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# Study Effect of Gap on Tensile Strength between Sheets Bonded with Spot Welding Process

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**ABSTRACT**

Resistance spot welding used widely in joining sheets with high strength and high speed production foroverlap joints, the process comprises of thermal, electrical and mechanical phenomenon. An experimental study concentrate on effect of gap between welded sheets as result of warp or bulging in the sheets on tensile shear strength and nugget size in the resistance spot welding, while the parameters (force, current, time and diameter of electrode) kept constant.The tested samples developed for welding two overlap sheets of 0.8 mm thick mild steel, with different gaps (0,0.05, 0.1 and 0.15)mm, also the distance between electrodes and edge of gap studied. The results of 21 samples obtained in the study show that the gap magnitude and distance of electrode from the gap edge have an influence in the tensile shear strength of welded sheets and nugget size.

**Key words:** Resistance spot welding, nugget, gap, electrode distance, tensile shear strength.

## 1. INTRODUCTION

Resistance spot welding (RSW) in manufacturing word is a popular welding process due to its high speed and low cost, it can be weld different materials such as, aluminum, low carbon steel, stainless steel, nickel, titanium, high-strength low alloy steel and copper alloy. (RSW) consider one of Forge or Pressure Welding Process, the metal sheets are heated to a plastic state below melting point and then the metal sheets start joining together by applying constant pressure for a small interval time on them, as shown in Figure 1.

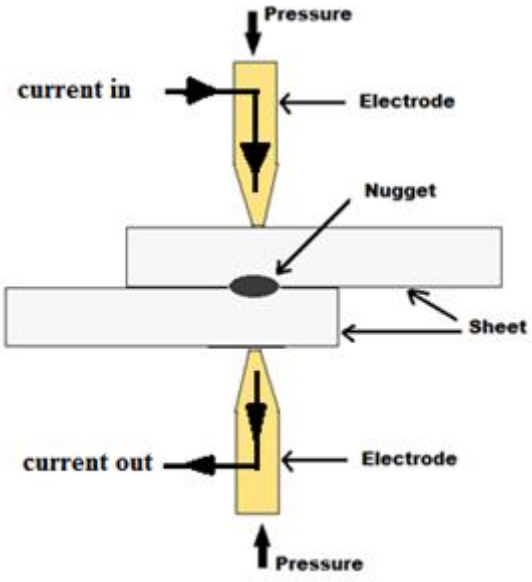


**Figure 1: schematic of Resistance spot Welding**

Resistance Spot Welding (RSW) excellent techno- economic method of joining metal to connect two or more of thin metalsheets, the other characteristic of spot welding it can beeasy robotic automated, (RSW) used in line welding to perform repeatable spot welding at a fast rate.Because of the(RSW) can be robotic automated and is a high speed process specifications during manufacturing where the actual time of welding is a small fraction of a second it is

applied widely in body structure assembly in the manufacturing of structures to joining in automotive industry of buses, trucks, cars and railway bodies, home appliances and air craft, for example more than 3,000 spots are made in a single vehicle structure [1].The other applications of(RSW) used in the crash repair.

The conventional process of (RSW) procedure starts when high amounts of electric current is passed through two welded sheets via electrodes has high electrical conductivity in a short time with pressure [2], the results of this current lead generation of heat to melting the contact zone between the two sheets. Then the electric current is turned off, the other function of electrodes by applying constant force on sheets during and after current cycle application, then molten metal between the two sheets starts cool and solidify,because of large temperature gradient from the melting point to room temperature. The Coalescence between the two surfaces of sheets start after reaching the melting temperature as a result of large current in short time, the behavior of melting contact surface between sheets follows Joule's Law, which can be evaluated from the equation (1).

$Q = RI^2t$ ……..1

Where: (Q) is the amount of heat generated, (R) is the electrical resistance of sheets, ($I$) is the current during the electrical cycle and (t) is the time during the electrical cycle.The phase changes occurring during solidifying metal leads to residual stresses in spot welded joint.Figure 2 shows the sequence of (RSW) process.

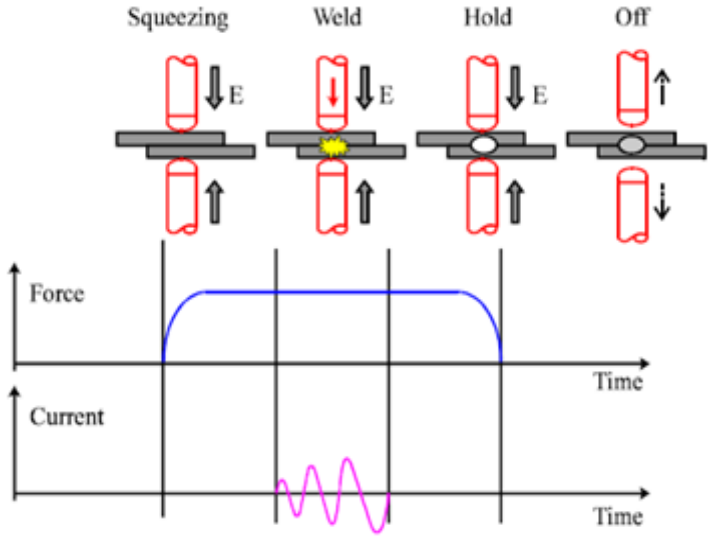


**Figure 2: The sequence of (RSW) process [3]**

## 2. LITERATURE REVIEW

A large number of experimental and theoretical studies on Resistance Spot Welding have been reviewed, where manydifferent parameterssuch as (force, current, time and diameter of the electrode) significantly influence on the strength of welded sheets.

Davood Afshari studied the effect of parameters on nugget size and mechanical strength of resistance spot welding, from results the residual stress and nugget size can be predicted in terms of resistance spot weld parameters. [4], Saleem and Majid used Finite Element Model to reach simulation to understand the nugget formation during welding. [5], Ramezani, Jeong and Pluvinage had used three dimensional finite Element model to analyze the tension and compression of lap joints. [6],Habibstudied the experimenter effect of overlap length, type of material and thickness of sheet on the strength of welded sheets using tensile test. Manurung and Muhammed investigated heat affected zone and nugget formation using experimental results and finite element method.[3].

In this study effect of gap between the welded sheets and distance from the electrode to gap edge as parameters investigated, while the other parameters (force, current, time and diameter of the electrode) kept constant. Generally the gap appears between welded sheets as result of projection, warpingand defects on the sheet surface after crushing whichprevent typical contact between welded sheets.

## 3. EXPERIMENTAL METHOD and PROCEDURE

Mild steel sheet as tested sample materialwith thickness 0.8 mm tested, table 1 shows the chemical composition of tested sheet material.

**Table1: Chemical Composition of testing sample**

| Element | % wt | Element | % wt |
|---|---|---|---|
| Fe | 98.9 | W | 0.1 |
| C | 0.26 | Al | 0.05 |
| Si | 0.13 | Cu | 0.07 |
| Mn | 0.12 | Co | 0.05 |
| Cr | 0.05 | Ti | 0.05 |
| Ni | 0.05 | Nb | 0.05 |
| Mo | 0.07 | Pb | 0.05 |

Three different groups (0.05mm, 0.1mm and 1.5 mm) between lap joined, welded sheets were selected to investigate the effect of gap on tensile strengthfor (RSW),while all other parameters (force, current, time and diameter of the electrode) kept constant during all tests. Table 2 shows the constant parameters magnitudes.

**Table2: Constant Parameters Magnitudes**

| Parameter | Force (N) | Power (KW) | Time (Sec.) | Diameter of Electrode(mm) |
|---|---|---|---|---|
| magnitude | 245 | 5 | 3 | 5.85 |

Also, two different positions between electrode and gaps edge adopted (15 mm and 20 mm) respectively, the gap thickness and distance between electrode and gap shown in figure 3.

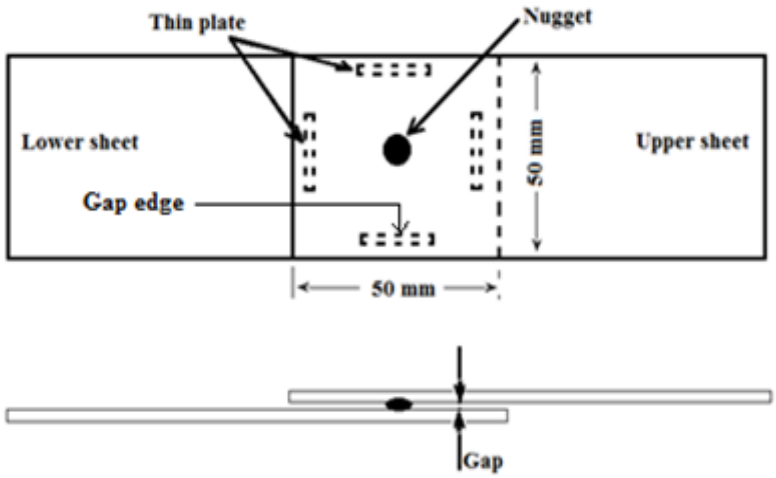


**Figure 3: Examined specimen dimensions and thin plate to make gap arrangement**

## 4. SPOT WELDING and TENSILE MACHINE

All lap joined weld performed by (KENDE- DN 16) spot welding machine, whilethe electrode cap with flat tip radius 5.85 mmin diameter used. The tensile shear strength testing (Destructive test) for 21 samples were carried out at room temperature and was performed on a (MATEST CYBER-PLUS EVOLUTION) tensile test machine, both sides of lap joined samples fixed on strength machine fixture. The loadincreasingrecorded during the testingtill thefailure appears in spot weld nugget.

## 5. ANALYSES AND DISCUSSION

Resistance Spot Welding(RSW) strength related to the heat necessary to start nugget formation, and it depends on amount of current following between electrodes, also it depends on electrode force, diameter of electrode tip and weld time. Gap between welded sheets as parameterexamined to analyzeits effect on the strength of spot welding. The other parameter is the distance between electrode tip and gap edge which performed by plate fixed between welded sheets to make a gap, the experimental results of investigation, whenthe distance between electrode and thin plate equal 15 mm shown in table 3.

**Table 3: Results of tensile shear strength and percentage deviation for distance 15 mm between thin plate (gap edge) and electrode.**

| Sample No. | Gap Thickness (mm) | Tensile shear strength (KN) | Deviation% |
|---|---|---|---|
| 1 | **0** | **1.84** | **0** |
| 2 | **0** | **1.90** | **0** |
| 3 | **0** | **1.76** | **0** |
| **1** | **0.05** | **1.186** | **35.6** |
| **2** | **0.05** | **1.23** | **35.5** |
| **3** | **0.05** | **1.179** | **33.0** |
| **1** | **0.1** | **1.163** | **34.1** |
| **2** | **0.1** | **1.155** | **34.2** |
| **3** | **0.1** | **1.159** | **34.1** |
| **1** | **0.15** | **1.141** | **38.1** |
| **2** | **0.15** | **1.107** | **42.0** |
| **3** | **0.15** | **0.954** | **45.0** |

Figure 4shows the results of tensile shear strength of all the gaps (0, 0.05, 0.1 and 0.15) mm when the distance between electrode tip and thin plated equal 15 mm.

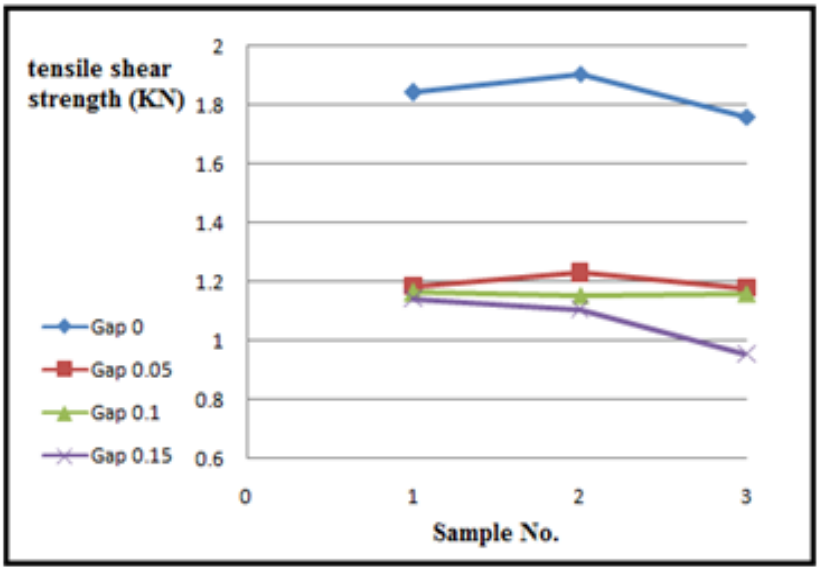


**Figure 4: Influence of gaps in behavior of welded joints for (15 mm) distance between electrode and gap edge**

As seen in figure 4, sample 1 when the gap parameter between sheets equal to zero the tensile shear strength, reach 1.84 KN, for second sample the tensile shear strength reaches 1.90 KN, while the third sample reach 1.76 KN before failure the welded over lap joint. The magnitude tensile shear strength decrease when there is a gap between the welded sheets, sample 1 when gap equal 0.05 mm comes out to be 1.18 KN, with a deviation of nearly 35.6% when compared with a sample one without a gap. Sample 2 with gap 0.05 reached 1.23 KN, with deviation of 35.5%, and for the third sample tensile shear strength is 1.17 KN, with deviation equal 33.0%.

For gap equal 0.1 mm between welded sheets, sample one tensile shear strength reach to 1.16 KN with deviation 36.9% comparing with gap equal zero, sample two is 1.15 KN with deviation 39.4%, while the third sample reached 1.15 KN, with deviation 34.1%. When gap increased to 0.15 mm, tensile shear strength results decreases, for samples1 tensile shear strength reached 1.14KN with deviation 38.1%, while sample two comes out to 1.10 KN with deviation equal 42.1%, sample three reached 0.95 KN with deviation 45.8%.

In the second tests the parameter distance between the electrode and sheet plate changed to 20 mm, in order to study behavior of welded sheets, table 4 shows percentage deviation of tensile shear strength for 9 samples with gap when distance between electrode and gap edge equal 20 mm.

**Table 4: Results of tensile shear strength and percentage deviation for distance 20 mm between thin plate (gap edge) and electrode.**

| Sample No. | Gap Thickness (mm) | Tensile shear strength (KN) | Deviation% |
|---|---|---|---|
| 1 | **0** | **1.84** | **0** |
| 2 | **0** | **1.90** | **0** |
| 3 | **0** | **1.76** | **0** |
| **1** | **0.05** | **1.41** | **23.3** |
| **2** | **0.05** | **1.35** | **38.5** |
| **3** | **0.05** | **1.34** | **29.0** |
| **1** | **0.1** | **1.22** | **34** |
| **2** | **0.1** | **1.19** | **37** |
| **3** | **0.1** | **1.25** | **29.0** |
| **1** | **0.15** | **1.18** | **36** |
| **2** | **0.15** | **1.17** | **38.0** |
| **3** | **0.15** | **1.19** | **32.0** |

Figure 5 shows the results of gap parameterfor four different gapvalues (0, 0.05, 0.1 and 0.15) mm when the distance between electrode tip andgap edge equal 20 mm.

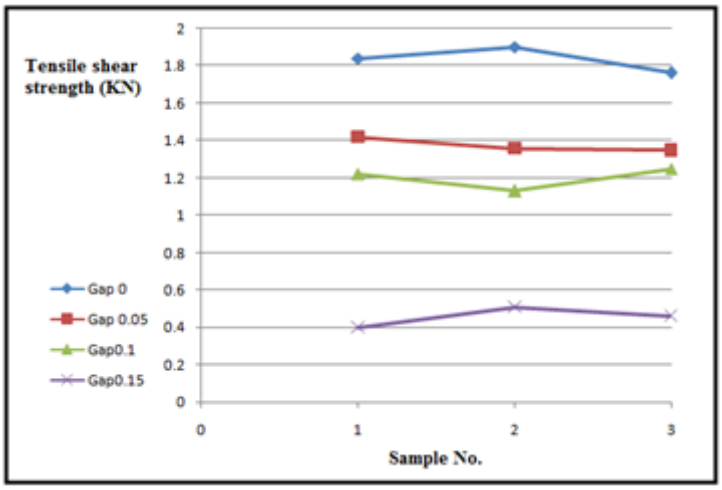


**Figure 5: Influence (20 mm) distance between electrode and gap edge on behavior of welded joints**

Results of figure 5 generally similar to the results of figure 5 written above, the strength behavior decrease by increasing the gap value between welded sheets, but with less deviation magnitude from the sample without gap.When two sheet welded without any gap between the welded sheets, samples (1,2 and 3) tensile shear strength reaches (1.84, 1.9 and 1.76)KN respectively, separating welded sheets with gap equal 0.05, the sample one tensile strength comes out to be 1.41 KN, with deviation 23.3% when compared with sample one without gap, and sample two reach1.35 KN, with deviation 28.5% while sample three reach 1.34 KN, with deviation 29.0%. For gap equal 0.1 mm,sample one tensile shear strength come out to be 1.22 KN with deviation 34.0% when compared with a sample one without a gap, while sample two reached to 1.19 KN, with deviation 37.0%, and the third sample reached 1.25 KN with deviation 29.0%. When gap become 0.15 mm all three sample tensile shear strength increased and became greater comparing with gap 0.1, sample one reached 1.18KN, with deviation 36.0%. Sample 2tensile shear strength reached to1.17 KN, with deviation 38.0%, while sample 3reached 1.19 KN with deviation 32.0%.

The nugget diameter after welding complete depends on the number of weld spot and electric geometry, when gap between welded sheets equal zero [7], this fact changed when there is gap between welded sheets, so the most of contact pressure for electrodes and heat generated will losses in the deformation of sheet surfaces, this amount of losses increase by increasing the gap between the sheets, after the deformation stop and two sheets touch each other the current can now flow through the fine contact bridge.The spot welding nugget diameter measured by using a vernier caliper, two measurements should adopt when measuring the nugget diameter, because not always nuggets exactly round, and vernier caliper should be taken 90° to one another, as shown in figure 6.

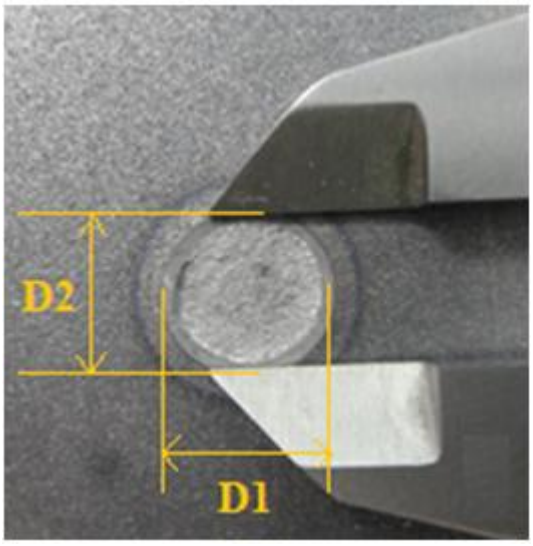


**Figure 6: Weld dimension to be measured**

Figure 7 shows the average of the nugget diameter when the distance between electrode and gap edge equal 15 mm. The mean diameter of three samples without gap obtained (7.8, 7.4 and 7.45) mm respectively. While the mean diameter of nugget decrease and becomes (7.2, 7.15 and 7.3) mm when gap equal 0.05 mm. The mean nugget diameter for three samples becomes (6.95, 6.80 and 6.85) mm, respectively when gap equal 0.1mm. Finally, when gap equal 0.15 mm the three samples mean nugget diameter becomes (6.50.6.65 and 6.75) mm respectively.

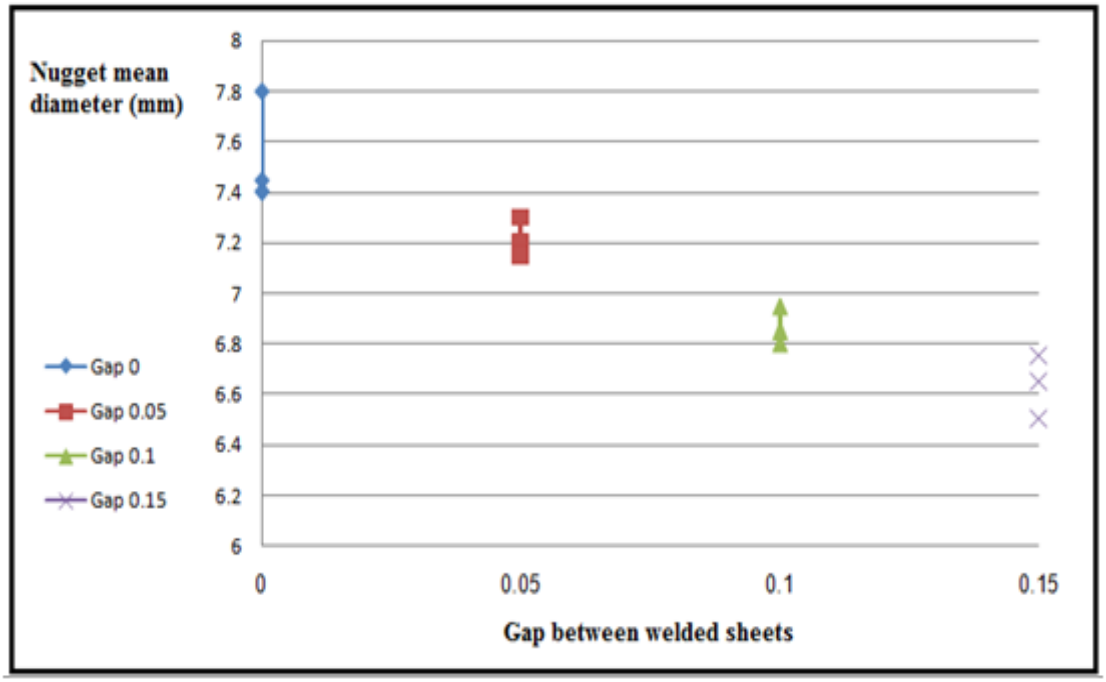


**Figure 7: Nugget diameter in gaps (0, 0.05, 0.1 and 0.15) mm when distance between electrode and thin sheet equal 15 mm**

## CONCLUSIONS

The mechanical behavior welded sheets using a spot welding process generally depends on parameters(force, current, time and diameter of the electrode), the gap parameter between welded sheets effect on tensile strength of spot welding. An initial force is applied by electrodes to ensure a good contact between the electrode and sheet as well as a good contact between the welded sheets itself, the gap between welded sheets effect on the quality of welded structure, an experimental study of the influence gap between welded sheets conducted on behavior of tensile test strength. From the results obtained that increasing the gap lead to decrease tensile strength and decrease size of the nugget and distance between electrodes and warping position also effect on tensile strength of overlap spot welding.

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