr	6.97	3.65
Fe	61.42	29.95
Ni	2.47	1.15
Si		
Mn		
Totals	100.00	100.00
Stainless Steel (BM-SS)		
Element(K)	Weight%	Atomic%
C	18.41	50.79
O		
Al		
Cr	15.12	9.64
Fe	58.39	34.64
Ni	6.52	3.68
Si	0.54	0.64
Mn	1.02	0.61
Totals	100.00	100.00

IV. CONCLUSION

The analysis of dissimilar spot welded joints of low carbon and stainless steels of 1mm sheets conclude that:

1. The parametric changes (current and time) have resulted proportional changes in tensile strength regardless of base materials.
2. Both current and weld time have caused diameters increments which increases bonding strength of weld pairs.
3. The hardness of welded areas has been increased and

the distributions along the areas are fluctuating.

4. The fusion zones of carbon steel are shorter than the stainless steel but the heat affected zones are wider than the stainless steel.
5. Asymmetrical views of nugget growths were not observe due to the thermal imbalance. These happened because of the electrical and thermal coefficients.

ACKNOWLEDGMENT

We would like to thank Ministry of Science, Technology and Innovation, Malaysia (MOSTI) for their financial support during the experiment.

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