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The ultrasonic testing of the spot welded different steel sheets

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Properties

ABSTRACT

Purpose: Purpose of this paper is to investigate the applicability of spot welded different steel sheets to ultrasonic testing, because resistance spot welding of the steel sheets is widely used in the car bodies and transport fields and ultrasonic testing is a good way to evaluate the fatique life of the spot welds.

Design/methodology/approach: Methodology of this paper is that two different steel sheets (AISI 304 type austenitic stainless steel sheet and Galvanized steel sheet) were welded to each other by using resistance spot welding. Some pre-welding tests were made to obtain suitable and optimum weld nugget diameter; and the welding current vs. nugget diameter curve were obtained. By using this curve and kepting constant welding parameters such as current, electrode pressure, weld time, etch., fully identical four spot welded specimens having 5 mm (±0.2) nugget diameter were obtained. The specimens and nugget diameters were tested by using a special ultrasonic test apparatus which is designed for spot welded joints.

Findings: Findings are that after the first ultrasonic tests, the four identical spot welded sheets which have AISI 304 – Galvanized steel sheet combination were subjected to the fatigue test in four different number of cycles. There is no any rupture or fracture in spot welded joints after fatigue tests. The spot welded specimens subjected to fatigue test were tested in ultrasonic test apparatus to observe the variation in the weld nugget and joint. The ultrasonic test results before fatigue and after fatigue were compared with each other; and the decreasing of the weld nugget diameter were observed while increasing the number of cycles. The results were shown in figures and discussed.

Research limitations/implications: Spot welding of different steel sheets forms different microstructures which respond different values to ultrasonic testing. Evaluation of these responses are quiet difficult.

Practical implications: Only a few spot welds can be evaluated among approximately 4 thousands of spot welds on a car body. Only selected spot welds can be ultrasonically tested.

Originality/value: Resistance spot welding of AISI 304 and galvanized steel forms austenitic, martensitic and ferritic microstrucutre in the same weld region. Ultrasonic testing of austenitic microstructures is different than the other microstructures. In this study the response of different microstructures to ultrasonic waves are investigated.

Keywords: Ultrasonic testing non-destructive; Resistance spot welding; Different austenitic steels

1. Introduction

The corrosion resistance of the steel sheets is very important in car bodies and thus galvanized steel and austenitic stainless steel sheets take the place of the uncoated steel sheets in automotive industries. One of the major concerns in the spot welded joints is fatigue, because these joints are exposed to variable loads in the automobile structures [1, 2]. The fatigue crack begins at the interior surface of welded sheets in the heat affected zone (HAZ) [3]. It is very important to know weld nugget formation of the spot welded member after the fatigue and hence

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determine the serviceability of the spot welds by ultrasonic testing before rupture [4,5] . Ultrasonic testing of austenitic structures are different the other types of structures [6, 7, 8, 9]

In the present work, galvanized steel and austenitic stainless steel (AISI 304) sheets were resistance spot welded as lap joints and fully identical four spot welded specimens having 5 mm (± 0,2) nugget diameter were obtained. The specimens and nugget diameters were tested by using a special ultrasonic test apparatus which is designed for spot welded joints. After the first ultrasonic tests, the four identical spot welded sheets which have AISI 304 – Galvanized steel sheet combination were subjected to the fatigue test in four different number of cycles. There is no any rupture or fracture in spot welded joints after fatigue tests. The spot welded specimens subjected to fatigue test were tested in ultrasonic test apparatus to observe the variation in the weld nugget and joint.

2. Welding process

In this work, commercial AISI 304 type stainless steel sheet and galvanized steel sheet were used. The sheet materials were joined as lap joints. The thicknesses of the galvanized and stainless steel sheets are 0,95 mm. and 1,03 mm., respectively.

Four identical spot welded specimens were obtained with galvanized steel – austenitic stainless steel sheet combination and 5 mm (±0,2) nugget diameter. In Figure 1, the photograph of the macro section of the weld nugget is given.

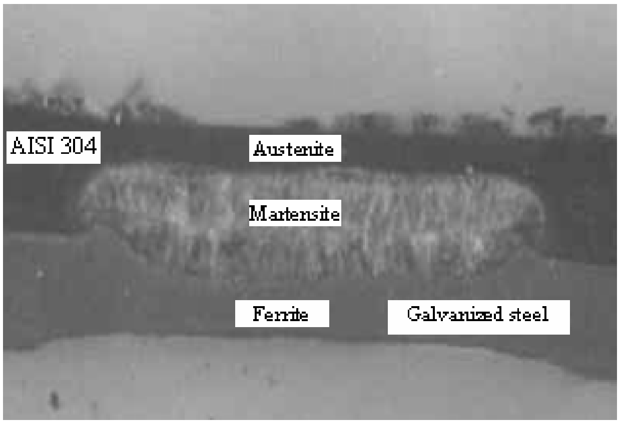


Fig. 1. The macro section of the weld nugget

The weld joint has an austenite + martensite + ferrite micro structure. These structures have fully different properties and grain sizes from those of base metals.

3. Fatigue tests

The fatigue testing was performed in laboratory conditions. As shown in Figure 2. All tests were performed using a sinusoidal waveform operating at 10 Hz. During the fatigue experiments, load and specimen displacements were recorded and monitored by the test control system. Each four spot welded specimens was exposed to fatigue test with 30000, 60000, 90000 and 104000 number of cycles respectively.

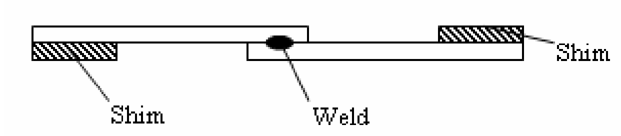


Fig. 2. Sketch of typical lap joint specimen with shims attached

4. Ultrasonic tests

Ultrasonic tests were performed before and after fatigue. Before fatigue tests operation, spot welded specimens are inspected by an ultrasonic test apparatus which has special spot welding probes with different diameters. The results before fatigue showed that four spot welded specimens have suitable nugget diameter, and the obtained weld joints are valid for operation. Figure 3 shows the used ultrasonic test apparatus, special spot weld probes and ultrasonic testing.

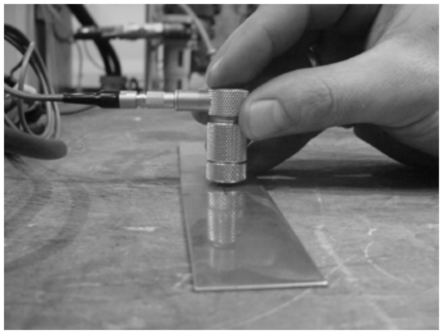


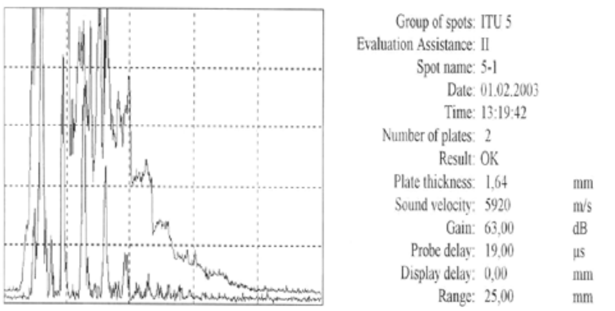
Fig. 3. Ultrasonic test apparatus and probes

During the fatigue test, the load range and load frequency were kept constant. The specimens exposed to the fatigue test were investigated and it was shown that there was no major damage and rupture on the joints between the steel sheets. After the fatigue test, to observe the decrease of the nugget diameter, the ultrasonic tests were repeated. The ultrasonic test results before and after the fatigue were monitored and compared with each other.

4.1. Ultrasonic test results

In this step of the study, the results taken by ultrasonic test apparatus were investigated and discussed. Figure 4 shows the ultrasonic test results of the fatigue specimen exposed to 30000 cycles fatigue.

Figure 4 shows that in the specimen with 30000 cycles fatigue, total sheet thickness decreases from 1,89 mm to 1,79 mm. During the welding operation a deformation is formed around the weld nugget of 0,1 mm. According to result of the ultrasonic test apparatus (bad – through weld) it can be said that the cold weld zone around the weld nugget is separated. In this welded specimen, the diameter of the weld nugget is not decreased.



a) Before fatigue (no failure)

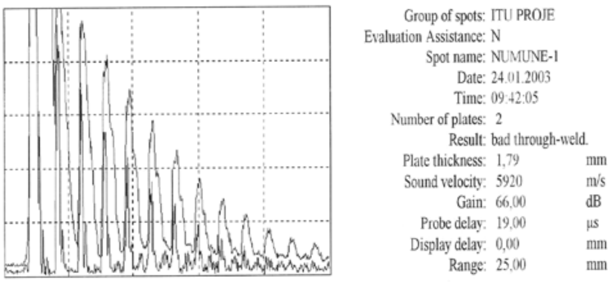


Fig. 4. The specimen exposed to 30000 cyles fatigue

In Figure 5, the ultrasonic test results of the fatigue specimen exposed to 60000 cycles fatigue is shown.

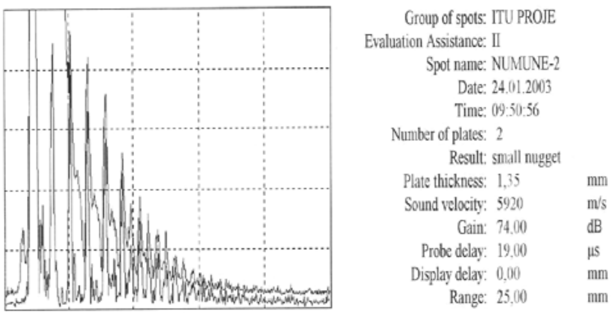


Fig. 5. The specimen exposed to 60000 cyles fatigue

In this spot welded specimen, the weld nugget diameter after fatigue is 30% less than the original nugget diameter. Total thickness of the weld zone decreases into 1,35 mm. After the 60000 cycles fatigue, both the cold weld zone around the nugget is deformed and a crack initiation is formed around the weld nugget. Also, decreasing the weld nugget diameter shows the same results. The test results is given as small nugget.

Figure 6 shows the ultrasonic test results of the fatigue specimen exposed to 900000 cycles fatigue.

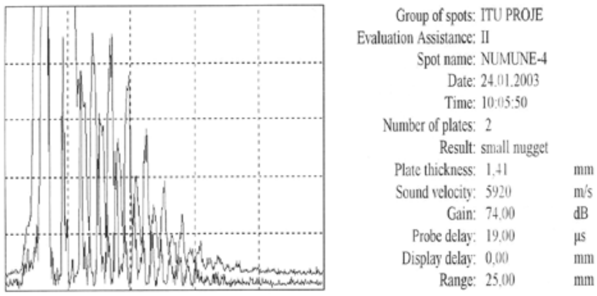


Fig. 6. The specimen exposed to 90000 cyles fatigue

Figure 6 shows that in the specimen with 90000 cycles, the nugget diameter decreases into 1 – 1,5 mm. The test result is given as small nugget. İt can be said that when the number of the cycles is decreases about 20% , a failure or a rupture can be seen on the weld zone.

In Figure 7, the ultrasonic test results of the fatigue specimen exposed to 1040000 cycles fatigue is shown.

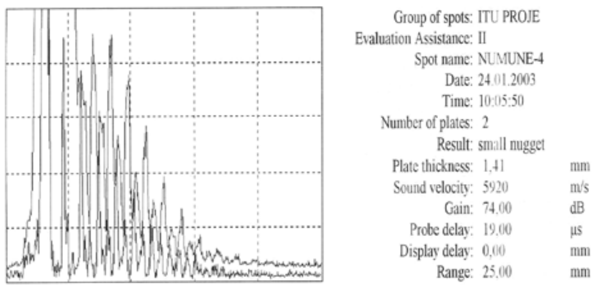


Fig. 7. The specimen exposed to 104000 cycles fatigue

In this 104000 cycles specimen, The nugget diameter decreases into approximately 1 mm. The test result is given again as small nugget.

The ultrasonic test results shows that while the number of fatigue cycle is increased, the weld nugget diameter decreases; but this decreasing is not linear. Figure 8 shows the effect of the number of the fatigue cycle on the nugget diameter.

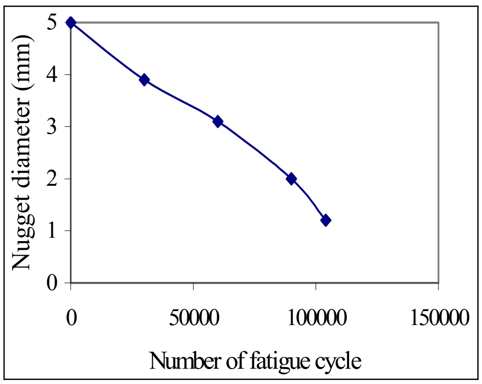


Fig. 8. The effect of the number of the fatigue cycle on the nugget diameter

As seen clearly from Figure 8, while the number of fatigue cycle is increased, the nugget diameter decreases rapidly. It can be said that, the crack growth rate during the fatigue is not constant and it increases while increasing the number of fatigue cycle.

5. Conclusions

In this study, two different steel sheets (AISI 304 type austenitic stainless steel sheet and galvanized steel sheet) were welded to each other by using resistance spot weld. The specimens and nugget diameters were tested by using a special ultrasonic test apparatus specially designed for spot welded joints. After the first ultrasonic tests, the four identical spot welded sheets which have AISI 304 – Galvanized steel sheet combination were subjected to the fatigue test up to 25% stiffness drop. There is no any rupture or fracture in spot welded joints after fatigue tests. The spot welded specimens subjected to fatigue test were tested in ultrasonic test apparatus to observe the variation in the weld nugget and joint.

In low number of fatigue cycles, such as 30000, total sheet thickness decreases from 1,89 mm to 1,79 mm. The deformation on the weld area is about 0,1 mm. The result of the ultrasonic test is given as ”bad – through weld” and the cold weld zone around the weld nugget deforms. The diameter of the weld nugget is still between the valid tolerances.

While the number of fatigue cycles is increased, weld nugget diameter decreases rapidly, and a crack occurs in the weld nugget accaording to loading mode. In high number of fatigue cycles, the results of the ultrasonic test apparatus are ”small nugget”. This results show that while the number of the fatigue cycle is increased expecially high levels, the weld nugget is not between the valid tolerances, and the crack growth rate increases rapidly.

According to the results of the ultrasonic tests, the diameters of the weld nuggets are decreased from 5 mm to 1 mm during the fatigue tests. Because the thickness of the materials at the weld zone are quiet small, the ultrasonic test did not show any difference for the different microstructures which are austenite, martensite and ferrite at the weld zone. This shows that ultrasonic tests can be applied to the spot welded joints of different steel sheets.

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