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Resistance Spot Weld assisted with Adhesive Bonding

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Abstract*: This paper presents an experimental investigation of the weld bonding of low carbon steel (JIS G3141) together with adhesive layers to increase the mechanical properties of weld bonding. Epoxy adhesive was used in this research applied on the sheet thickness of 1.2 mm. The weld-bonding was carried out by applying layer of adhesive followed by resistance spot welding on surface samples. The relative properties and characteristics of the resulting weld-bonded-adhesive joints are evaluated and compared with the conventional spot-welding through tensile-shear, peel, hardness tests and macro-etching observations. The strength of weld bond joints was calculated and compared with those in as-weld and adhesive-bond joints. Results showed that the strength of weld-bond adhesive is higher than as-weld specimen. The hardness distribution of weld bond adhesive joints was investigated, at three regions i.e. base metal (BM), the heat-affected zone (HAZ), and the fusion zone (FZ) using micro-hardness Vickers machine. It can conclude that the presence of adhesive does not affect the hardness of weld-bonded. From macro- etching observation, the layer adhesive influenced the weld bond via the size nugget of weld-bonded which is smaller than as-weld. The introduction of adhesive layer in spot welding improves the joint strength and quality of spot weld.

***Keywords*: Heat Affected Zone, Mechanical properties, Nugget, Spot welding, Weld-bonding.**

I. INTRODUCTION

In resistance Spot Welding (RSW) fast heat is generated in the air gap between contact points when the current passed through the resistance using copper electrode. [1].

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Difference in conductivity between copper electrode and workpiece, caused the heat remains in the air gap. The workpiece will melt at the desired spot due to the large concentration of the heat.

Weld-adhesive bond is also known as hybrid joining is a process where spot weld process is combined with adhesive layer applied on faying surfaces (Fig. 1) of the metal part [2]. Messler [3] stated that the process commonly acknowledged as hybrid joining consists of weld-brazing, rivet-bonding, and weld-bonding. For weld bonding, compared to spot weld process, the stress concentration in the nugget part is relaxed so that body rigidity can be improved.

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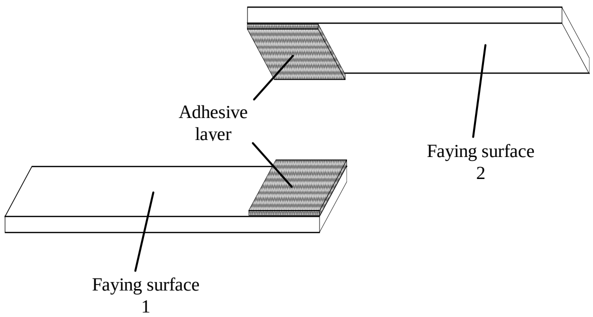

Fig 1. Schematic of the adhesive layer weld bond sample.

Hybrid joint process offers the best of both procedures; produce high joint effectiveness, imperviousness to different and complex stacking, stretch focus softening, and increase resistance of glue holding to boost and improve the quality of the joint.

The stress concentration at weld nugget is reduced by the adhesive as it distributes the stress equally [4]. Weld-adhesive bonding has several advantages such as shortened the joining process, ability to withstand high stress due to in or out of plane loads whether of a tensile, compressive, or shear nature and high tolerance for temperature. Furthermore, the corrosion and noise resistance of metal improves with the presence of adhesive layer on the surface sheet metal. Mechanical properties of weld bond joints such as quality and performance, especially in aluminium and stainless-steel adherents are well reported, however adherent of low carbon steel are less reported [5]-[9].

The aim of this study is to investigate the weld bonding of low carbon steel with adhesive layer as a treatment to increase the mechanical properties. The weld strength was investigated using a lap-shear, peel joints and hardness testing. The influence of adhesive layer on hardness of weld bond area were evaluated by optical observation.

II. EXPERIMENTAL PROCEDURE

A. Material and Sample

The samples used for the study is a joining of a low-carbon steel (LCS) JIS G3141 material with a single lap shear joint and peel joint. The geometry of the test samples utilized on spot weld, weld bond and adhesive bond are shown in Fig. 2 with the thickness of 1.2 mm and width of 45 mm. Samples were prepared according to American Welding standard D8.9m. The chemical composition of the steel is given in Table I.

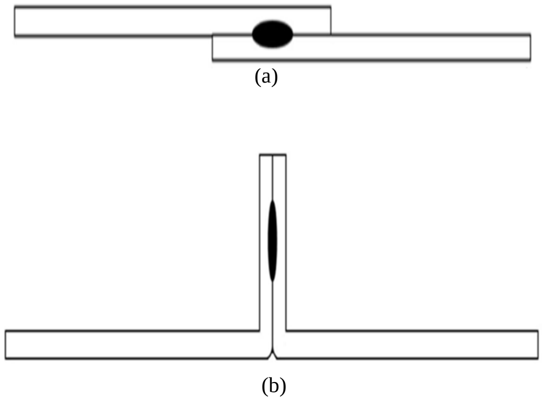

Fig. 2. Geometry of the test samples applied; (a) lap-shear joint and (b) peel joint.

Table-I: Chemical Composition of Low Carbon Steel

LCS	C	Mn	P	S
	0.127	0.168	0.0012	0.0067

A. Spot Weld and Weld Adhesive Bonding Process

The spot weld joints were prepared using 75 KVA spot welding machine with 5 mm in diameter electrode tips. The spot weld process parameter is shown in Table II.

Table- II: Welding parameters

Parameters	RSW
Welding current (kA)	12
Squeeze time (cycles)	2
Upslope current (cycles)	38
Weld time (cycles)	15
Hold time (cycles)	2
Off time (cycles)	26
Electrode forces (kN)	3.1

The adhesive was prepared prior to the spot-welding process. Selleys epoxy resin-based adhesive was used with hardener and resin ratio of 1 to 1. Spot welding process then applied before the adhesive fully cured.

B. Test Method

The mechanical test of tensile testing was conducted at a crosshead of 5 mm/mm with an Instron 5985 testing machine. Two commonly applied methods of tensile testing were adopted, i.e. tension-shear and peel testing (Fig. 3). The difference between both testing was the direction of tension applied on the weld samples. For the tensile shear, the direction of tension is parallel to the weld area, while tensile peel, the direction is perpendicular.

Vickers hardness testing is measured and converted to a hardness value by applying 200g load using diamond indenter and dwell time of 15s.

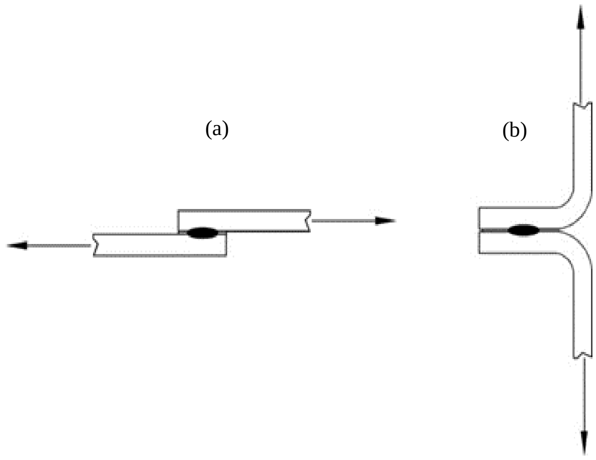

Fig. 3. Tensile test load: (a) tension-shear and (b) peel

The macrostructural studies of weld nugget and thickness layer of adhesive with evaluation of nugget size of both the spot weld and weld-bonded were carried out under Olympus Microscope model SZ61.

III. EXPERIMENTAL RESULTS

A. Effect of Adhesive Layer on the Spot Weld Strength

The peak load obtained by tensile test of joint produces by weld-bond, as-weld and adhesive bond as depicted in Table II

Table-III: Tensile Load of Various Process

Joint Design	Weld adhesive bond	As- weld	Adhesive bond
Lap	8.66	8.33	2.58
Peel	2.06	1.79	0.07

The maximum load carried by the weld adhesive bond joints is nearly equal to spot weld joint. The weld-adhesive bond has the highest load which is 8.66 kN at extension of 4 mm and followed by as-weld process which is 8.33kN at extension of 5 mm as illustrated in Fig. 4. The different maximum load of these two processes are not significant.

Adhesive process has the lowest maximum load compare to weld-adhesive bond and as-weld process. The weld-adhesive bond samples show a significant increment of 3.81% in tensile-shear load from the as-weld value. Comparing the samples results of the weld adhesive bond joint with those of the spot weld joint, it is found that the weld adhesive bond is able to stand relatively larger force in the lap shear due to adherents of epoxy layers [10].

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For peel joint test, the same trends as tensile shear test was observed. The weld adhesive bond samples showed highest load (2.06 kN) followed by as-weld process (1.76 kN). For peel test, adhesive bond has the lowest maximum load (0.07 kN) compare to other processes.

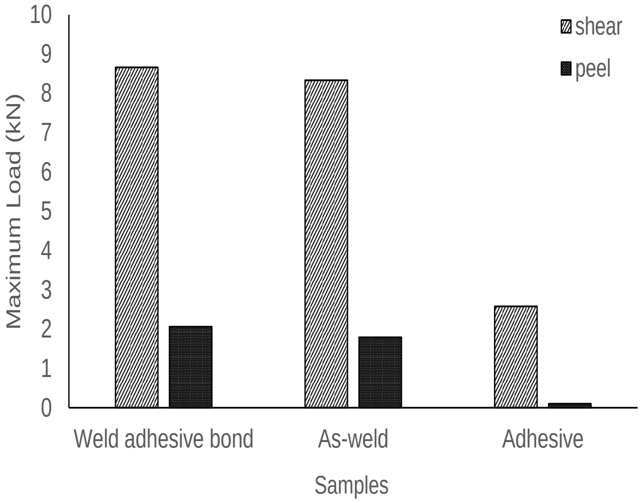

Fig. 4. Tensile load of various process.

The percentage increase in the peel strength between weld-adhesive bonded and as-weld strength is about 13%. Hence, the epoxy used which act as an adhesive improved the peel joint strength [11].

B. Effect of Adhesive on the Hardness of RSW

The hardness test focused on three regions i.e. weld nugget zone (zone a), heat affected zone (zone b), and base metal (zone c). The result is shown in Fig. 5, the hardness of weld-bond samples has the similar trend as an as-weld samples, but small changes still exist at a certain location outside weld nugget.

For example, at location 8mm, the hardness of weld adhesive bonded is higher than as-weld. The hardness of base metal at various areas has been found in the range of 115-130 HV.

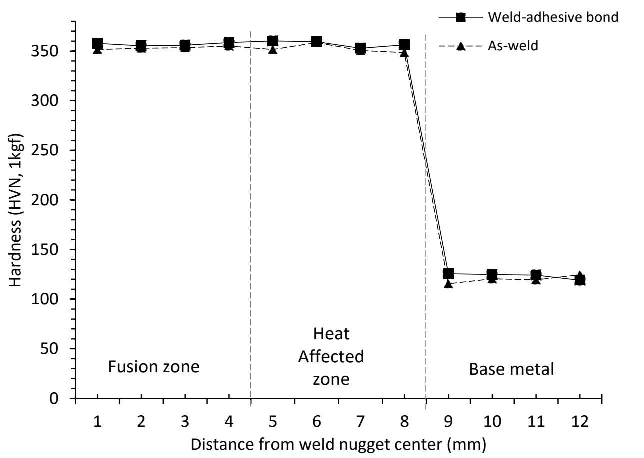

Fig. 5. Hardness of as-weld and weld-adhesive bonded samples.

The base metal for both weld joints has the lowest hardness compare to HAZ and fusion zone. The hardness of both samples increased intensely at HAZ and fusion zone region. This is due to melting and re-solidification process during welding. Relatively large volume fraction of ferrite morphologies formed which induced to softening of the zone [12], [13]. The HAZ region recorded highest hardness for both samples. The HAZ zone experienced solid-state phase transformation as there was no melting induced during the welding process.

a. Macrostructure Analysis

The result of macrostructure for weld adhesive-bonded and as-weld was recorded, and the size of weld nugget and thickness layer of adhesive were measured as shown in Fig. 6 and Fig. 7. This clearly shown that adhesive can affect the size of weld nugget.

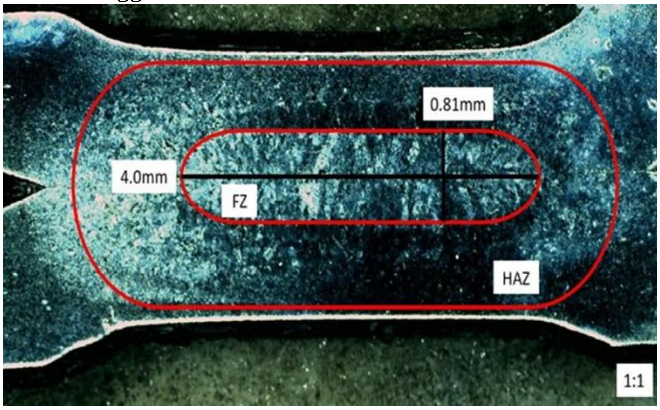

Fig. 6. Macrostructure of weld-adhesive bonded sample.

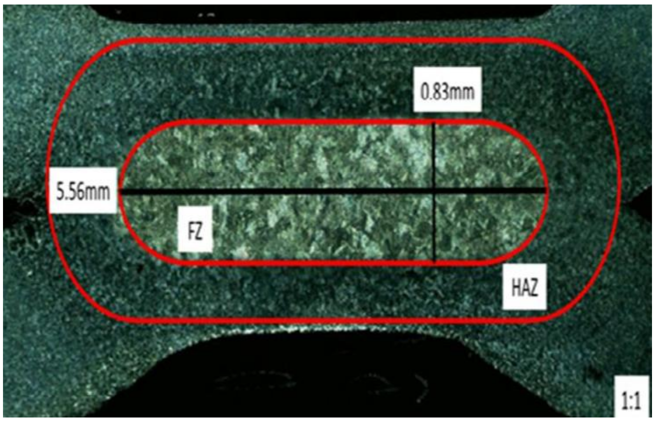

Fig. 7. Macrostructure of as-weld sample.

The size of weld nugget in weld-adhesive bond is smaller than weld nugget in as-weld samples. The percentage deduction of weld nugget size is 28.06 percent. This is attributed to concentration of significant amount of thermal energy by the presence of the adhesive layer in between weld region.

The average thickness layer of adhesive for each specimen is 0.436 mm as depicted in Fig. 8. The strength of weld-bond is affected by thickness of the adhesive, the strength increased as the adhesive layer increased [5],[14].

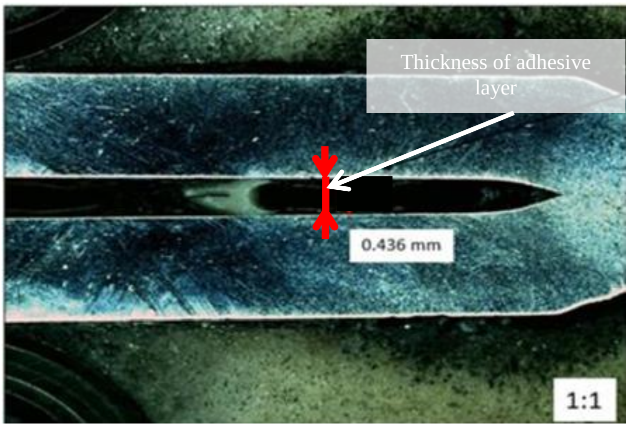

Fig. 8. The thickness layer of adhesive in weld-adhesive bonded.

IV. CONCLUSION

The presence of adhesive layer between the joint increased the strength of RSW. In tensile-shear and peel tests, weld-adhesive bond sample has higher strength compared to as-weld sample. The hardness strength of weld-adhesive bond joints has similar trend with as-weld process for every region measured. Only at certain location has indicated the hardness of weld-adhesive bonded is slightly higher than as-weld. It is concluded the presence of adhesive does not affect the hardness of RSW.

From the result of macrostructures analysis, the size of weld-bonded nuggets is comparatively small than resistance spot welding nuggets. This is primarily attributed to absorption of thermal energy by the adhesive layer presence in between sheets at the welded area. It can be concluded that the presence of adhesive improves the strength of resistance spot welding.

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