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Research paper

Hemispherical Low Blow Impact Treatment Spot-welded Joint

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Abstract

Resistance spot welding (RSW) is one of the latest techniques to join sheet metals together by utilizing both current and pressure through specific or localized area. In this study, the effect of tensile shear on the resistance spot welding after the low blow impact treatment of low carbon steel sheet with 1.2 mm thickness, using a hemispherical head are investigated. The microstructures of the welded parts were also examined. In the automotive industry, this technique is widely used due to several advantages. In addition, the hardness of the samples was also evaluated. Before conducting the experiment, the samples were examined using a spectrometer in order to identify the essential elements in the sample. Tensile shear test and hardness test were conducted to investigate the mechanical properties of the steel with and without post welding treatment that is the low blow impact treatment (LBIT) by using a hemispherical head. Based on the results obtained, it was found that samples that have been treated with LBIT of 20 Joule energy level had the highest maximum load, in which it can withstand 5.744 kN load before failure. This suggests that the hemispherical LBIT on the spot welded has a high potential technique that could be used to improve the mechanical properties of the join.

Keywords: *LBIT; Mild steel; Post Weld Treatment; RSW.*

1. Introduction

Welding is one of the best methods for joining metals. Resistance spot welding (RSW) is one type of the welding techniques for joining two materials. The heat gained from electric current is used in this resistance spot welding. By exerting certain pressure clamped with copper electrode to concentrate the current into a small spot at the particular welded metal, the joining process will be complete. Treatments are needed to ensure compressive residual stresses are induced at the weld part [1]. Welding force and flowing of current are needed in resistance spot welding. This is a good enhancement to the weld part. Resistance spot welding for joining metal is usually used in the automotive industry. In the automotive industry, the resistance spot welding is widely used for manufacturing the body of a car. Most of the RSW in the automotive industry uses automatic robotic welding. This is to ensure the consistency of the RSW on the body part of the automotive vehicle. Three remarkable advantages of post treatment are to reduce stress concentration at weld toe, increase local hardness and also to induce compressive residual stress [2]. The resistance spot welding had been used in joining mild steel components for many years.

Nowadays, industrial machines have significant structures that provide enough support when subjected over the period of its life span. Most of the machine at least has one part that is assembled through welding process. This requires enough strength of the welded part or joins in order to sustain those loads that change over the period of time. Each machine has been designed with a specific safety factor and whenever they carry exceeding load, consequently it would fail due to cracking. This always happens as the load is applied repeatedly to the subject. Thus, for this study, another method for treatment has been used which is low blow impact treatment, a method that is improvised from PIT.

Subsequently, this study is to demonstrate that the mechanical behavior of mild steel resistance spot welding could be improved after experiencing post weld treatment of low blow impact treatment using hemispherical head. The test that was conducted was tensile shear test. Other than that, the microstructure of mild steel was examined after it undergoes the resistance spot welding process. The objectives of this study are to enhance the understanding in RSW technique, to determine the tensile and hardness properties of mild steel RSW with post weld treatment and to examine the fracture behavior that occurred.

The main purpose of this research work is to introduce an innovative technique for treatment that is low in cost and could strengthen the welded part in numerous applications.

2. Experimental Procedures

2.1. Material, Spot Weld Process and Experimental Set-up

The low carbon steel sheets of 1.2 mm thickness were used to generate the experiment. The steels were cut into two parts. The first part (welded join) was 105 mm in length and 45 mm in width. The second part (shim) was 35 mm in length and 45 mm in width and was prepared to minimize the bending during the tests. The contact overlap was 35 mm. An illustration of the specimen size prepared for resistance spot welding is shown in Fig. 1.

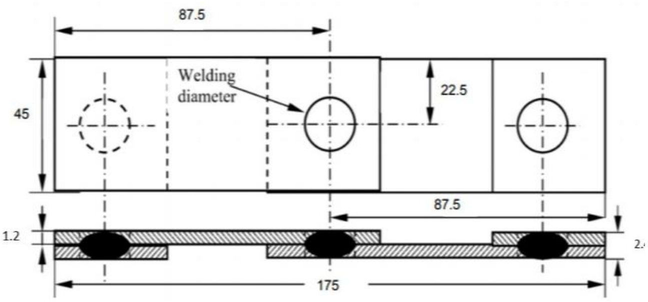

Fig. 1: Spot welding sample dimension

A pedestal spot welder that is capable of producing 75 kVA secondary current was used for spot welding. The parameter was set using the welding time of 0.2s, electrode force of 2.3 kN, and welding current of 10 kA [3]. The electrodes were made of copper alloy, and had a flattened face diameter of 6 mm.

Spot welds were subjected to tensile-shear loads using a universal testing machine. The test was performed by following the standard BS EN ISO 14271: 2011. Cross-head speed was kept constant at 2mm/min. Load-displacement curve and peak load were extracted from the cross-head. Failure mode was detected from failed samples.

Cross-sectioned samples were ground, polished and etched with 15% nital alcohol mixture with the swab method for about 5 seconds to reveal the features of the welded zones. Optical microscope was then used for examination of microstructure profiles. Vicker's microhardness testing was conducted along the diagonal direction of joins. An indenter with 1kgf load and dwell time of 15 s was adopted.

2.2. Hemispherical Low Blow Impact Treatment (LBIT)

Hemispherical Low Blow Impact Treatment (LBIT) was performed using mini falling weight impact tester. This treatment is conducted manually on the spot weld samples. The sample was clamped and the impactor was adjusted before conducting the test to ensure that the dropping impactor hit the weld region of each sample. The impact energy of the sample was calculated using the equation (1),

$$E=mgh \quad (1)$$

Where; m = the mass of the impactor plus any mass added on it; g = acceleration due to the gravity (9.81m/s^2); and h = the height of impactor from the sample. The level of the impact was tabulated in Table 1. The schematic illustration of hemispherical LBIT on welded samples is shown in Fig. 2.

Table 1: Energy level and required height.

Energy level (Joule)	Height (mm)
4	100
8	200
12	300
16	400
20	500

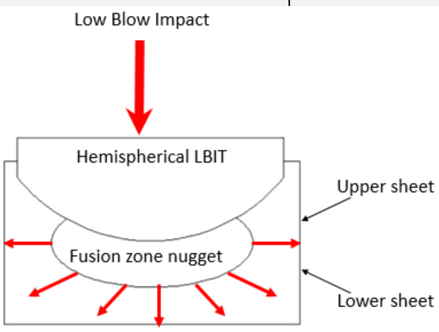

Fig. 2: Schematic illustration of LBIT process

3. Result and Discussion

3.1. Microstructure

Microstructure profiles showing the comparison of the LBIT welded joints and as-welded samples are shown in Fig. 3. The different zones are shown in this section. Those zones are fusion zone and heat affected zone. The development of complex microstructure in RSW could impact the failure behavior of the welds [4].

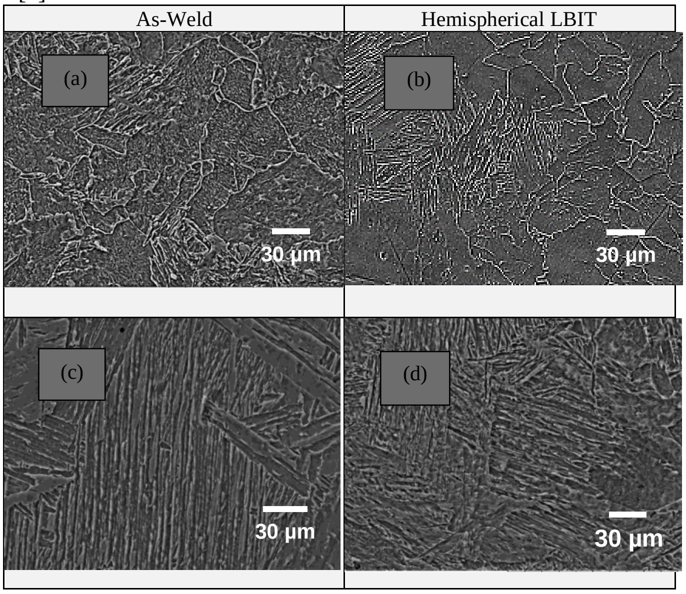

Fig. 3: Microstructure changes of (a) HAZ as-welded, (b) HAZ 20 Joule LBIT (c) fusion zone as-welded and (d) fusion zone 20 Joule LBIT

The existed microstructure above are because of the specific etchant used to distinguish the microstructure which is martensite (white), ferrite (grey) and bainite (black) [5]. The difference that could be observed in the microstructure of FZ is that the grain is columnar if compared to the microstructure of HAZ.

3.2. Tensile Test

The highest energy level of LBIT shows an increment of 11% in the load from the RSW as welded. This is due to the strong bond produced during compressive stress that causes the increment in the tensile-shear load of the RSW LBIT. The compressive stress that was applied by low blow impact was intentionally to reduce the residual stress that existed in the spot weld joint [6].
Table 2 shows that sample with 20 Joule LBIT exhibits the highest average maximum load that it could endure before it failed. For 20 Joule LBIT sample, the failure mode was observed to be a complete pullout button as shown in Fig. 4. This failure is generally the preferred fracture mode in resistance spot welding due to higher plastic deformation and energy absorption [7]. High failure load was obtained in FZ nugget caused by strain hardening effect during the treatment process.

Table 2: Maximum load of samples

Description of Sample	Maximum Load (kN)
RSW as welded	5.223
LBIT 4 Joule	5.245
LBIT 8 Joule	5.371
LBIT 12 Joule	5.409
LBIT 16 Joule	5.558
LBIT 20 Joule	5.744

The failure mode of LBIT 4 Joule sample that has an interfacial failure affected the performance of the load it could withstand before failure as shown in Fig. 5. Interfacial failure could be the factor of low load carrying behaviors mentioned by Donders et al [8].

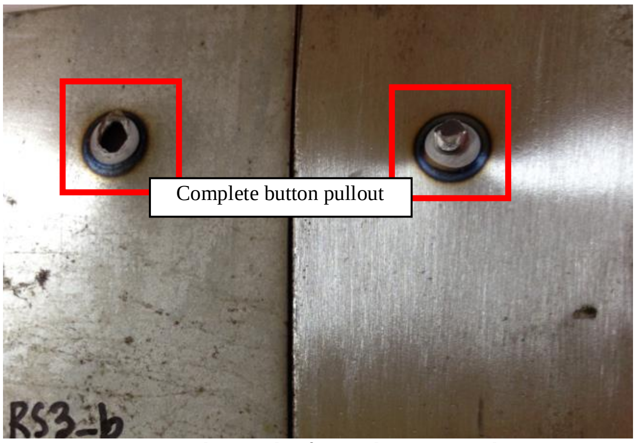

Fig. 4: Failure mode of 20 Joule LBIT samples.

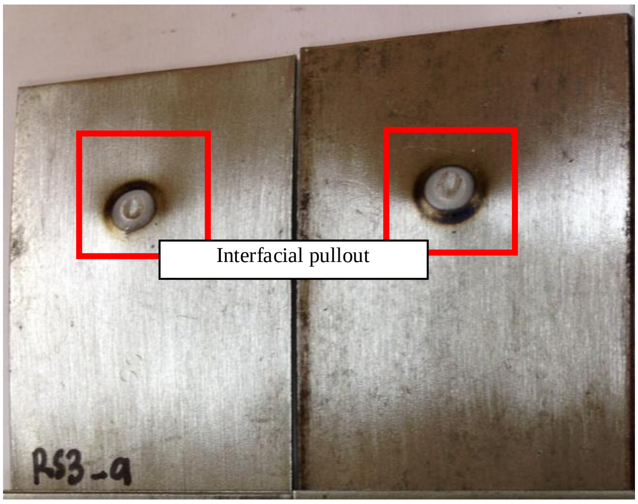

Fig. 5: Failure mode of 4 Joule LBIT samples

3.3. Micro-Vickers Hardness

The LBIT was performed on the spot-welded area, hence it mostly affects the fusion zone and slightly in the HAZ. The hardness of the base metal of all samples showed about the same value (~ 128 and 154 HV). The highest energy level of LBIT showed optimum result in making the hardness of fusion zone at the highest value. Ramazani et al [9] mentioned that the low hardness of the HAZ compared to the FZ is said to be due to the distortion in the crystal volume of the of FZ grains.

This distortion is known as the elastic distortion that leads to martensite transformation that could boost the hardness in the FZ [8]. Inducing increment of LBIT treatment in the weld joint also could be one of factor that helped in the elastic distortion in crystal volume of the FZ grains. The hardness of the samples is shown in Fig. 6.

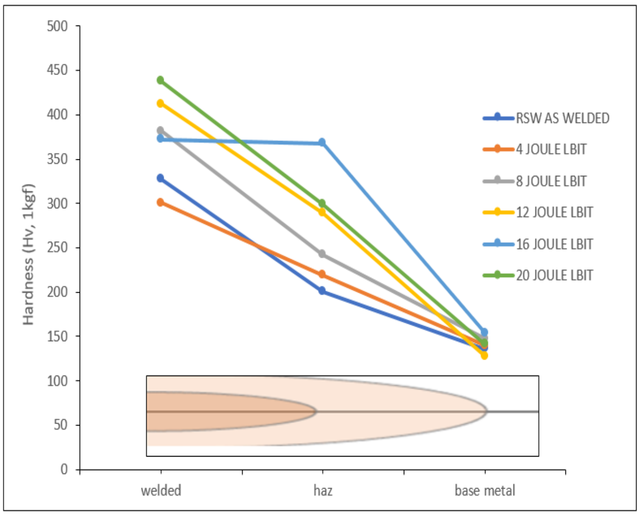

Fig. 6: Hardness profile of the samples.

4. Conclusion

The application of low blow impact treatment on resistance spot welded joint has resulted in stress distribution on the weld nugget so that the tensile shear strength is achieved. Based on the result obtained, impact treated samples has increased its strength in terms of the tensile strength as the energy level of the impact treatment increases. The LBIT treatment, which is one of the post weld treatment, could be used to enhance the tensile strength and the hardness of the weld nugget. LBIT treatment can help to strengthen metals even through cold working, as there is no heat required for the treatment.

The understanding of the resistance spot welding technique were acquired and it showed there are several parameters that needed to be focused on when performing the resistance spot welding such as the welding current, the weld time, the electrode force and the hold time. The LBIT 20 Joule was the highest maximum load it can endure before failure as compared to other samples that is 5.744 kN as recorded. The hardness at fusion zone of LBIT 20 J was also the highest compared to other samples. The third objective, which is to examine the fracture behaviour was also achieved. LBIT 20 J samples showed double pullout failure. Therefore, the mechanical properties of these RSW increased almost linearly with the increase of energy level for hemispherical low blow impact treatment.

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