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Effect of Heat Treatments on 302 Austenitic Stainless Steel Spot Weld

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Abstract. The shear strength of 302 austenitic stainless steel spot welds has been studied. The welding current in resistance spot welding process (RSW) plays a significant role. However, this item's effect is well known and extensively studied in the previous literature. This work aims to show the heat treatment's effect on different joints that welded at various current. The experimental results show that the tensile shear strength is increased with increasing the current. Annealing treatment improves the tensile shear strength due to the reformation of the grain size and removes the residual stresses. Grain refinement is an effective technique for improving the strength. Therefore, the tensile shear strength is increased by annealing treatment temperature up to 750 °C. However, at 850°C, the tensile shear strength is dropped down.

Introduction

The heat generation in any welding process increases the amount of molten metal that connect the pieces. The current in RSW plays a significant role in this issue.

RSW process depends on the fusion between the sheets' metal using a combination of pressure and heat. The amount of heat is generated due to the electrical resistance to the flow of current at the interfaces of the workpieces. Hence, the nugget between the faying surfaces is produced [1,2]. The resistance of the circuit and the time of the current flow effect the heat generation, but in lower rate [2,3,4].

RSW is an effective way to join metal sheets in many manufacturing [1,5,6,7,8,9,10]. Typically, car body contains thousands of spot welds to join the sheets of various metals and thicknesses [11, 12]. Hence, the process is used extensively for joining low carbon steel, stainless steels, and galvanized steel components due to their wide applications [13,14,15].

Recently, aluminum alloys are also used in the automotive industry for bodies due to the suitable weight to strength ratio [8][16]. In addition, dissimilar materials are welded for the best combination of the properties.

The cracking, insufficient weld depths, lack of penetration LOP, and cavitations of the nugget are the most reason of the toughness reduction and failure, see Refs. [17]–[32]. The selection of suitable welding conditions plays a significant role for toughness determination [20]–[22], [25].

Stainless steel is used for medical devices. Since it has a desirable corrosion resistance, biocompatible, and fracture toughness [33]. To maintain the fracture toughness and other properties, post weld heat treatment is used.

This work investigates the effect of heat treatment on the joint toughness of 302 austenitic stainless steel. For comparison, the welding current was changed. Therefore, this work determines the reason of crack in the spot weld of stainless steel 302.

Experimental Work

Material

The AISI 302 austenitic stainless sheets of steel were used. It has a wide range of applications due to their resistance to corrosion, high ductility, and the good weldability [34]. The specimens have been prepared according to the American Welding Society Standard (ASTM) [20]–[22][25][35].

The plate thickness is 1 mm. The material properties and chemical composition are shown in Tables 1, and 2, respectively, see Ref. [36].

Table 1. Percentage Chemical composition of 302 S.S.

302 S.S.	C	Cr	Ni	Mn	Si	Cu	S	P
	0.0145	18.4	8.5	2.005	1	0.062	0.03	0.045

Table 2. Mechanical properties of S.S 302 [36,37]

302 S.S.	σ_y [MPa]	$\sigma_{Maximum}$ [MPa]	Elongation%	Brinell hardness
	275	620	55	147

Specimen Preparation

The specimen dimensions are shown in Fig. 1. The width, length, and overlap distance are 19, 76, and 19 mm, respectively. They are welded according to ANSI and AWS [38,39]. The specimens were cleaned before the welding to eliminate the contaminations, hence, reduce the resistance variation of the surfaces [41].

The lap shear specimens according to AWS/ANSI standards are widely used as systematic testing for weldment joint, welding defects and failure mode [11,41,42].

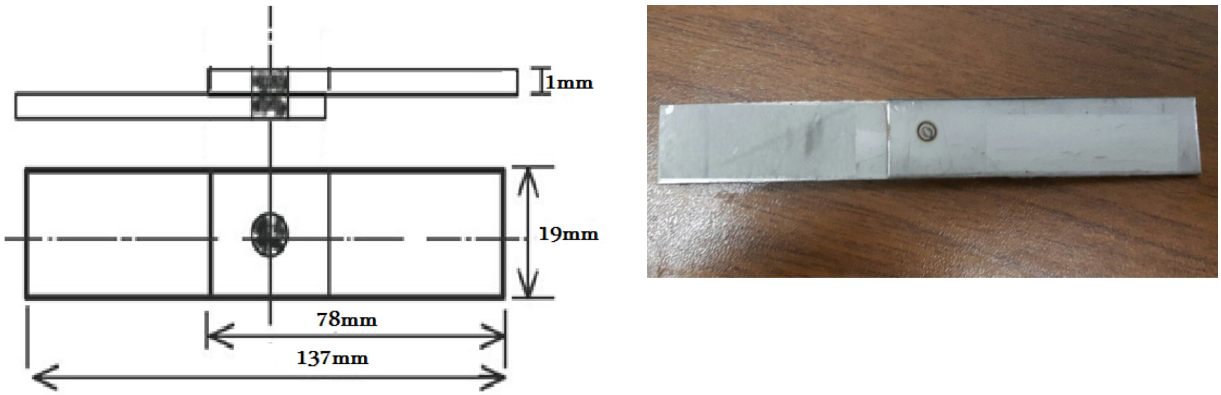

Figure 1. Welding specimen (mm) according to AWS, ANSI standards

Process and Machine

Welding process was performed using a pneumatically operated machine. The welding current is controlled directly. The electrodes used in this machine were 5 mm end diameter. The specimens were welded by fixing the welding time at 0.2 seconds, and 4 bar electrode pressure, and varying the current from 1 kA to 5 kA. For each value of current, five joints have been prepared. Four of them have been subjected to heat treatment at varying temperature, hence, to investigate the tensile shear strength, see Table 3.

Annealing Treatment

Heat treatment applied to austenitic stainless steels in order to dissolve precipitated chromium carbides. In this work annealing treatment has been applied at varying temperatures; 550 °C, 650 °C, 750 °C, and 850 °C. The specimens have been cooled slowly inside the furnace, see Fig. 2.

Figure 2. Annealing temperatures for weldments

Results and Discussion

Tensile-Shear Strength Test

The tensile strength was measured according to AWS standard practice using the conventional tensile shear lap specimens, see Fig. 1. The results are shown in Table 3.

Table 3. Effect of annealing on the tensile strength

Current [Amp.]	Annealing Temp. [°C]	Shear strength [MPa]
1000	Without annealing	137
	550	144
	650	149
	750	151
	850	130
2000	Without annealing	190
	550	205
	650	211
	750	215
	850	189
3000	Without annealing	202
	550	207
	650	214
	750	218
	850	200
4000	Without annealing	209
	550	211
	650	223
	750	225
	850	203
5000	Without annealing	223
	550	230
	650	233
	750	235
	850	218

Effect of Welding Current

The experimental work shown that the current has a huge effect on the tensile shear strength, see Refs. [20,22,25]. According to the Joule law; $Q = I^2Rt$; (where Q is the generated heat, I is the current, R is the electrical resistance, and t is time), the increasing of the welding current increases the melting zone, hence, increasing the weld area and strength. The results agree with different studies, see Refs. [3,43,44], see Fig. 3.

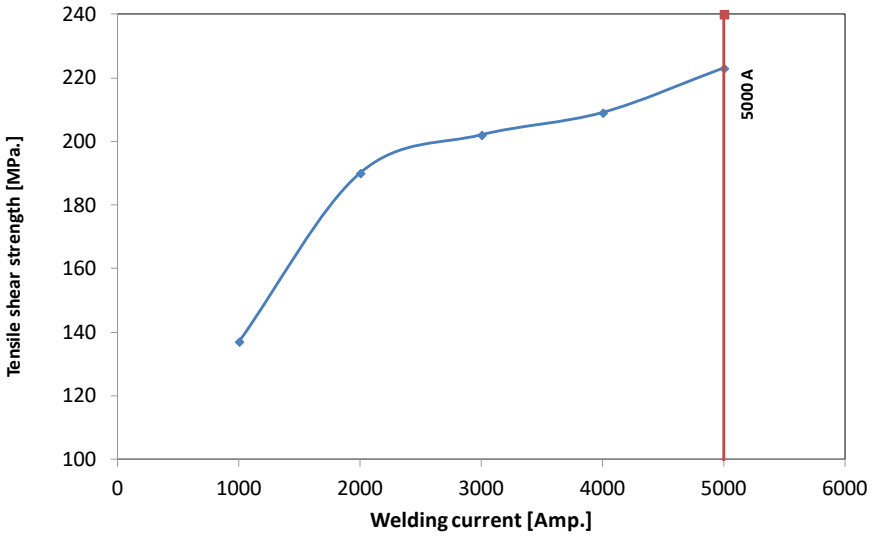

Figure 3. Effect of welding current on tensile shear strength

Effect of Annealing Treatment

The annealing improves the mechanical properties. Heating the specimen to a certain temperature and slow cooling in the furnace will be refining the grain size and removed the residual stresses, see Refs. [20,22,25,28,29]. Grain refinement is still an effective tool for improving the strength [46], see Fig. 4.

The shear strength increases with the increase of annealing temperature up to 750 °C. At 850°C, the tensile shear strength will drop down and it goes lower than those at 750 °C, however, the weld nugget at the ideal condition (i.e. at 5000 A), see Fig. 5. This phenomenon has been determined for the first time in spot weld nugget of austenitic stainless steel, see Refs. [21,30]. The cracks will be initiated at the temperature above than 750 °C. These cracks will affect the structural integrity of the joints and will propagate to failure, see Fig. 5.

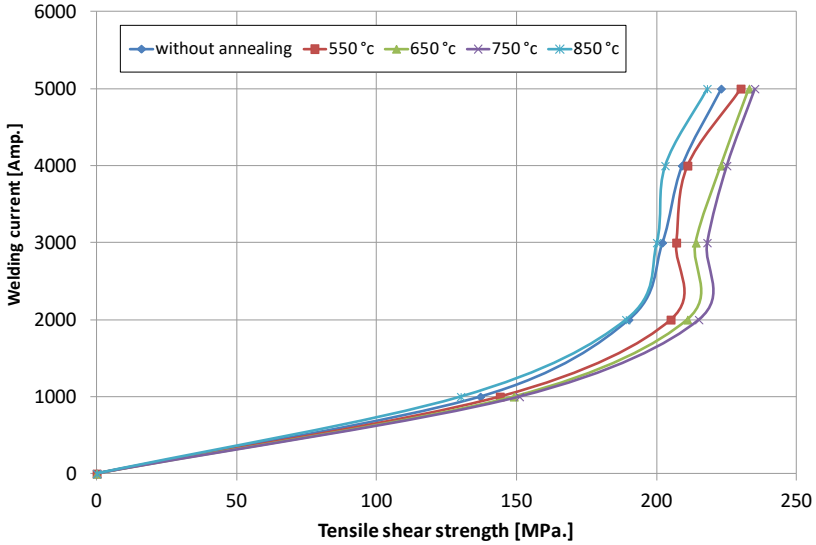

Figure 4. Effect of annealing temperatures on the tensile shear stress

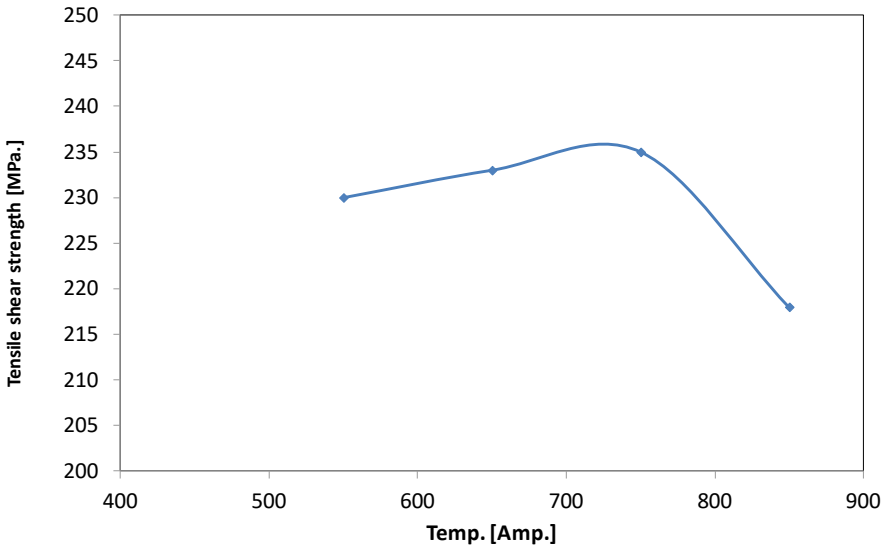

Figure 5. Effect of annealing temperature, I=5000 A

At 850 °C, the Pearlite, and Austenite have been converted into Cemnetite. Therefore, the difference in solidification rate will be causing the cracks. That also appears by decreasing the elongation.

Conclusions

Mechanical properties and quality of spot weldments improve by increasing the welding current. Residual stresses are induced in the spot weld area due to a large amount of heating in short time is induced in a sheet metal. Post weld heat treatment temperatures have been used. It was found that the annealing treatment refines the grain size and removes most of the residual stresses. So the strength will be improved up to annealing temperature of 750°C. The annealing temperature above 850 °C will decrease the tensile shear strength. Because the transformation of the austenite grains gradually to Cementite gives more hardness and little elongation. In addition, the differences in solidification rates between compounds producing cracks.

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