Identification of the Thickness of Nugget on Worksheet Spot Welding Using Non Destructive Test (NDT) – Effect of Pressure

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Abstract. Resistance Spot Welding (RSW) is a process of connecting between two worksheet with thermomechanical loading process, RSW is widely used in automotive industry, the quality of splicing spot welding is influenced by several factors. One of the factors at the time of the welding process is pressure. The quality of welding on the nuggets can be determined by undertaking non-destructive testing by using Non Destructive Test (NDT) - Ultrasonic Test. In the NDT test is done by detecting the thickness of the nugget area, the purpose of research conducted to determine the effect of pressure to welding quality with Nugget thickness gauge measurement with Non Destructive Test method and manual measurement with micrometer, Experimental welding process by entering the welding parameters that have been specified and pressure variables 1-5 bars on the worksheet thickness of 1 mm. The results of testing with NDT show there is addition of thickness in nugget superiority after compare with measurement result of thickness of nugget with micrometer which slightly experience thickness in nugget area, this indicates that the welding results have a connection between worksheet 1 and worksheet 2.

1. Introduction

Resistance Spot Welding (RSW) is a process of connecting between two worksheet and an electrode with thermal-mechanical loading process, RSW is widely used in automotive industry, the quality of splicing spot welding is influenced by several factors, such as welding time, current, electrode voltage, welding cycle, metallurgical properties, diameter tip electrode, force/pressure and others.[1 -6] One of the factors at the time of the welding process is pressure, where two plates are combined with a thermal-mechanical load, the mechanical load is in the form of electrode pressure on the surface of the worksheet, and at the same time there is a heating process.

The quality of welding on a nugget can be determined by performing a damage test or undamaged test. The damage test on welding results can be done with shear test worksheet, metallographic test and others, while the test is undamaged can be by using Non Destructive Test (NDT) - Ultrasonic Test (UT). [7] NDT commonly used test quality testing or looking for defects in SMAW welding results. In the NDT test is done by detecting the thickness of the nugget area, detecting the thickness of nugget to assess the quality spot weld [8]. NDT is performed by using a probe to scan the thickness of the
conjugated material, where the test is performed by scanning the welded material by utilizing the propagation power of the material, NDT is efficiency and reliability method to assess the damage [9].

In this study experimental welding process will be carried out to determine the quality of welding influenced by the mechanical loads of pressure, pressure variations made in the welding process, then measured the quality of spot welding using Non Destructive Test method to determine the joining between the two worksheet [10], and impact of the electrode pressure factor. The purpose of research conducted to determine the effect of pressure on the quality of welding with Nugget thickness gauge measurement with Non Destructive Test method (NDT) and manual measurement with micrometer. Experimental welding process by entering the welding parameters that have been specified and pressure variables 1-5 bar on the worksheet thickness 1 mm with used material Fe.

2. Methods

![Flow chart Identification of thickness](image)

**Figure 1.** Flow chart Identification of thickness

In the process of identifying the thickness of nuggets to determine the quality of the spot welding results, then performed several stages of the process, the determination of materials and dimensions of the electrodes and worksheets is very important in relation to the welding parameters at the time of the experiment, which is the determination of the parameters to determine the quality of the welding corresponding to the worksheet pairs and electrodes.

2.1. Material
Before doing experimental spot welding, the composition test was performed on the worksheet, the test specimen was tested using ARL 3460 testing machine spectrometry, at room temperature 25° C, with moisture 51% with the result of composition test as follows:
Table 1. Composition of Worksheet (Fe)

| Composition | Percentage (%) |
|-------------|----------------|
| C           | 0.05           |
| Si          | 0.01           |
| S           | 0.05           |
| P           | 0.01           |
| Mn          | 0.22           |
| Ni          | 0.06           |
| Cr          | 0.02           |
| Cu          | 0.01           |
| Al          | 0.04           |
| Fe          | 99.65          |

Spot welding process, using Cu electrode with tip diameter \((5\sqrt{t})\), where \(t\) = thickness worksheet (mm), in the worksheet welding process using Fe material with thickness \((1 + 1)\) mm [11].

2.2. Experimental

In this study experimental method, the pressure parameters on the spot welding machine vary between 1 Bar – 5 Bar, with 30% current output from Output Current Spot Weld JPC35 (9000 A), cooling used by water cooling.

Table 2. Specification of Machine Spot Weld

| Parameter                        | JPC 35 |
|---------------------------------|--------|
| Model                           | JPC 35 |
| Rated Capacity                  | 35 KVA |
| Rated Primary Voltage           | 380 V  |
| Rated Frequency                 | 50/60 HZ |
| Rated Sec. Current (max)        | 14,000 A |
| Duty Cycle                      | 8.5/7.5% |
| Output Current                  | 9000A  |

![Cycles/Current](image)

**Figure 2.** Parameters of Spot Welding

Experimental welding process with input parameters Current voltage 30%, then output current 270 KA and welding time 55 cycle \((55 \times 20\text{ms}) \approx 1100\text{ ms}\), size diameter tip of electrode 5 mm, and thickness of worksheet \((1 + 1)\) mm, with experimental process as follows:
2.3. Identification

The results of welding tested with Non-Destructive Test- Ultrasonic Test using normal TR (Transmitter and Receiver) probes. Frequency 4 MHz, Sound Velocity of 2267 m / s, range 100 and couplant using oil, boundary selection method using 6 dB drop, The tools used Ultrasonic Flaw Detector Karl Deutsch Echograph 1090 [11].

Some steps to do Non Destructive Test (NDT) using normal Transmitter –Receiver (TR) ultrasonic testing (UT) [11]:

1. First step Standard UT probe on surface of reference specimen (Calibration block).
2. The second step Ultrasonic Testing Turn on the device and select the type of menu that is normally used probe.
3. The third step select the menu with a range of 50 mm.
4. Step four Choose two-point calibration on the display menu and make sure the material speed for steel is 2267 m / s.
5. Make sure the five-pulse steps will appear on display scales 2.5, 5.0, 7.5, and 10.0
6. The final step of the final stage probe reading will appear on the display instrument.
3. Results and Discussion

![Spot Welding Results](image)

Figure 5. Spot Welding Results

![Graph](image)

Figure 6. Graph the results of measurement of nugget diameter

Zhao DW. et al. has argued that the greater the force applied to the electrode the larger the nugget diameter of the worksheet [12]. The experimental welding process with a pressure of 1-5 bar, spot welding results with different pressure variations can be seen in Figure 5 and 6, where it can be seen the difference of nugget diameter between 1 bar to 5 bar. Heat Affected Zone (HAZ) at 1 bar pressure has bigger area compared to HAZ on welding results with a pressure of 5 bar.
Figure 7. Results Non Destructive Test – Pressure of 1 Bar and 5 Bar

Non Destructive Test Result on welding result, using TR type normal probes, the following test result with different pressure show in Figure 7. The results of the test with NDT, where the amplitude detected by the probe shows the same character but with different results, wherein (a) shows the result of identification at the welding result with a pressure of 1 bar with the result of the identification 27.2 mm (25 mm media + worksheet 1 + worksheet 2), and (b) shows the result of identification on the welding result with pressure of 1 bar with the result of identification 27.4 mm (25 mm media + worksheet 1 + worksheet 2).

Figure 8. Results Measurement of Thickness NDT and Micrometer
Figure 8 shows the comparison of nugget thickness measurements on the worksheet, after identification with NDT and micrometer has a difference. The blue line on the graph shows identification with NDT, where at the pressure of 1 bar and 2 bar have the same value, seen from the visual (figure) the HAZ area is close to the same, whereas at the pressure of 2 bar has a value higher than the pressure of 1 and 2 bars, whereas at the pressure of 4 and 5 bar has the same thickness value, but greater than the pressure of 1.2 and 3 bar, the pressure shows a greater thickness, this is in comparison with the manual measurement with the micrometer. The average of the measurement with the micrometer is smaller than the measurement using NDT, it shows visually there is a pressure mark on the nugget area, whereas identification with NDT shows the overall impact of the area on the nugget against the thickness, this indicates that the welding results have a connection between worksheet 1 and worksheet 2.

4. Conclusions
In this study, it can be concluded that welding experiments are given 270KA output current parameters, Welding Time 1100 ms or 55 cycles on the spot welding machine 1-5 Bar, with worksheet thickness each 1 mm and diameter tip electrode 5 mm, where test results are tested with Non Destructive Test (NDT) with 25 mm propagation media , the results of testing on the welding results with Pressure 1 Bar and 2 Bar has a thickness value of 27.2 mm (media + worksheet1 + worksheet2), at the pressure of 3 Bar test results show 27.3 mm. (medium + worksheet1 + Worksheet2), on welding results with 4 bar and 5 bar pressure with same 27.2 mm thickness, NDT test results show the addition of thickness is proportional to the pressure and visually the smaller HAZ is inversely proportional to pressure and re-tested manually with a micrometer showing a reduction in thickness on the surface of the nuggets, identification using NDT identifies the edge of nugget surface area, this indicates that the welding results have a connection between worksheet 1 and worksheet 2.

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