Improvement of Mechanical Properties in Treated Spot Welded Joint

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ABSTRACT

Post Weld Impact Treatment (PWIT) is one of the treatment method usually applied on weld region to reduce the level of residual stress originated from welding process. During the spot weld process, the formation of stress produced around the weld area and degrade the mechanical properties of the joint. This paper focused on the improvement of mechanical properties of spot welding joint via Pneumatic Impact Treatment (PIT) process. This experiment used the material of low-carbon steel with welded single lap shear joint with the constant thickness of 1.2 mm. All the welded samples were subjected to tensile-shear test, failure mode and hardness test. The tensile-shear load and fusion zone hardness of RSW joint after PIT was improved by 8% and 27%, respectively. The results indicated improvement in tensile-shear strength and hardness of treated samples compared to as-welded samples. From the observation, the failure mode was the failure mode type which was generally accepted failure for spot-weld joint. The improvements of the mechanical properties is envisaged as the result of the mechanical pulses produced by unique fluidic muscle conveyed to the surface of the RSW joint during PIT process.

Keywords: *spot welded; mechanical properties; pneumatic impact treatment.*

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Introduction

Low-carbon steel accommodates the biggest percent of material welded with the resistance spot welding process [1]. Resistance spot welding (RSW) is a welding technique that joins two or more metal sheets through fusion on the contact area of electrode tips. This procedure basically makes use of two copper electrodes to compress the sheets together and supplies huge amount of current through the contact area of electrodes [2]. Whilst the melting point of the steel is reached, the steel will begin to fuse and a nugget starts to form. The current is then switched off and the nugget is cooled down to solidify under pressure [3] and because of the weld thermal cycle, a heterogeneous structure could be created in spot weld and the region around it.

The melted and solidified regions of base metals are then, referred to as weld nuggets and it includes 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 is remained unaffected during welding process. Generally, spot welding joints occur in two distinguished failure modes which are interfacial failure (IF) and pullout failure (PF) [4].

In the spot welding process, the mechanical properties of the joining metals are related to the residual stress and also influence the in-service performance of the structures [5]. The improvement of weld properties in some case can be achieved by post-weld heat treatment. 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 also known as Pneumatic Impact Treatment (PIT) where it is a high frequency hammer peening method where pins are accelerated by air pressure and produces plastic deformation which results in beneficial compressive resistive spot in the material, reduction of residual stresses and smoother weld toe profile. The induced compressive residual stresses in the treatment prevent the track cracking and the crack propagation on the surface [7]. Consequently, high frequency hammer peening was investigated as a mean for improving mechanical properties in RSW.

Several literature [8-11] has assessed the local mechanical properties of spot welded low carbon steel, however scarcely have assessed the effects of impact treatment on the mechanical properties on RSW. In this study, the PIT hammer peening was used to introduce the compressive residual stress into low carbon RSW. The influence of the peening on the mechanical properties of the RSW samples were evaluated.

Methodology

This section presents the method on preparation of low-carbon steel RSW samples, spot-weld treatment process, tensile-shear test procedures and hardness measurement method. The Pneumatic Impact Treatment (PIT) was used in the spot-weld treatment process.

RSW Samples Preparation, Treatment and Testing Equipment

The lap-shear joint are made of low-carbon steel grade JIS G3141 was cut into 105 mm x 45mm pieces in accordance to the AWS D8.9m standard. The two pieces of sheet (Figure 1) was welded using JPC 75 kVa [1]. The machine was set to AC waveform, and the 5 mm diameter electrode was truncated 30º. The chemical composition and mechanical properties of these steel was listed in Table 1.

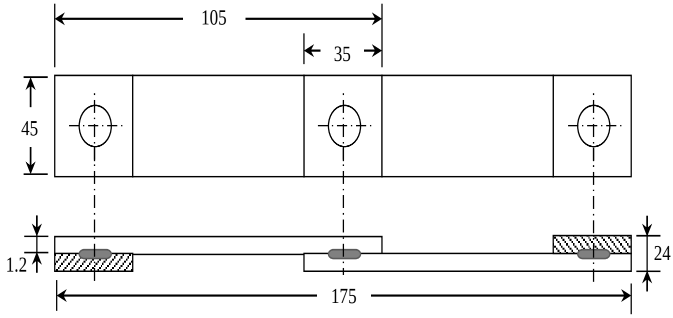

Figure 1: Spot-welded sample.

Table 1: Chemical compositions and mechanical properties

Composition	C	Si	Mn	P	S	Fe
%	0.05	0.01	0.21	0.011	0.005	Bal

Treatment Equipment and Parameters

Treatment was performed using pneumatic impact treatment (PIT) on the spot-welded area. The PIT hammer peening operated with a hardened pin with a ball resting on the work piece with a diameter of 3 mm. This pin is hammered with an adjustable intensity at 90 Hz at the spot-weld area and pressure applied from compressor is 4 bar. Figure 2 shows the surface of spot-welded area of the single lap-shear joint with the application PIT hammer peening. Local mechanical deformations occur in the form of a treatment track.

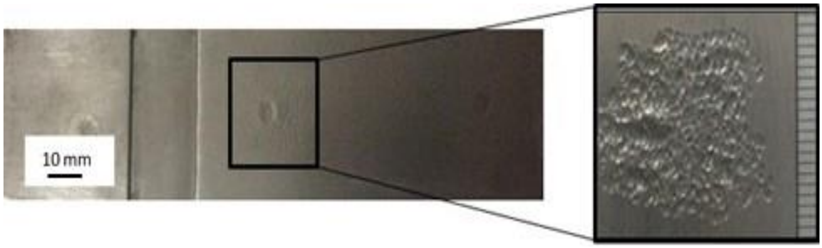

Figure 2: Area of spot-welded PIT treated samples.

Evaluation of Tensile-shear Load

The tensile-shear tests were performed at cross-head speed of 2 mm/min with a 100-kN testing machine according to the ISO 14323 standard.

Measurement of Hardness

Samples for both conditions were analysed on their hardness with the load of 1kgf acting on the sample surface using Hardness Vickers Tester with diamond indentation. Time taken for each indentation is about 15 second. Readings of hardness (HV) were taken for micro-hardness measurement profile along the weldments as shown in Figure 3 [12].

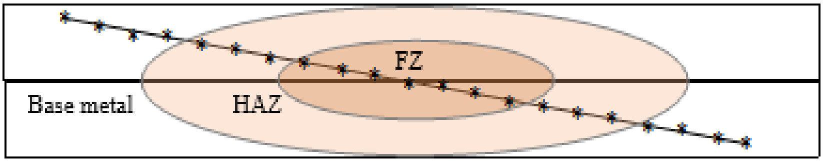

Figure 3: Hardness test profile.

Results and Discussion

In this section, the findings on tensile-shear test, failure observation and hardness measurements of RSW as-welded and treated samples are presented.

Effect of PIT on Shear Load and Failure Modes

Tensile-shear test was done to determine the strength of the samples as for RSW PIT and as-welded samples of spot welded carbon steel. The comparison of tensile-shear load of RSW PIT and as-welded samples is shown in Figure 4. The error bars represent standard deviations which shows the variation of the sample tested values.

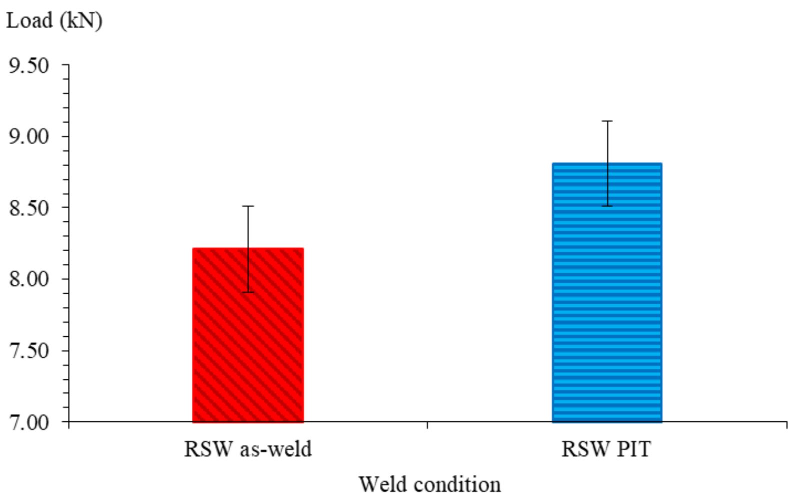

Figure 4: Comparison of tensile shear-load of RSW PIT and as-welded samples.

The RSW PIT samples show increment of 8% in tensile-shear load from the as-welded sample. The strong bond of base metal and the introduction of hardening precipitates, as well as the increment in pre-existing dislocations mainly, cause the increment in the tensile-shear load of the RSW PIT condition [13]. The increased in tensile-shear strength mainly due to compressive stress applied which is reduces and negate any residual stress generation during hammer peening process [14]. The tensile-shear failure of RSW PIT is shown in Figure 5. The treated sample was experienced pullout failure (PF) and generally the preferred failure mode in weld quality testing [15].

The failure modes have substantial influence on the peak failure load of spot weld. Furthermore, the energy absorption capability and its load carrying capacity are significantly affected by the failure modes. Tension and compression stress (Figure 6) were the driving forces for the interfacial and pullout failure mode. In the PF mode, increase in loading acting and stress in tension site on the treatment weld structures leads to higher plastic deformation since the amount of energy absorbed by the weld was bigger than in the case of IF where it was dominant for as-welded samples.

Figure 5: Pullout failure (PF) of treated samples.

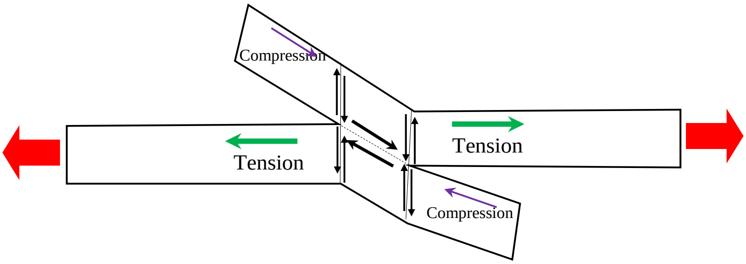

Figure 6: Force of the welded joint during shear tensile test.

Effect of PIT on Hardness

Figure 7 shows the hardness profile of spot welded carbon steels with acting loading of 1 kgf. Points of the indentation were most taken in the FZ in order to analyse peening region for treated samples. It was found that the hardness of base metal material for both RSW samples are about the same which is between 149 and 155 HV. It could be seen that the hardness of HAZ was higher than the fusion zone and base metal.

The HAZ experienced solid state phase transformation but no melting was induced during the welding process. The hardness of HAZ as moved toward the fusion zone experiences noticeable drop. Based on previous literatures, this drop was identified as HAZ softening which was mainly caused by the development of tempering martensite [16][17][18].

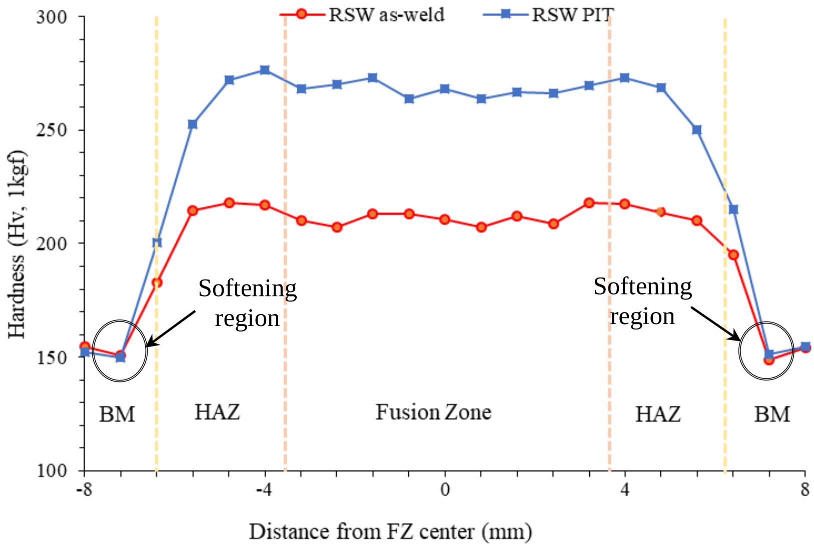

Figure 7: Micro hardness profile for treated and as-welded samples using Hardness Vickers.

Hardness value for treated samples experienced vast increased in rather than as-welded samples. The hardness for base metal seemed to be lower than HAZ and FZ region due to unaffected region during solidification process for both samples and also during the hammer peening process [19].

For treated samples, it shows a huge difference in the range of FZ and HAZ. No phase transformation occurred because BM of carbon steel was not affected during the hammer peening process. Hardness at nuggets and HAZ were showed considerably higher values than that at base steel. For the hardness properties, it can be stated that treatment sample was harder than the as-welded sample.

Conclusion

The tensile-shear load of RSW PIT exhibits the highest value (8.81 kN) as compared to RSW as-welded (8.20 kN). The post-weld impact treatment effect on the failure type was significant. Spot-welded joint treated with pneumatic impact treatment tends to have the pullout failure with tearing at base metal. This failure showed that, by implementing pneumatic impact treatment, the applied compressive stress diminished the tensile residual stress that occurred in the samples and highly plastically deformed. The spot-welded joint via pneumatic impact treatment effect the hardness value. The fusion zone hardness of RSW PIT attained the highest hardness value of 268 HV, followed by RSW as-welded of 211 HV.

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