Evaluation of Thin-Plate Low Carbon Steel in Spot Welding with Non-Destructive Test (NDT) and Destructive-Test (DT): Pressure Effect

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Abstract

This paper has the purpose of how the pressure affects the weld quality and weldability on thin-plate low carbon steel with a thickness of 1 + 1 mm on the Resistance Spot Welding (RSW) process. The method used to know the impact of the welding quality by experimenting on the welding process uses low carbon steel thin plate material with a composition of 99,65% Fe and 0,05% C. It is low carbon steel and has a thickness of 1 + 1 mm using Cu electrode by providing the various parameters given the pressure of 1-5 bar, testing of Non-Destructive Test (NDT) using ultrasonic test and destructive test (DT) of shear testing, and microstructure test. The result of NDT testing obtained deformation of thick plate thickness at 1 bar pressure has more significant deformation compared to 5 bar pressure, while in microstructure test result of 1-2 bar pressure has better weldability than the pressure of 3-5 bar, while the result of the tensile - shear test obtained a large load of 1 bar of 544 kg greater than 5 bar tensile - shear test with load 248 kg, it can be recommended for welding on thin-plate low carbon steel 1 + 1 mm thickness can be given 1 bar loading.

Keywords: *Spot weld, non-destructive test, pressure*

I. INTRODUCTION

THE resistance spot welding (RSW) process can be a connecting process two materials, in general, are widely employed in the industry, especially the automotive sector [1-2]. RSW is applied within the automotive industry cause be its robustness, speed, flexibility, and low-cost operation [3]. Several factors influence this, welding time, pressure, plate material, plate thickness, etc. Process parameters such as current, time, and pressure are closely controlled to urge superior weld quality [4]. The electrode force/pressure aims to squeeze the parts to be welded, and thus, the primary purpose is to carry to verify the parts in intimate contact at the joining [3].

The automotive industry uses a plate of varied thickness [3]. The resistance spot welding during the process usually uses force and current at the plate surfaces and to forge the metal during post-heating [5], welding pressure is produced by force exerted on the joint by the electrodes [6]. The standard of a quality weld is typically used features measurable, like the physical and the strength, when evaluated in either a destructive or non-destructive manner [6].

Referring to several parameters in the spot-welding process, one of the parameters determining the welding quality is pressure. It is essential to decide how much heat, time, and pressure are required to process the spot welding simultaneously. Non-destructive testing is very effective and efficient. The influence of the pressure parameter is one of the references in evaluating the quality of the welding results with non-destructive methods. This paper aims to determine how the effect of pressure and weldability on thin plates of low carbon steel with a thickness of 1+1 mm, evaluation of welding quality results is carried out by the non-destructive test method (NDT), compared with the results of the destructive test (DT) such as microstructure and shear-tensile test, where the test results can be seen the impact on the quality results of the welding process on the pressure parameters that occur during the spot welding process.

II. Materials and Methods

A. Materials

The method used to know the impact of pressure in welding quality results by experimenting, it is with the welding process on low carbon steel material thin plate with the composition shown in Table 1, has a thickness of 1 + 1 mm, and property material low carbon steel shown in Table 2 and using Cu electrode [7] by providing the various parameters given the variety of pressure between1-5 bar, testing of the non-destructive test (ultrasonic test), tensile - shear testing, and microstructure test, with the composition of thin plate materials used as Table 1 [2,8]:

Table 1. The specimen composition of thin plate low carbon steel

Element	Percentage (%)
Fe	99,65
Mn	0,22
Ni	0,06
S	0,05
C	0,05
Al	0,04
Cr	0,02
others	-

Table 2. Property material low carbon steel [7]

Yield Strength (MPa)	Tensile Strength (MPa)	Strain (%)	Modulus (MPa)	Load Peak (N)
62	139	0,5	36	1759

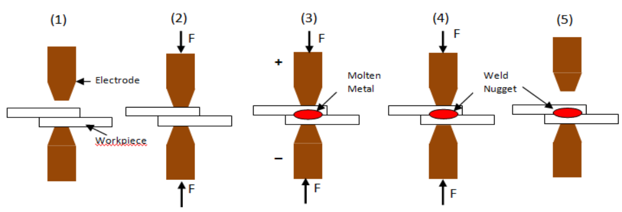
B. Methods

Set-Up

The experimental process of welding process was carried out by providing several parameters: Current of 5,6 kA, pressure 1-5 bar [2], welding time 1,2 s, diameter tip electrode of 5 mm [7], with the specification of the machine used in Table 3 [2]:

Table 3. Spot weld machine specification

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%



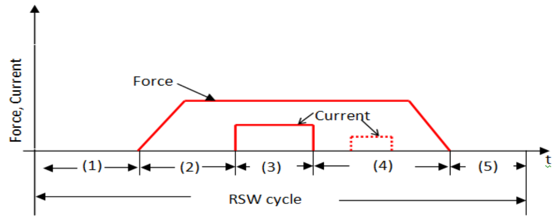


Figure 1. Resistance spot welding cycle [9]

Figure 1 RSW process experiment the sequence is: (1) workpiece inserted between open electrodes, (2) top electrodes down and applied pressure, (3) weld time and current is switched on, (4) current is turned off and the applied pressure is maintained or increased and (5) electrodes are opened, and the workpiece assembly is removed [9].

Non Destructive Test

The non-destructive method is carried out by measuring the thickness of the spot weld on the nugget due to the amount of pressure applied during the spot welding process after conducting a welding experiment. Evaluation of nugget thickness through the non-destructive test (NDT) method is shown in Figure 2.

The process of measuring the thickness of the nugget uses a normal transmitter that works to emit ultrasonic waves and is paired with a receiver (TR), the specifications of the ultrasonic probe used are 4 MHz frequency, 2267 ms sound speed for range 100 steel and couplant oil, limit selection method using a drop of 6 dB. Non-destructive testing using an ultrasonic flaw detector with the type of Karl Deutsch Echograph-1090 [2], [8].

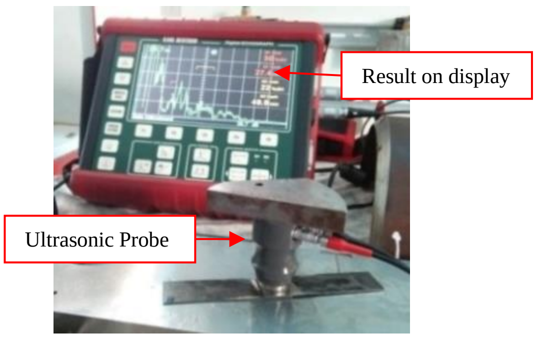


Figure 2. Ultrasonic test (non-destructive test)

Microstructure test

Microstructure test using the Olympus GX71 machine shown in Figure 3. This test aims to know the result of the welding connection.

Figure 3. Olympus GX71 machine

Tensile- Shear Test

The tensile shear test is carried out using a tensile test machine which will pull the test object until it breaks, then the test results in the form of shear stress can be known through a graph. The shear stress of the test results indicates the magnitude of the shear force acting on the test object.

III. Results and Discussions

A. Non – Destructive Test

The result of NDT is shown graphically in Figure 4. The display shows the thickness of the nugget on the workpiece.

Figure 4. Display of non destructive test

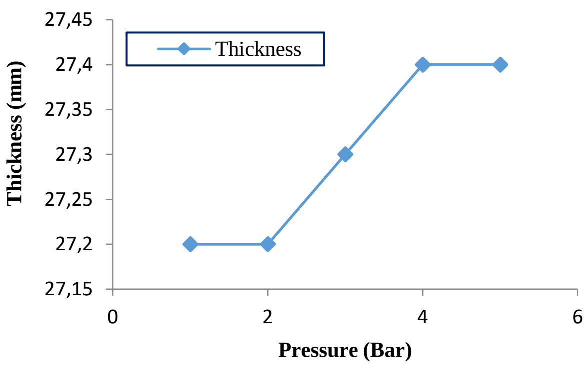


Figure 5. Results of non destructive test

The non-destructive test used the Ultrasonic Flaw Detector with Karl Deutsch Digital Echograph machine type, with the test using ultrasonic waves and a normal probe. The purpose of NDT testing is to know whether the welding results in the nugget area are properly connected. This test is carried out on a block V with a thickness of 25 mm, so that if added two specimens, where one specimen is 1 mm, then the total measurement is 27,3 mm. Figure 5 shows the ultrasonic test results, where the greater the pressure indicates the greater thickness of the nugget, it's like the results of research Raut M et al. States that the electrode force increase will affect the decrease heat, another effect is a high pressure that exerted on the weld joining process will decrease the resistance at the point of contact between the electrode tips, and the surface of the parts [1].

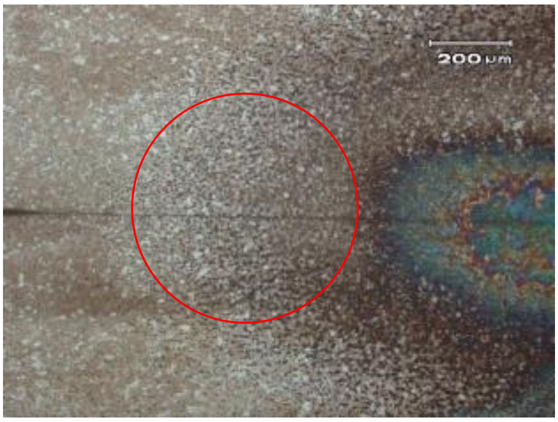
B. Destructive – Test

Microstructure

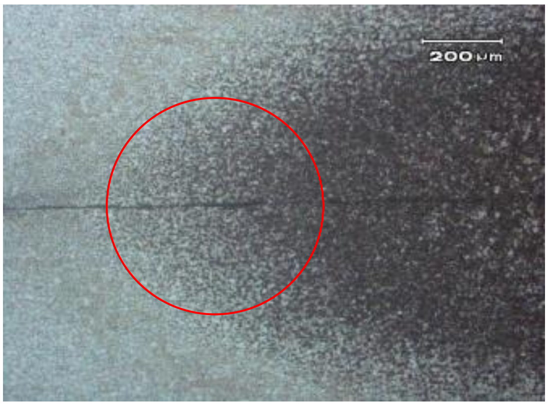
After the non-destructive test was carried out, the results of the spot welding process then continued with the destructive test. The first destructive test was the microstructure, while the destructive test results that had been carried out are shown in Figure 6.

(a)

(b)



(c)



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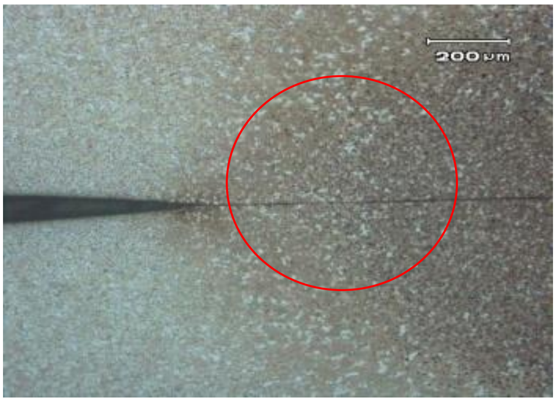

(e)

Figure 6. Result of micorstructure test (a) 1 bar, (b) 2 bar,(c) 3 bar, (d) 4 bar, (e) 5 bar.

Figure 6 shows the results of microstructure testing, on (a) welding with 1 bar load and (b) welding with 2 bar load (red circle), indicating that the welding and material connections are fused, at (c) welding with a load 3 bar, (d) with a load of 4 bar, and (e) welding with 5 bar load still show welding gap, which means the welding connection, and the material does not joint, caused by the amount of pressure, and lack of heating in the welding process.

Tensile-Shear Test

Evaluation with the destructive test at a later stage with tensile shear testing is done to determine the shear strength of the point weld welding results. This determines mechanical behavior under static conditions on spot welding results [10 -11].

Figure 7. Specimen of tensile-shear test

Figure 7 shows the fault area at 1 bar, not on the welding joint but the material, while 2 to 5 bar breaks in the welded joint area.

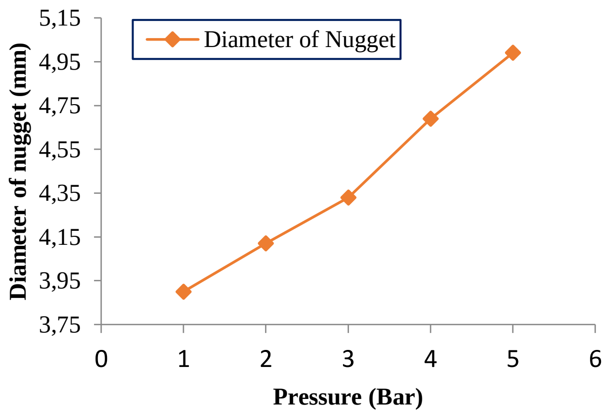

Figure 8. Diameter of nuggets

One of the determinants of joint quality at the spot weld, more specifically, can be known by measuring the diameter of the nugget [6]. Figure 8 show of the effect of pressure on the nugget diameter, the force applied is greater. It will have an impact on the large nugget diameter of the plate [12].

Figure 9 shown the tensile-shear in the specimen with a pressure condition of 1 bar is greater than the specimen under other pressure conditions. The parameters input of resistance spot welding, which one considered for spot welding process on the thin- plate are the force of electrode, time and current of welding, however, the nugget tensile strength becomes the output parameters [13].

Generally, the performance of the spot welding would consider in static or quasi-static conditions and load [10]. As the pressure is increased, the contact resistance and the heat generated at the interface will decrease [6].

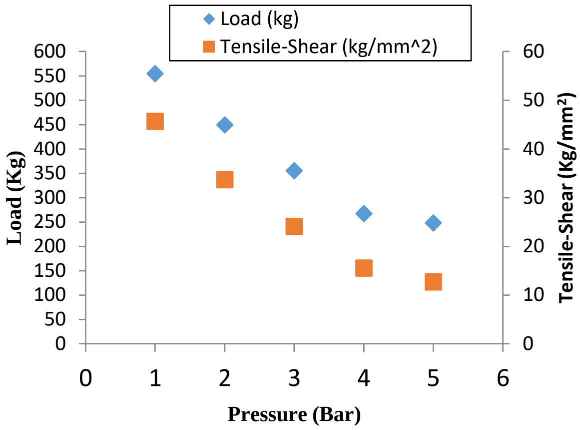

Figure 9. Result of tensile-shear test

The results of experiments and tests using NDT and DT showed that testing using NDT measured thickness due to pressure in the welding process was shown at a value pressure 1 bar and 2 bar, because the thin of the plate of sample a pressure 1 bar and 2 bar is thinner compared to the results experimental 3 bars, 4 bars, and 5 bars, whereas microstructural test results show that the unification of the two materials in the welding results with a value pressure 1 bar and 2 bar.

Those results shows the similar results of the NDT, but related to strength and ability to withstand the load, the tensile - shear test results, showing the nugget diameter at 1 bar pressure is smaller, and shows able to withstand greater loads and has greater shear stress compared to other pressures, this shows the best welding quality and good weldability on low carbon thin plates occurs at a pressure of 1 bar, this shows the correlation between the nugget diameter and the shear strength [14].

The results of the tensile-shear test and the measurement of the nugget diameter showed that the nugget diameter had the largest diameter at a pressure of 5 bar, showing a very low tensile strength compared to the others, this shows that during the welding process, the presence of a greater pressure resulted in an enlarged nugget diameter but has an impact on the inhibition of heating in the nugget area and has an impact on the small tensile strength [15].

IV. Conclusions

The result of NDT testing obtained deformation on the plate thickness, where there, on the plate thickness show the deformation has bigger at 1 bar compared to 5 bar pressure, while in microstructure test result of 1-2 bar pressure has better weldability than the pressure of 3-5 bar. In contrast, the result of DT, the tensile-shear test obtained a large load of 1 bar of 544 kg more significant than 5 bar tensile-shear test with load 248 kg, it can be recommended for welding on thin-plate low carbon steel 1 + 1 mm thickness can be given the pressure 1 bar.

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