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Evaluation of Tensile and Hardness Properties for Friction Stir Welded ZE42 Magnesium Alloys

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Abstract: Friction stir welding technique is applicable to weld both similar and dissimilar group metals. The present study focus on the influence of various parameters related to the weld-ment regions of magnesium alloys. Investigation is carried with different proportions of tool feed and tool speed. The welded materials are measured for hardness by Vickers Hardness Tester and tensile strength by computerized universal testing machine at weld-ment regions. The results after experimentation reveal tool rotational speed have definite influence on the hardness and tensile values. It is also confirmed that friction stir welding of magnesium alloy would serve better as an emerging material for various automotive applications.

Key words: Welding · Magnesium alloys · Vickers Hardness · Tensile test · Automotive applications · Emerging material

INTRODUCTION

In recent times, researchers are attempting to use magnesium alloys for numerous industrial applications as it possess less weight and is environment friendly in nature. To join these materials using conventional welding techniques results in several defects. This yields in a poor quality material not suitable for industrial applications. Nowadays FSW gains popularity as a new solid-state joining technique in joining these types of alloys which overcomes the defects created by conventional welding methods [1-5]. Here the tool profile used is a cylindrical type having a shoulder and probe on its base. During welding the tool probe is plunged into the joining region and moved over the entire region to be joined. The welding is made by the combined action of heat produced through friction and the mechanical action made by the tool during its rotation. The maximum temperature produced limits to an order of 80 percentage of the melting temperature of the base material. FSW process usually forms four different zones at the joints as shown in Fig. 1.

These regions can be categorized as heat affected region (zone) and thermo mechanically affected region (zone) i.e., TMAZ. The formations of above zones are influenced by the material characteristics and the weld parameters. The TMAZ should be less to produce a quality weld.

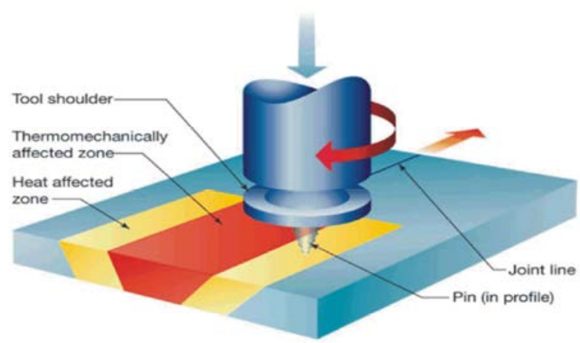

Fig. 1. Frictions stir weldment regions.

Also the weld quality depends on the parameters such as tool design, tilt angle, the rotational speed, weld speed, weld pressure and the characteristics of weld material [6-10]. The changes in various process parameters that influence the mechanical properties are discussed in this work.

Literature: Nagasawa *et al.* [11] welded 6-mm AZ31 magnesium plates and studied the mechanical characters. The authors found that ductility of the welded material

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improved while comparing with the base material. Park *et al.* [12]. welded 6-mm AZ31 magnesium plates and conducted tensile test. The authors found that the tensile properties like yield strength and elongation showed improvement in base material strength which was evident with a micro-texture analysis.

S. Rouhi *et al.* [13] welded AZ91C magnesium samples exposed to air as well as in water. The tensile and hardness properties of samples exposed to different environment were discussed. The results showed that the welding environment in water had definite impact on the mechanical properties of the welded material. K Okamoto *et al.* [14] welded AZ31 magnesium alloys for butt joint. The mechanical test showed that the ultimate tensile strength of friction stir welded magnesium samples were equivalent to annealed parent metal and it can be used for automotive industries.

Shen *et al.* [15] welded similar combinations of magnesium and aluminium materials followed with dissimilar combinations of magnesium and aluminium materials respectively. Tensile test showed that welds with similar combinations hold highest tensile strengths and the dissimilar combinations of aluminium and magnesium welds had the lowest strength.

Experimentation: The magnesium alloys of 4mm thickness in form of plates were procured locally. It was then sized to ASTM standard size for butt welding. Later the samples were friction stir welded under vertical milling machine (Fig. 2) to form but joint.

Fig. 3 shows the chosen tool H13 steel material which possesses less deformation and high hardness. The tool material used is pin type one with a shoulder length 40mm with shoulder diameter 16mm and pin length 3.7mm with pin diameter 5mm.

A constant axial force of 5KN has been applied with different rotational and welding speeds at FSW joints. Specimens (Fig. 4) were exposed to normal room temperature during welding. Once the FSW process was completed all the samples were prepared as per ASTM standards for testing tensile strength and micro hardness values. The tensile testing was performed on all samples using a computerized universal testing machine. The micro hardness was performed on all specimens along the weld zone using a standard Vickers micro-hardness tester.

Tensile Testing: The samples after welding were sized to standard ASTM specimen for tensile testing. Fig. 5 represents photographs of the prepared tensile specimens

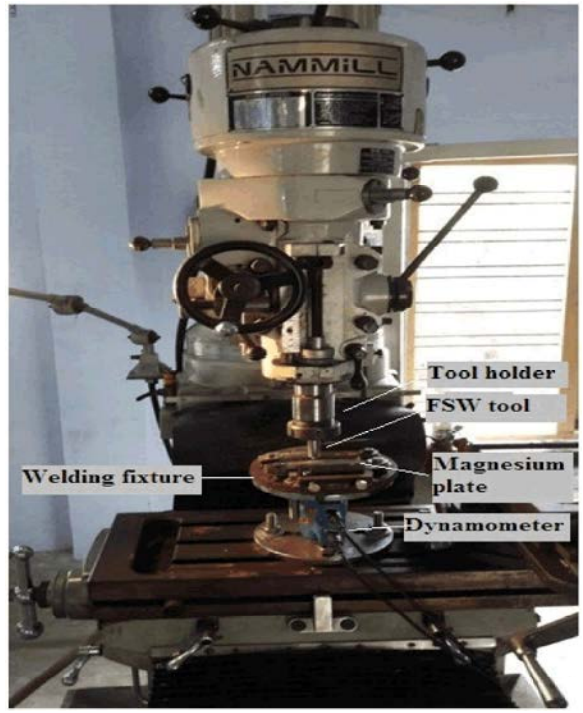

Fig. 2: FSW arrangement.

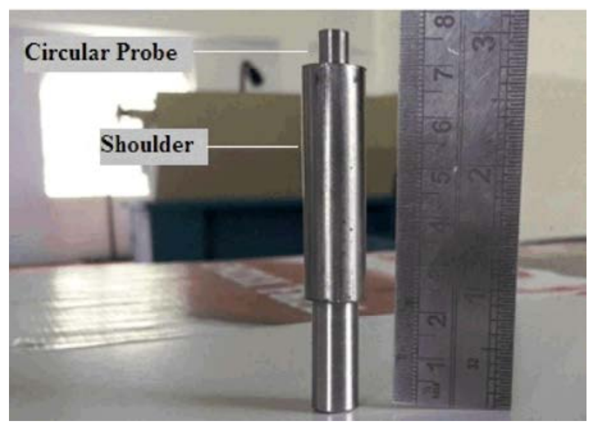

Fig. 3: FSW tool used.

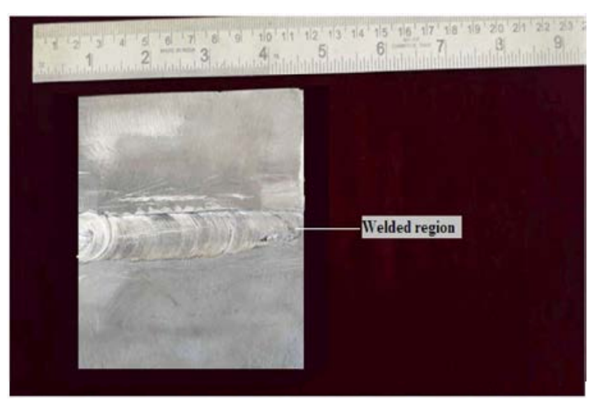

Fig. 4: Magnesium samples joined after FSW.

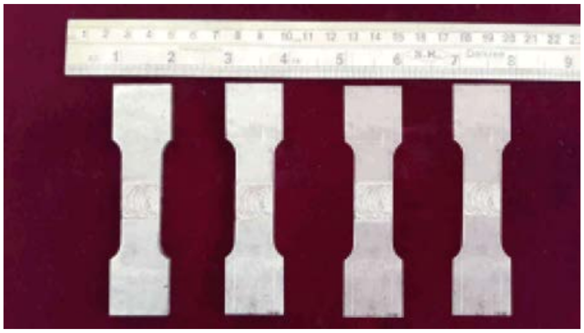

Fig. 5: Prepared Tensile samples as per ASTM

Fig. 6: Tensile specimen clamped in Universal testing machine

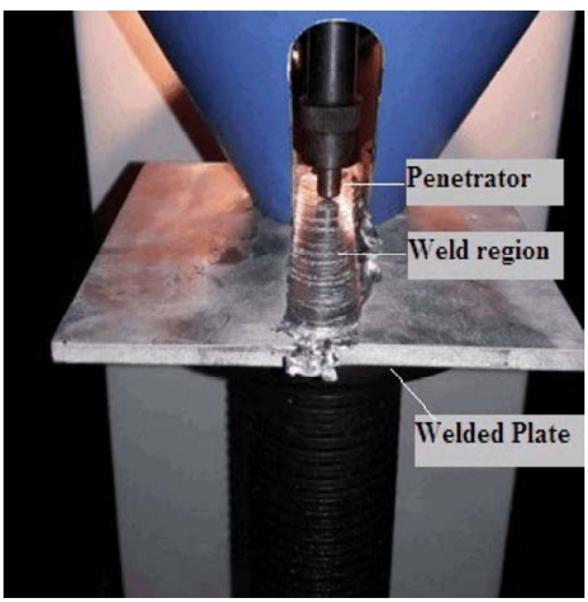

Fig. 7: Microhardness Testing Machine

for testing. These samples were tested using a computerized universal testing machine as shown in Fig.6 as per the ASTM guidelines [16, 17].

Vickers Hardness: The hardness testing of the welds were performed using a standard Vickers hardness tester as shown in Fig. 7. The Hardness properties of the specimens were measured after mounting the samples on a table and penetrating with a diamond penetrator. The load applied was about 10 kg maintained constantly for 20 sec at different locations on the specimens. All the readings were measured at very close distances across the weldment and the mean value was recorded as the hardness.

RESULTS AND DISCUSSIONS

The magnesium alloys tested according to ASTM guidelines were discussed in detail as follows.

Tensile Test Results: The tensile test results were tabulated and graph between tensile strength versus samples was plotted as shown in Fig.8. The results shows that the tensile property of the weld material improved considerably when compared to base metal.

Hardness Test Results: The hardness values recorded after testing for various combinations of tool speeds and feed were tabulated in Table 1. Fig. 9 shows the graphs drawn between the hardness versus samples.

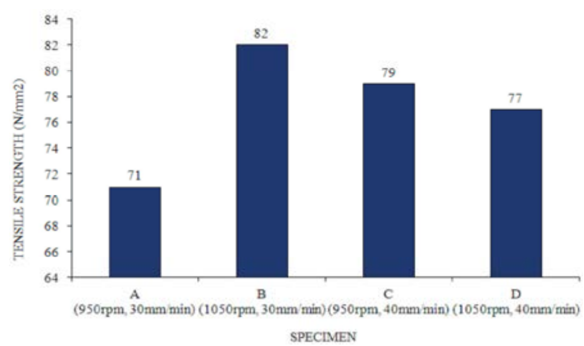

Fig. 8: Tensile strength versus Specimens

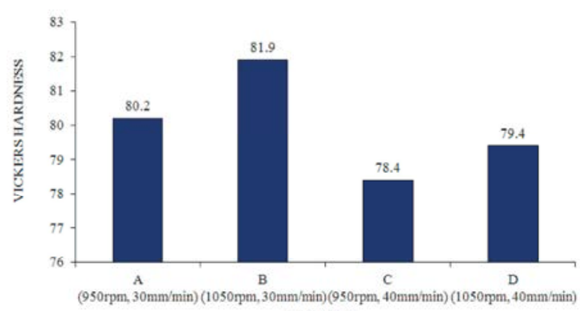

Fig. 9: Hardness versus Specimens

Table I: Weld Distance Vs Hardness

Distance from weld	A (950rpm, 30mm/min)	B (1050rpm, 30mm/min)	C (950rpm, 40mm/min)	D (1050rpm, 40mm/min)
-15	77.1	77.5	74.7	71.6
-10	75.3	79.2	71.4	72.5
-5	79.4	78.5	68.3	69.9
0	81.9	80.2	78.4	79.4
5	84.3	81.2	79.8	80.2
10	78.4	73.4	80.5	77.5
15	69.4	78.9	69.7	70.8

CONCLUSIONS

The present work shows an extensive effort to optimize the process parameters like tool feed and tool speed on welding magnesium alloys. For FSW process with 1050 rpm tool rotational speed, 30mm/min feed, the tensile and hardness values across the weld zone was uniform and hence homogeneity is maintained among the newly re-formed grains within the magnesium matrix. For the rest FSW process the tensile and hardness values across the weld zone was not uniform and hence homogeneity is not maintained. High tool rotational speed leads to increase frictional heat between tool shoulder and base metal that lead to welding defects. Hence the friction stir welded magnesium alloy with an optimum rotational speed of 1050 rpm, 30mm/min feed, would serve well as an emerging material with high tensile strength and hardness for various automotive applications.

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