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An Experimental Study on Effects of Post Weld Impact Treatment on Spot Welded Steel

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Abstract

Post Weld Impact Treatment (PWIT) is an impact treatment method for improving mechanical properties of welded joints. The mechanical properties of the welded joint were reduced due to the distortion and stress corrosion cracking caused by the welding process. This paper focuses on the study of influences of pneumatic impact treatment (PIT) and low blow impact treatment (LBIT) for spot welded joint of similar materials through the mechanical properties. This experiment was conducted with the 1.2mm thickness material of carbon steel with welded single lap shear joint. All the welded samples were tested for its mechanical properties by performing the tensile- shear and hardness test. The study has shown the effect of the tensile shear and hardness which focusing on the base metal (BM), fusion zone (FZ) and heat affected zone (HAZ) of the material after being impact treated. The improvement of the tensile behaviour in such local areas can increase significantly the efficiency of higher carbon steel in the entire structure. This paper deals with the influence of PIT and LBI on mechanical properties in carbon steel spot welded plates to determine other beneficial of treatment effectiveness. The experimental investigations follow the standard of AWS D8.9m which tested using Universal Tensile Test Machine (UTM) and Vickers Hardness tester. Further, the comparison of the tensile strength and hardness value in as-welded (untreated) and treatment samples are to be established. The finding shows that tensile strength is improved, and the fracture location is shifted from critical weld metal to base metal area.

Keywords: Spot welding; Post Weld Impact Treatment; Pneumatic Impact Treatment; Low Blow Impact Treatment

INTRODUCTION

Resistance spot welding (RSW) is considered as the leading process for joining two or more metal sheets through fusion at the contact area of electrode tips in the automotive industry. Low-carbon steel encompasses the largest percentage of material welded with the spot weld process [1]. This process uses two copper electrodes to compress the sheets together and supply an enormous amount of current through the contact area of electrodes [2]. When the melting point of the metal is reached, the metal will begin to fuse, and a nugget begins to form. The current is then switched off, and the nugget is cooled down to solidify under pressure [3]. Due to the weld thermal cycle, a heterogeneous structure will be created in spot weld and the region around it. The melted and solidified areas of base metals are then, called as weld nuggets, and it consists of three major zones which are fusion zone (FZ) which is melted during welding process and is re-solidified showing a cast structure, heat affected zone (HAZ) which is not melted but undergoes microstructural changes, and base metal (BM) which remains unaffected during welding process [4].

In the spot welding process, the mechanical properties of the joining metals are reduced because of the distribution of residual stress. Generally, spot welding joints occur in two failure modes which are an interfacial failure (IF) and pullout failure (PF) [5]. High-Frequency Mechanical Impact (HFMI) has significantly developed as a reliable, effective and user-friendly method for post-weld treatment in order to improve dynamic load capacity of the structures [6]. It is also known as pneumatic impact treatment (PIT) where it is a high-frequency hammer peening method where pins are accelerated by air pressure and produce plastic deformation which results in a beneficial compressive resistive spot in the material, reduction of residual stresses and smoother weld toe profile, also improve the fatigue resistance of welded structures. The induced compressive residual stresses in the treatment prevent the track cracking and the crack propagation on the surface [7].

This study focuses on examining the influences of the application of post weld impact treatment (PWIT) for spot welded joint of similar materials through the shear, tensile and hardness properties. Comparisons in terms of the mechanical properties have to be made for the samples to verify the results of impact treatment on the improvement for the spot weld joining. Regarding this concern, all the welded samples were later subjected by performing a tensile shear test to test the strength of the welded joint to fail or tear apart in terms of its load and the properties through the failure modes to the energy-absorbing capacity of a weldment. Microhardness distribution from base metal (BM) to fusion zone (FZ) will be measured. This paper aims to study the effect of PWIT for spot welded joint of similar materials through the mechanical properties.

EXPERIMENTAL PROCEDURE

Material and Sample Preparation

The sample used for the study is a joining of a low-carbon steel (LCS) material with a single lap shear joint. The sheet steels were prepared in a rectangular shape with a size of the length (170mm), width (45mm) and thickness (1.2mm). The chemical composition of the steel is given in Table 1 [8].

Table 1: Chemical Composition of low carbon steel

LCS	C	S	Mn	P	S	Fe
	0.05	0.01	0.21	0.011	0.005	Bal.

Samples were prepared according to AWS (American Welding Standard) standard which is D8.9M [9]. The resistance spot welding (RSW) process parameter are presented in Table 2 [10].

Table 2: Welding Parameters

Welding Parameter	Unit
Electrode Force	2.3 kN
Welding Time	0.2 sec
Welding Current	10 kA

Treatment Equipment and Parameters

HFMI was performed using pneumatic impact treatment (PIT) on the welded structures. The HFMI hammer operates with a hardened pin with a ball resting on the workpiece with a diameter of 3 mm. This pin was hammered with an adjustable intensity at minimal frequency requirement of 90 Hz [11] at the welded region and pressure applied from the compressor is 4.5 bar. Local mechanical deformations occur in the form of a treatment track. The weld toe was deformed plastically and bonded.

Low blow impact treatment (LBIT) was performed manually by Mini falling weight impact tester. The LBIT was done on the spot weld samples. The LBIT involved with the low-velocity impaction without destroying the samples. The localized damaged that imposed on the spot weld samples were then study as one of the treatment methods. The samples were clamped between two steel plates having 18mm diameter hole at the centre. The impactor was adjusted before conducting impact tests to ensure that the dropping impactor hit the weld region of each sample. Fig. 1(a) shows the schematic of the post-weld impact treatment process by using pneumatic impact treatment, while Fig. 1(b) shows the low blow impact treatment.

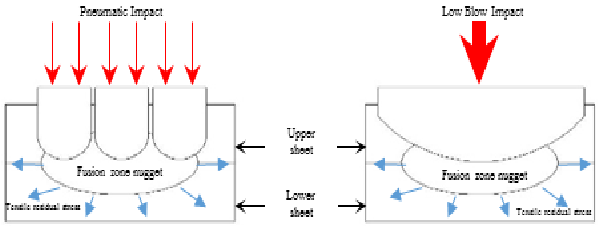

Figure 1: Schematic illustration on post-weld impact treatment process, (a) pneumatic impact treatment and (b) low blow impact treatment.

Tensile shear Test

The mechanical tests of tensile-shear were conducted at a crosshead of 2 mm/min with an Instron universal testing machine as according to AWS standard [9]. The maximum load was taken which the breaking of weld occurred. Peak load (maximum load) and the failure energy were extracted from the load-extension curve. Data points for peak load and extension were the average of the measured values for the five samples.

Hardness Test

Samples for RSW as-weld, RSW PIT, and RSW LBIT were analysed on their toughness and hardness of the average of five different samples with the load of 1kgf acting on the sample surface using Mitutoyo MVK-H1 Vickers Hardness test machine according to AWS standard [9]. Time taken for each indentation was about 15 seconds. Readings of hardness (HV) and distance (mm) were taken for microhardness measurement profile along the weldment, as shown in Figure 2.

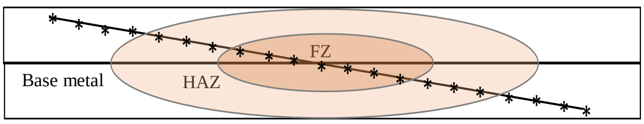

Figure 2: Hardness test profile

RESULTS AND DISCUSSION

Tensile-shear Properties of spot-welded joint

The tensile shear curve of base metal and RSW as-welded is provided in Figure 3 and Table 3. The as-welded samples show a significant increment of 74% in tensile-shear load from the base metal value. In addition, one can be observed that base metal exhibit obvious elongation and ductility as compared to the RSW as-welded sample. The increment in the tensile-shear load of the RSW as-welded condition is mainly caused by the strong bond of base metal and the introduction of hardening precipitates as well as the increment in pre-existing dislocations [12].

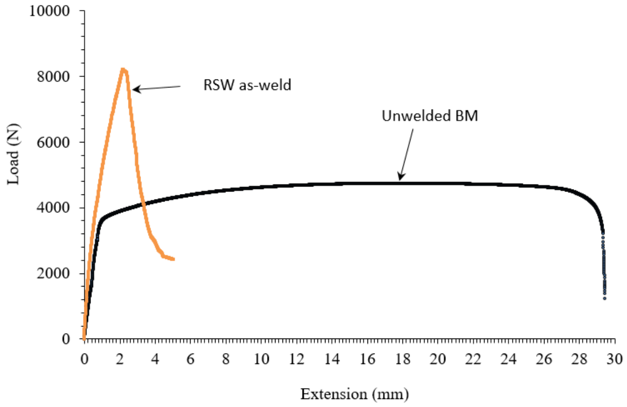

Figure 3: Tensile-shear curves.

During the welding process, the force, heat and time affect the RSW joint of physical characteristics such as fusion zone size, heat affected zone size, indentation, and defects. The austenite and ferrite phase will form in fusion zone based on the base metal composition. Upon cooling different morphologies can be observed in weld zones thus resulting in an increment of shear strength value [13, 14].

Table 3: Welding Parameter

Description of tensile sample condition	Load (kN)
Un-welded BM	4.72
RSW as-weld	8.20

Effect of Post-Weld Impact Treatment on Tensile-shear of Spot-Welded Joint

Several post-weld treatments were applied on the spot-welded joint. Post-weld treatment involved in welding area consists of Pneumatic Impact Treatment (PIT) and Low Blow Impact Treatment (LBIT). The mechanical properties of each post-weld treatment were discussed in this section. Tensile-shear test was done to determine the shear strength of the samples as for RSW as-weld, RSW PIT and RSW LBIT of spot-welded joint. Table 4 presents the tensile-shear load for all samples.

Table 4: Welding Parameter Tensile-Shear Load for RSW PIT, RSW LBIT and RSW as-weld

Peak Load (kN)	RSW PIT	RSW LBIT	RSW as-weld
	8.81(0.07)	8.42(0.07)	7.71(0.12)

RSW as-weld samples failed early and reached the break point when the loading is 7.71 kN. Meanwhile for the RSW PIT sample experienced higher loading acting on the sample which is 8.81 kN. The comparison between the shear load of RSW PIT and as-welded samples are shown in Figure. 4.

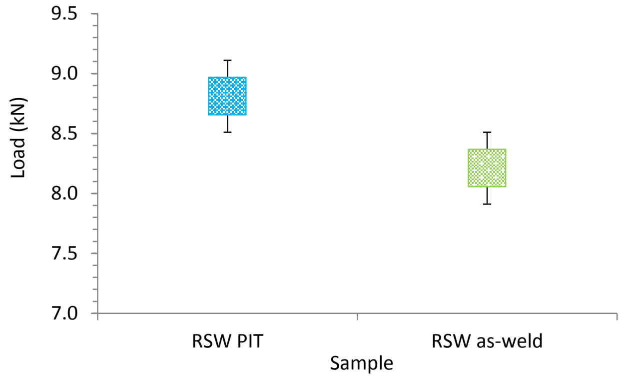

Figure 4: Tensile-shear Load of RSW PIT and as-welded samples

The extension of the RSW PIT samples is much higher which is 4.057 mm and the extension of the RSW as-weld samples is about 3.583 mm. PIT samples experienced an enormous increased in weld strength due to the rise of permanent dislocation of the atomic structures in weld metal which required much more load in tension to destruction or tear apart. From the analysis of the maximum extension, it shows RSW PIT samples experienced high ductility while getting an increase in strength, hence it will give benefit for the weldability to avoid sudden break when fail. The increased in tensile-shear strength mainly due to compressive stress applied which is reduced and negate any residual stress generation during pneumatic impact treatment process [15].

The shear strength of the samples as for both RSW LBIT and RSW as-weld samples of spot-welded joint as shown in Figure 5. The shear load for RSW LBIT samples was higher than the RSW as-weld samples which are almost 9%.

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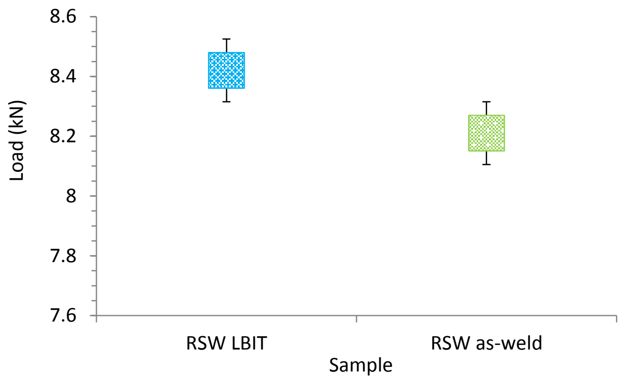

Figure 5: Tensile-shear Load of RSW LBIT and as-welded samples

Effect of Post-Weld Impact Treatment on Hardness of Spot-Welded Joint

The hardness of the fusion zone was measured in spot-welded joint section as well as in the through thickness of welded zone as shown in Figure 6. It is found that the hardness of base metal material for both RSW as-weld and PIT samples are about the same between 149 and 155 HV. It was observed that the hardness of FZ was higher than the heat affected and base metal. The hardness of HAZ approaching the base metal experiences visibly drop. The previous researchers thought that the drop phenomenon was due to the HAZ softening which was the reduction of hardness in respect to base metal because of the tempering effect [16-18].

Compared to the HAZ region, the effect of melting, the microstructure in fusion zone resolidified in RSW joints plays a major role in the elimination of strain hardening which significantly softens the weld zone [19]. This, in turn, causes a decrement of the hardness values in the vicinity of the fusion zone. The mean hardness value of the fusion zone in the as-welded condition is recorded at 211 HV compared to the average value of 268 HV obtained for the PIT treated.

Figure 7 shown the hardness value for LBIT samples increased rather than untreated samples as expected. The hardness of base metal seemed to be lower than HAZ and FZ region due to the unaffected region during solidification process for both samples and also during impact treatment [12]. For LBIT samples, the hardness value of the fusion zone increases almost 8% after treated using low blow impact. From this results, it can be seen that, the weld joint which treating with low blow impact contributed to maximum hardness with brittle manner of weld zone but with some plastic deformation which represents by the softening region.

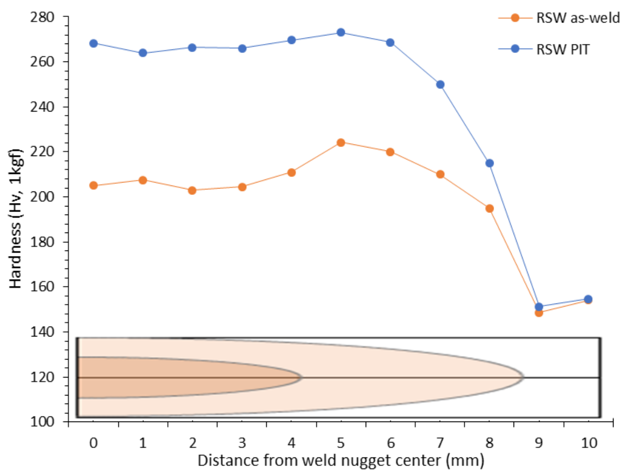

Figure 6: Microhardness profile for RSW PIT and RSW as-weld samples using Hardness Vickers

Hardness at fusion zone and HAZ were showed considerably higher values than that at base steel. Due to melting conditions during the welding process, re-solidify displayed relatively large volume fraction of ferrite morphologies which induced to softening of the zone. For the hardness properties, it can be stated that LBIT samples are harder than as-weld samples.

The hardness values in the fusion zone cross-section of all three different samples are shown in Figure 8. Almost identical hardness distribution is achieved for all samples. The distribution clearly demonstrates that the hardness value of RSW was largely affected by the applied post-weld conditions.

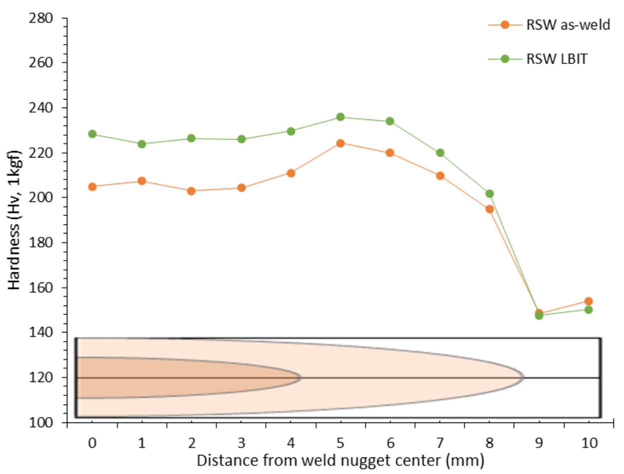

Figure 7: Microhardness profile for RSWLBIT and RSW as-weld samples using Hardness Vickers

The RSW PIT was found to have the largest increment from the RSW as-welded condition in the FZ which the followed by LBIT. The HAZ in as-weld samples recorded the lowest hardness value within a range of 140-220 HV while the PIT reached readings up to 280 HV. These discrepancies are most likely caused by work hardening process due to dynamic loading and the additional surface hardening effect induced by PIT caused the RSW with PIT joint to have the highest increment.

The PIT influences the weld geometry by reducing the stress concentration. Furthermore, the local hardness is increased due to local cold forming, and beneficial local compressive residual stresses are induced [11, 20, 21]. The low impact energy produced during LBIT also caused severe deformation and extensive plastic flow in treated zone successively improved the local hardness of the samples, but the compressive residual stress is partially attributed to the weld zone as compared to the PIT.

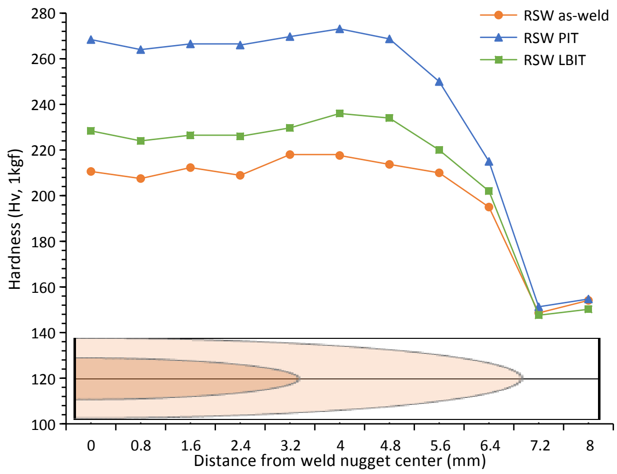

Figure 8: Microhardness profile for RSW PIT, RSW LBIT and RSW as-weld samples using Hardness Vickers

CONCLUSION

Application of PWIT has resulted in an increment in plastic deformation in the weld nuggets formation and therefore the increment of tensile strength was obtained. Impact treated samples have shown higher strength than RSW as-weld samples which can result in extending the joining lifetime for carbon steel. The hardness values of welded areas dominant to HAZ were increased due to the treatment applied. By analysing the results from the tests, it shows that the application of PWIT enhances the weldability of carbon steel with the joining of spot welding related to its mechanical properties. In other words, it is proven throughout the experimental analysis that the PWIT has increased the lifetime for the carbon steel spot weld joining which can result in the high potential of material cost saving for loading structures in industries.

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