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ASSESSMENTS OF MECHANICAL PROPERTIES OF RESISTANCE SPOT WELD OF AISI 316 AND AISI 202

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ABSTRACT

Research on resistance spot weld ability of stainless steel attracts more and more attention with the increasing usage of various types of stainless steel in industries. In this dissertation works done on resistance spot welding of stainless steel is presented. The most used variety of stainless steel. Though less, research works have been reported on other varieties of stainless steel also. The areas chosen for most of the works by researchers in the past have been found as process, failure mode analysis and characterization of resistance spot welds. In this research work spot welding of two dissimilar metals namely AISI 316 and AISI 202 is carried and its microstructure and macrostructure is studied to accomplish optimum tensile strength of the weld joint hardness of the weld joint and also to detect any internal flaws due to increase in the current value.

Keywords: Resistance welding; Spot welding; AISI 316 and AISI 202

INTRODUCTION

Resistance spot welding is frequently used as a successful joining method for a variety of work commonly in automotive and other manufacturing processes. For example, the typical car body contains about 5000 spot welds joining a mixture of sheet metal material types and thicknesses. If the quality of the products is considered, it is clear that the quality of the product is directly related to the quality of the spot weld.

Resistance welding is a thermo-electric process in which heat is generated at the interface of the parts to be joined by passing an electrical current through the parts for a precisely controlled time and under a controlled pressure (also called force). The name "resistance" welding derives from the fact that the resistance of the work pieces and electrodes are used in combination or contrast to generate the heat at their interface. Resistance welding is a fairly simple heat generation process: the passage of current through a resistance generates heat. This is the same principle used in the operation of heating coils. In addition to the bulk resistances, the contact resistances also play a major role. The contact resistances are influenced by the surface condition (surface roughness, cleanliness, oxidation, and plating).

Resistance welding is capable when current is started to flow through electrode tips and the separate pieces of metal to be joined. Localized heating in the joint is caused by resistance of the base metal to electrical current flow, and the weld is made.

In resistance spot welding process, the application of electric current (I) causes generation of electrical energy (E), in duration of time (t) thereby causing heating of the resistance (R), represented as:

$E = I2 \times R\times t$

This electrical energy is converted into heat energy heat energy and causes welding of the closely placed components. Further, forces are applied to hold the pieces together. Normally, the heat and pressure are applied to the work piece using the electrodes. The heat is generated using the electric current and pressure is applied, which eventually causes the formation of the nugget at the interface. The nugget formation mechanism involves generation of sufficient thermal energy to raise the temperature of the base material. The dimensions of the nugget formed at the weld region also depend upon several parameters. The sheets are

placed one over the other and the electric current is applied. The sheets are coated with suitable materials before welding. The characteristics and properties of the weld is influenced by two factors:
i) Thermal factors and
ii) Electrical factors.

Very often two sets of welded specimens created using exactly the same welding parameters on identical specimens, but different welders, yield significantly different results when tested. The only logical explanation to this observation is that welders make the difference. A resistance welder consists of two distinctly different, yet closely related systems: electrical and mechanical. The characteristics of the mechanical system, such as machine stiffness, friction, and mass, play an important role in the functionality and performance of a welding machine, and subsequently influence the welding process and weld quality. According to published literature, research on the influences of welding machines began in the 1970s. Early work focused on the differences of machine types without attempting to understand the mechanisms. A key parameter of all types of resistance welding is weld pressure or force. The proper and consistent application of force improves the mating of the materials increasing the current paths, reducing the interface resistance, and insuring that any oxide barriers between the work pieces are broken through. Repeatable force control insures repeatable weld quality through consistent electrical contact resistance and consistent heat balance. Force control can also be used to trigger welding energy when a pre-determined force level has been achieved, often called “force firing.” Optimum welds are achieved when the applied force is precise, repeatable, controlled by time schedule, used to fire the power supply, and regulated both to reduce the initial impact and not to become excessive after the weld. Weld force control is equally as important as weld energy and time control. The power supplies with either an internal or external transformer both powers and controls the application of heat and time in the resistance welding process. In general terms, resistance welding applies high current with low voltage. Further, the material chosen for coating the strips also is important. The coating provided significantly influences the energy and force transferred to the strips, at the junction of which the weld is formed. The physical metallurgy of the materials to be welded determines the application of the resistance welding process variables. In general there are two categories of metals to be welded: “Conductive” (such as aluminum, copper, silver and gold), and “Resistive” (steel, nickel, titanium, tungsten, molybdenum) with a third, small, middle ground category occupied primarily by brass. In general, electrically conductive materials are also more thermally conductive and are softer. These categories apply equally to both the work pieces to be joined and to the electrodes. As discussed earlier, higher electrical resistance produces higher heat and better welds. Thus the “rule of opposites” applies to matching electrodes to work pieces to be welded. The general rule (with a few exceptions such as aluminum and beryllium copper) is to utilize conductive electrodes against resistive parts and resistive electrodes against conductive parts. By extension, when welding dissimilar materials, the upper and lower (or anode and cathode) electrodes must be of different materials to each other in order to apply the “rule of opposites.”

In this study, the properties of resistance spot weld of dissimilar steels have been studied. Attempts were made to link a weld’s quality to its attributes under tensile testing. The stainless steel grade 202 and grade 316 were used for the present study to explore the strength using input process parameters selected for welding.

LITERATURE SURVEY

RSW is a technique in which faying surfaces are bonded in one or more spots by the heat generated via resistance to the flow of electric current through work pieces that are held together under force using electrodes. A short time pulse of high-amperage current heats the contacting surfaces in the region of current concentration. When the flow of current terminates, the electrode force is maintained while the weld metal quickly cools and solidifies. The electrodes are retracted after each weld, which usually are completed in a fraction of a second (Mersereau, 1998).

Resistance spot welding is extensively used joining process for fabricating sheet metal assemblies for example automobiles, rail vehicles and home applications because of its benefits in welding efficiency and appropriateness for automation. The process is also used in preference to mechanical fasteners, such as rivets or screws, when disassembly for repairs is not required [Jawad Saleem, et. al., 2012]. For example, a modern auto-body assembly needs 7000 to 12,000 spots of welding according to the size of a car, so the spot welding is a chief process in auto-body assembly. Over the last few years, the weight of automobiles has increased strikingly because of addition of safety related items, such as impact resistance bumpers and door impact beams, emission control apparatus and convenience items, such as air conditioning. At the same time fuel consumption has increased significantly mainly due to emission control equipment. The spot weld ability of sheet metal depends to a great degree on its thickness, surface conditions and mechanical and physical properties. This reproducibility is governed by resistance spot weld ability of the material and also on the choice of proper welding process [Y.H.P. Manurung et al., 2010].

Research on welding is carried out at numerous research institutions [A.G.Thakur and V.M. Nandedkar, 2010]. The dissimilar materials selected for the overall study included AISI 316 grade steel and AISI 202 steel. The tensile strength, hardness, microstructure and macrostructure of weldment on varying current were investigated so that the weld ability of dissimilar materials (AISI 316 and AISI 202 steel) was determined.

The ease with which cold formed steel can be manufactured, shipped and erected has made it an indispensable product in the modern construction industry. One of the most often used applications of cold formed steel is as steel deck. There are a number of different methods used to attach steel deck to hot-rolled steel. Perhaps the most common method is the use of arc spot welds, also known as puddle welds. Arc spot welds are produced by striking an arc on the upper sheet, forcing a hole to form, while the lower unit is raised to fusion temperature. With the attainment of proper temperature, the electrode is moved in a circular pattern until the hole is filled and fusion attained on the arc-puddle perimeter (Luttrell, 2004).

Steel decks frequently act as horizontal diaphragms, transmitting lateral loads to some lateral force resisting system. The amount of load that the diaphragm is able to transmit is dependent on the deck strength as well as the spacing and strength of the arc spot welds attaching it to the structure. If the weld strength is overestimated, too great of spacing between welds could be specified, thereby compromising the diaphragm strength and the lateral stability of the structure.

The current design strength equations for arc spot welds are based principally on research conducted at Cornell University by Pekoz and McGuire (1980) and research conducted by Blodgett (1978) of the Lincoln Electric Company. The equations used to predict the tearing and bearing at the weld contour limit state were first developed analytically by Blodgett (1978) in his report on Proposed Standards for Sheet Steel Welding. The equations were later supported through data collected by Pekoz and McGuire (1980). Pekoz and McGuire also developed an equation for the effective weld diameter, used to predict the weld shear failure limit state. Other limit states such as edge failure and net section failure are prevented by adhering to the minimum end and edge distance requirements given in section E2.2.1 of the 2001 AISI Specification.

The most common usage of arc spot welding is in the attachment of cold-formed steel roof deck to structural framing. Because the roof deck often acts as a horizontal diaphragm, transmitting lateral loads through shear into perpendicular lateral force resisting systems, it is important to know the exact shear strength of each diaphragm connection (Muhammad et al., 2013). Past research has focused on both the proper formation of arc spot welds and their ultimate strength. In January of 1975, the AWS Structural Welding Committee set up a Task Group, now known as Subcommittee 11, to investigate the problem of sheet steel welding and to develop a proposed set of standards (Blodgett, 1978).

METHODOLOGY ADOPTED

In this study, AISI 202 grade steel and AISI 316L grade stainless steel sheets of thickness 1.5 mm having the chemical compositions as given in Table 1.1 were used. Both materials were cut into pieces in dimensions of 101 mm×40 mm. Before welding, the surfaces of the all samples were cleaned mechanically. AISI 202 is a common purpose stainless steel having low nickel content and more manganese which consequences in weak corrosion resistance capability of the material. AISI 316 stainless steel is broadly used in forming applications because of its better formability.

TABLE 1.1 CHEMICAL COMPOSITIONS OF SHEET MATERIALS (WT%)

AISI 202 (JT)	C	Si	Mn	Cr	Ni	Mo	Cu	V	Co	S	P
	0.096	0.351	10.38	14.17	0.225	0.017	0.735	0.0362	0.0278	0.0087	0.0534
AISI 316L	C	Si	Mn	Cr	Ni	Mo	Cu	V	Co	S	P
	0.028	0.453	1.68	18.10	8.097	0.320	0.384	0.0795	0.1609	0.0093	0.0316

EXPERIMENTAL SETUP

For the joining 9, 12, 15 and 18 kA peak currents were applied while the other welding parameters were kept constant. The parameters used in the resistance spot welding of the sheets are given in Table 1.2.

TABLE 1.2 WELDING PARAMETERS USED IN RESISTANCE SPOT WELDING

Effective current (kA)	Holding time (cycle)	Welding time (cycle)	Electrode pressure (bar)	Weld atmosphere
9	30	17	6	Ambient
12	30	17	6	Ambient
15	30	17	6	Ambient
18	30	17	6	Ambient

For macro testing, we have to cut a sample from the welded joint. In this we have adopted cold cutting methods i.e. use of bandsaw. The cross section of the weld region is then observed. After this the surface is polished followed by filing away burrs and rough marks. When smooth even polished surface is obtained, an acid solution was applied with a soft clean cloth, wiping over the test piece. The acid used in this test is nitric acid which is dissolved in distilled water. Nitric acid is used because of its rapid oxidising properties. After a short time, the parent metal and weld areas began to discolour. After obtaining the visible results, the sample is rinsed off and carefully dried. The results show distinctive colour difference between the actual weld metal and the parent metal in the immediate area. The weld show up lighter and the darker material next to it is the rearranged grain structure, due to the heating and cooling cycle. Figure 1.1 shows a sample of stainless steel. In this grain structure can be seen quite clearly and level of penetration is also quite large.

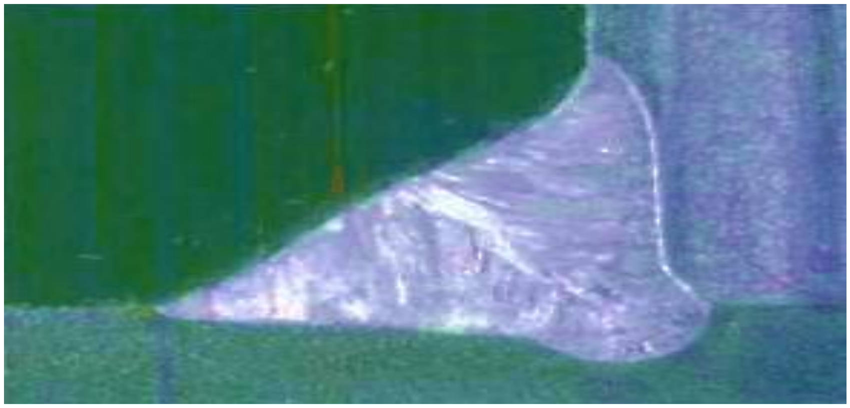

Figure 1.1 Grain structure in Stainless steel sample after weld

For ultrasonic testing, ultrasonic waves are made to propagate in the dissimilar materials (AISI 316 with AISI 202). In this very short ultrasonic pulse-waves with centre frequency 15 MHz is transmitted into materials to detect internal flaws.

Because the additional friction only results in worse porosity, the tensile-shear strength of weld does not change significantly. The reduction in strength is generally not statistically significant for the steels and aluminum alloys tested, the comparisons of the joint strength under different conditions. It can be concluded, based on the comparisons, that friction is unfavorable for both steel and aluminum welding. However, some of strength reduction may not be statistically significant since the data ranges overlap. In general, the influence of friction varies with welding conditions. In summary, machine friction influences welding process and weld quality. The friction always opposes electrode movement and makes it difficult for electrodes to follow nugget expansion during welding and contraction during cooling. The latter effect may help the creation of internal discontinuities in welds. Three sensors, force, displacement, and electric current sensors, were used for the study. The electric current sensors were used to identify the end of the squeeze period (as the start of the current) and the start of the cooling period (as the end of the current). The measured squeeze time is defined as the period starting from the moment at which electrodes start to move, characterized by the start of increase of displacement value. The time ends when electric current is applied. The results obtained after performing all the tests and conclusion are discussed in the next section.

RESULTS AND CONCLUSION

ULTRASONIC TESTING

The results obtained from the ultrasonic testing shows that no crack was observed on Heat Affected Zone (HAZ) and fusion was complete.

MACRO TESTING

On Macro examination spot butt weld found to be satisfactory as there was no through crack on the surface of metal or on Heat Affected Zone (HAZ) was observed. Macro examination was carried by cutting a sample from the welded joint and obtaining smooth even polished cross section surface on which an acid solution (10% Nitric acid and 90% water) was applied with a soft clean cloth, wiping over the test piece. The results show distinctive colour difference between the actual weld metal and the parent metal in the immediate area.

On macro examination no through crack on metal or on HAZ was observed. Thus on macro etching, spot butt weld found to be satisfactory.

So, from the above study we can conclude that in the welding of dissimilar sheets of austenitic stainless steels (i.e. AISI 202 to AISI 316), current is an important influencing factor i.e. increasing the value of welding current increases the welding heat input and accordingly increases the chance of defects formation. Moreover, the high welding current reduces the Ultimate Tensile Strength (UTS) and Hardness of weld metal. Increasing in welding speed could be the remedy which can decrease the welding heat input and chance of defects formation in weld metal. Therefore we can say that increasing the welding speed can decreases the chances of defect and ultimately increases the hardness and UTS of weld metal.

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