ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

# STUDY AND ASSESSMENT OF MECHANICAL PROPERTIES OF RESISTANCE SPOT WELD OF TWO DISSIMILAR METALS (AISI)

**Anand Prakash Singh[*1], Dharamvir Mangal[2]**
[*1]Research Scholar, Mechanical Engineering Department, Sunrise University, Alwar (Rajasthan) India
[2]Director, Geeta Institute of Management and Technology, Kurukshetra, Kurukshetra University, Kurukshetra, (Haryana) India

**DOI**: 10.5281/zenodo.1012521

## ABSTRACT
Resistance spot welding is an extensively used welding process for joining thin metal sheets in automobile, rail and aircraft industries. The resistance spot weld must have shear strength which is equal to the base metal shear strength and must exceed the strength of a rivet or a fusion plug weld of same cross sectional area. Shear strength is generally recognized as the criteria for resistance spot weld stipulations, while other methods may also be used. In this research work spot welding of two dissimilar metals namely AISI 316 and AISI 202 is carried and its tensile strength and hardness is studied to accomplish optimum tensile strength of the weld joint and hardness of the weld joint. Internal flaws due to increase in the current value have also been analyzed.

**KEYWORDS**: Resistance welding; Spot welding; AISI 316 and AISI 202.

## I. INTRODUCTION
Spot welding is a resistance process, relying on the electrical resistance of the components to generate heat when a current is passes through them. Resistance spot welding is one of the oldest of the electric welding processes in use by industry today. Resistance spot welding depends on the resistance of the base metal and the amount of current flowing to produce the heat necessary to make the spot weld. Another important factor is time. In most cases, more than a few thousand amperes are used in creating the spot weld. Such amperage values, flowing through a relatively high resistance, will create a lot of heat in a short time. It is necessary to have close control of the time the current is flowing in order to make good resistance spot welds.

Actually, time is the only controllable variable in most single impulse resistance spot welding applications. Current is very often economically impractical to control. It is also unpredictable in many cases.

A usual practice is to peel two welded sample strips away from each other to see if a clean rivet is pulled from one piece. If it is, the resistance spot welding condition is considered accurate.

With magnetic materials such as mild steel, the current through the weld can vary substantially depending on how much of the magnetic material is within the tong loop. The tong loop is sometimes called the “throat” of the resistance spot welding machine.

Resistance spot welding (RSW) has a very essential role as a joining process in the automotive industry and a typical vehicle contains more than 3000 spot welds. The quality and strength of the spot welds are very significant to the durability and safety design of the vehicles. 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 modelling and finite element analysis, dissimilar metal welding, failure mode analysis, parametric optimization and characterization of resistance spot welds. It is felt that the information presented in this work may definitely give the fresh researchers, a bird’s eye view of the research work done in the past, in this field, and is expected to provide them the right direction for the future research work, in this area. The resistance spot weld of dissimilar materials is generally more thought-provoking than that of similar materials due to variances in the physical, chemical and mechanical properties of the base metals.

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**200 Series stainless steel**

200 Series stainless steels are not new. They have been in use around for many years. To date they have traditionally not proved very popular outside the USA. However, since they have a much lower Nickel content than 300 Series Austentics, the much high Nickel price over recent years has led to expressively more interest. Equally, stainless steel producers have an ongoing programme of development designed to enhance existing grades and produce new grades. These new grades are occasionally established for specific end uses and occasionally to improve upon prevailing grade.

**300 Series stainless steel**

300 Series stainless steels are classified as austenitic which are hardenable only by cold working methods. These grades of stainless have chromium (approx. 18 to 30%) and nickel (approx. 6 to 20%) as their major alloying additions. Type 316 is the most widely used alloy of all stainless steels. 300 Series Stainless steel alloys resist corrosion, preserve their strength at high temperatures and are stress-free to maintain. 300 series grades are inventoried in stainless steel plate, sheet, bar, pipe, tube and structural products.

Arc spot welds are used extensively in the construction industry for the attachment of cold-formed metal deck to structural steel. They can be used to temporarily hold the deck in place until a permanent attachment is made, as in composite construction. They can also be used as a permanent connection, as is often done with roof decks. When used as a permanent connection, the welds are relied upon to transfer lateral forces from the deck to parallel lateral force resisting systems through shear. 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.

## II. 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.

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 [15, 4]. 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 [2]. Research on welding is carried out at numerous research institutions [10, 13].

The dissimilar materials selected for the overall study included AISI 304 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 304 and AISI 202 steel) was determined.

J.B. Shamsul et al. [6] studied the relationship of nugget diameter and welding current in resistance spot welding of AISI 304 stainless steel. Hardness distribution along welding zone was also investigated. The results indicated that increasing welding current gave large nugget diameter. However, the welding current not much affected the hardness distribution. Also it was reported that nugget size does not influence the hardness distribution.

Bouyousfi et al. [3], have studied the effect of process parameters (arc intensity, welding duration and applied load) on the mechanical characteristics of the weld joint of austenitic stainless steel 304L. The results showed

ISSN: 2277-9655
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CODEN: IJESS7

that the applied load seems to be the control factor of the mechanical characteristics of weld joint compared to the welding duration and the current intensity.

M. Pouranvari et al. [8], in an another study on resistance spot welding of stainless steel, investigated the effect of welding current on the energy absorption capability of austenitic stainless steel AISI304 resistance spot welds during the quasistatic tensile-shear test . Results showed that there is a direct relationship between the fusion zone size and failure energy in expulsion free samples.

Nachimani Charde et al.[12], in a paper ,on investigation of spot weld growth on 304 austenitic stainless steel(2 mm) sheets ,reported that the growth of a spot weld is primarily determined by its parameters such as current, weld time, electrode tip and force. This paper is intended to analyze only the effects of nuggets growth due to the current and weld time increment with constant force and unchanged electrode tips. He reported that the hardness of welded zones is greater than the hardness of the un-welded zone and also the heat affected zones.
Welding Current Effect on Mechanical Properties of Spot Welded Dissimilar Metals between Stainless Steel and Low Carbon Steel was investigated by AgustinusEko Budi Nusantara et al. [1] in the year 2011. It was reported that increasing of welding current had increased the nugget size and tensile-shear load bearing capacity of the joint. It also changed the interfacial failure to pull out failure.

Vural et al. [9], investigated the effect of welding nugget diameter on the fatigue strength of the resistance spot-welded joints of different steel sheets such as galvanized steel sheets and austenitic stainless steel.

Triyono et al.[14] made a comparative study on the fatigue strength of resistance spot-welded unequal and equal sheet thickness austenitic stainless steel grade AISI 304.Due to significant thickness difference, the asymmetric weld nugget, high micro hardness on the edge of nugget and tearing fatigue fracture mode were reported.

Yan (2009) investigated the mechanical properties and microstructure of stainless steel and results showed that the microstructure consists of delta ferrite and gamma ferrite phase. [16].

Morisada (2012) showed the effect and use of high frequency tungsten inert gas welding method in order to decrease the blow holes in a weld [11].

The hardness of the weld metal was lower than that of the heat affected zone (HAZ) metal area and heat affected zone was lower than that of base metal concluded by Durgutlu (2003) in the research where he observed that increasing hydrogen content in the shielding gas reduced the mechanical properties [5].

Kang (2008) analyzed the effect of alternate supply of method of shielding gases in austenitic stainless steel using Gas tungsten arc welding and concluded that welding speed of Ar+67 % He was more than that of supplying alone argon (Ar) but less than Ar ::He ratio [7].

## III. 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.

The sheets were cut parallel to the rolling direction. The dimension of sheet are 101 mm length (L), 40 mm width (w) and 1.5 mm thick (t) (Figure 1.1). Overlap is equal to width of the sheet (i.e. 40mm) as per AWS standard. Sheet surfaces were chemically cleaned with acetone before resistance spot welding to eradicate surface contamination. The tests were carried out using a current and time controlled electric resistance spot welding machine. The electrode material was Chromium alloy having end diameter of 5 mm. This machine was equipped with a pneumatic pressure system. Welding, squeezing and holding cycle was manually selected.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

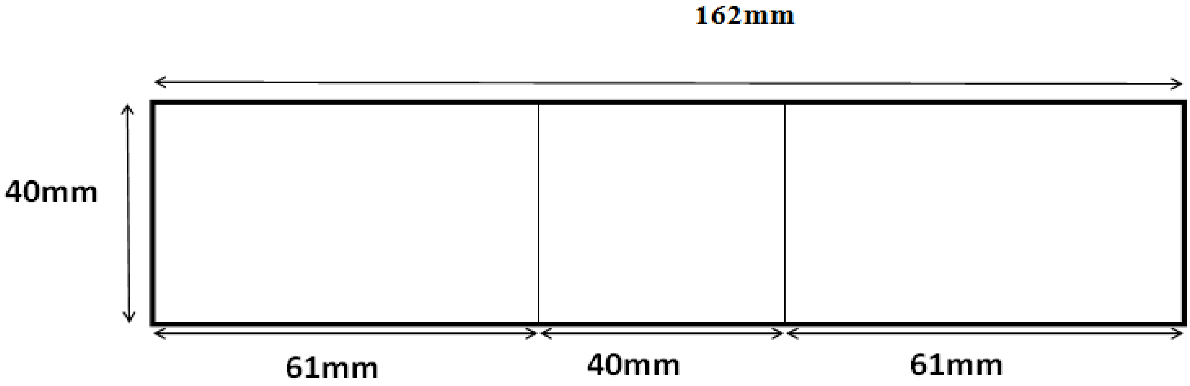


*Figure 1.1 Dimension of specimen*

*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 hardness measurement, Rockwell hardness measurement machine was used under 500g load acting over a period of 10 sec. In this process we have indented both the test materials (AISI 316 with AISI 202) with a hardened steel ball indenter in order to obtain the hardness number of both the materials. The indenter is forced

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into the test materials under a preliminary minor load $F_o$ usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration. When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

## IV. RESULTS AND CONCLUSION

**Tensile testing**

The tensile strength obtained is 251.50-268-264-261.60N/mm2 which is fair enough to deal in the prescribed applications. Thus optimum value of tensile strength comes out to be 268 N/mm2 which is obtained on current value 12kA after which it drops non-uniformly.

The possible reason for decrease in tensile strength with increase in current is that the tensile strength depends on the mean distance between the molecules/atoms of the material. As the current increase, there is increase in temperature which further increases the mean distance (and the size expand) and the tensile strength decrease. Thus, if we raise the value of current above optimum value i.e. 12kA, the temperature becomes high enough that the molecules/atoms cannot retain their position inside the material and the tensile strength is decreased.

**Hardness testing**

On testing hardness, Rockwell hardness number for stainless steel grade 202 and grade 316 comes out to be 23-25 HRC and 82-83 HRB respectively and optimum value of hardness of the joint comes out to be 22-24 HRC on current value 12kA after which it started decreasing. Thus we can conclude that increasing the value of welding current, increases the welding heat input and accordingly the chance of defects formation. Finally, the high welding current reduces the hardness.

**Recommendations**

- **Requirements for Weld Arc Time**

This research has proven that arc time has a tremendous influence on arc spot weld shear strength. It is therefore imperative that measures be taken to insure welds formed in the field are completed using the proper arc time. Naturally, every welder has a slightly different technique and may require slightly different amounts of time to complete an arc spot weld. The variation in required arc time from welder to welder was not accounted for in this research. Therefore it is not recommended that either the 12.8 second 3/4 in. welds or 8.1 second 5/8 in. welds used by the welder in this research be set as any sort of standard. Instead, a new procedure must be devised that will accommodate a welders individual technique and required arc time

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## CITE AN ARTICLE

**Singh, A. P., & Mangal, D. (2017). Resistance welding; Spot welding; AISI 316 and AISI 202. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*(10), 297-302.**