

The Optimization Conditions of Friction Stir Welding (FSW) for Different Rotational and Weld speeds

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Abstract

The effect of welding parameters on mechanical properties of aluminum alloy 3003 H14 Friction stir-welded (FSW) joints were investigated in the present study. Different welded specimens were produced by employing variable rotating speeds (1000, 1250, 1500, 2000 r.p.m.), and welding speeds (20, 40, 60, 80 mm/min). Microhardness measurements and tensile strength of the produced joints were tested. The experimental results indicated that the process parameters have a significant effect on mechanical properties of joints. The optimum results of the weld gained at the parameter 80mm/min weld speed and 1500 rpm rotation speed where the efficiency reaches to 89% of the ultimate tensile strength of the parent metal

Keywords

FSW (friction stir welding), Mechanical Properties, Al 3003-H14.

Introduction

Friction stir welding (FSW) is a relatively new technique for joining aluminum alloys [1]; Friction stir welding (FSW) is a highly important and recently developed joining technology that produces a solid phase bond. It uses a rotating tool to generate frictional heat that causes material of the components to be welded to soften without reaching the melting point and allows the tool to move along the weld line. Plasticized material is transferred from the leading edge to trailing edge of the tool probe, leaving a solid phase bond between the two parts [2]. The process is carried out by plunging a rotating FSW tool into the interface of two rigidly clamped sheets, until the shoulder touches the surface of the material being welded, and traversed along the weld line. The frictional heat and deformation heat are utilized for the bonding under the applied normal force[3]. Mechanism of friction stirs welding with nomenclature shown in Fig.1.[4]

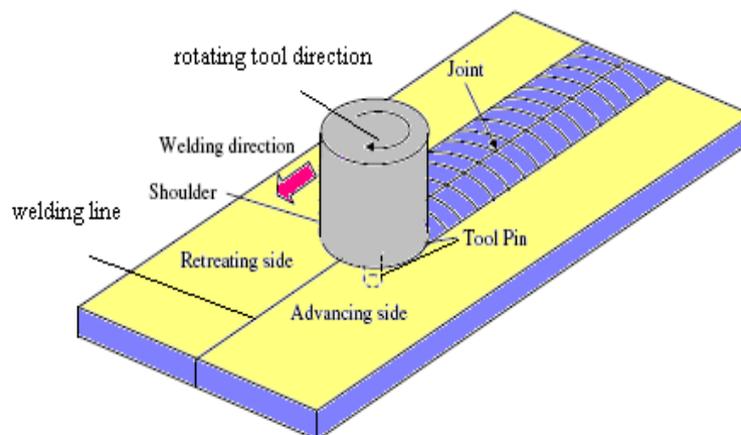


Figure 1: FSW mechanism [4]

Friction stir welding structures and properties, the influence of axial load, and the effect of position of the interface with respect to the tool axis on tensile strength of the friction stir welded joint have been studied [5-7]. Welding parameters and stirrer geometry effect, and tool effect on FSW have been studied [8-9]. The typical welding defects and welding material aspects and the Effect of Friction Stir Welding on Dynamic Properties of some aluminum alloys also have been investigated [10-12].

Other investigations have been studied the fatigue of friction stir welding and studied their properties, and crack propagation of fatigue on friction stir welding [13-19]. In this investigation mechanical properties of 3003-H14 aluminum alloy was studied after determined the best values of rotational speed and welding speed to produce best welding efficiency

Experimental work

In this study Al 3003-H14 was selected. The standard mechanical properties and chemical composition of Al 3003-H14 is given in table 1 and table 2 respectively. To carry out FSW process two aluminum plates 3mm in thickness, 100 mm length, and 150 mm width Fig 2, a clamping fixture was utilized in order to fix the specimens to be welded on a Hermen milling machine Fig.3. Specially prepared stirrer Fig. 4 was pressed against the bonding line and the welding process was started. The length of the stirrer was same as the required welding depth. The welding process was carried out by rotating the stirrer at different rotational and welding speeds under a constant friction force

Table 1: Mechanical properties of Al 3003-H14				
Ultimate strength(MPa)	Yield strength(MPa)	Shear ultimate strength(MPa)	Fatigue endurance limits(MPa)	Modulus of elasticity(GPa)
150	145	95	60	69

Table 2: Chemical Composition of Al-3003 H14 alloy										
	Zn	Cu	Fe	Pb	Mn	Ti	Si	Mg	Co	Al
Measured	0.046	0.104	0.402	0.002	1.041	0.122	0.192	0.0	0.015	Balance
Standard		0.12			1.2		0.18			Balance

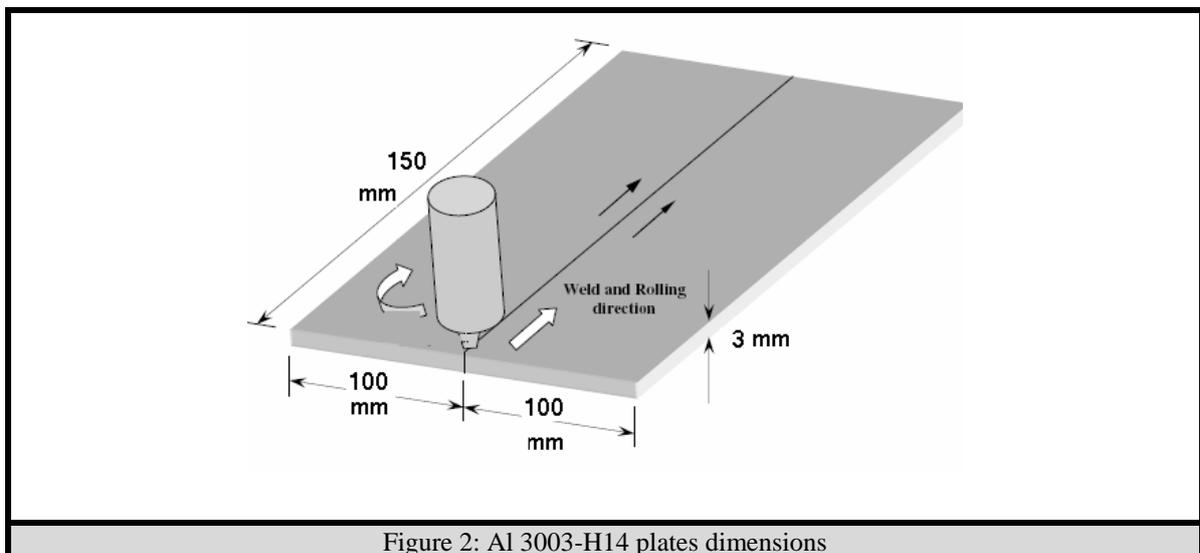


Figure 2: Al 3003-H14 plates dimensions

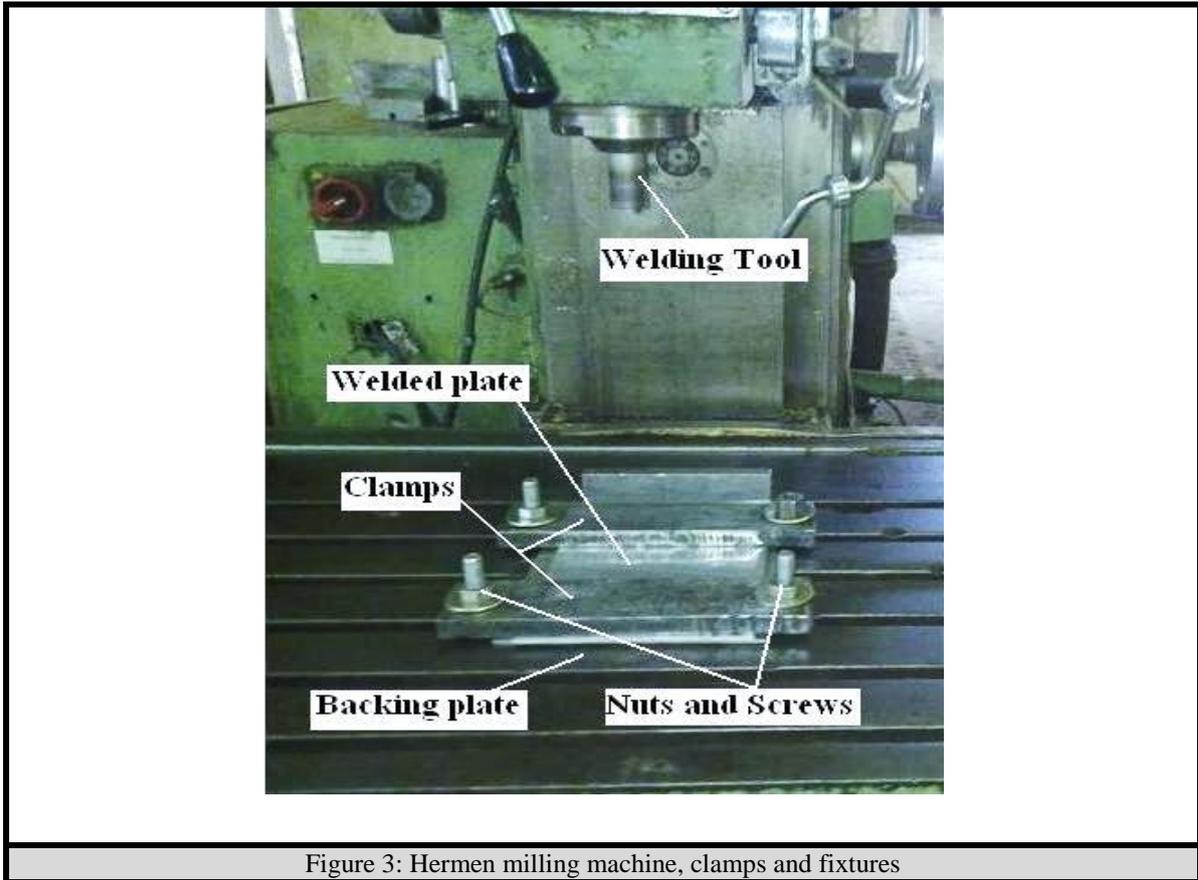


Figure 3: Hermen milling machine, clamps and fixtures

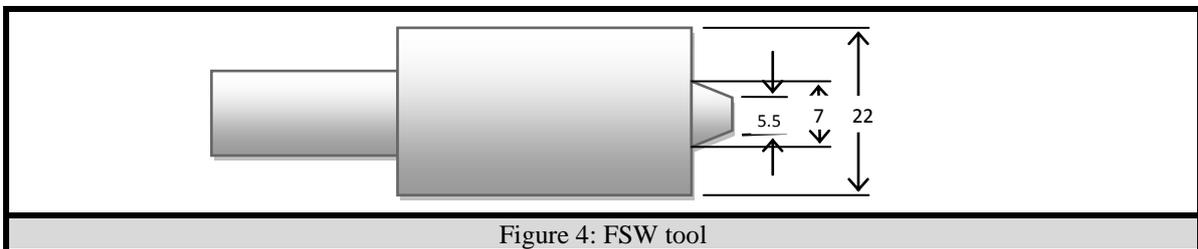


Figure 4: FSW tool

Understanding the tool design plays a very important role in friction stir welding products. The initial FSW tool designed was a simple cylindrical tool with 22 mm shoulder diameter and 7mm pin diameter, height of the pin equal to the distance that plunged in the plate and it was 2.9 mm of the sheets processed. The forces generated using this tool especially during the penetration of the tool into the work piece, were

very high and caused excessive machine vibration. Then the pin of the tool is tapered (Fig. 4) in order to reduce the initial high forces during plunging operation, the welding tool was made of tool steel X38 as the chemical composition shown in table 3.

Table 3: Chemical Composition of welding too								
C	Si	Mn	P	Cr	Ni	Mo	Co	Fe
0.88-0.96	0.45	0.40	0.03	0.03	-	4.7-2.0	4.5-5.0	Balance.

Given the Al-Mn alloys are rather easily weldable even with conventional techniques; it was decided to verify weldability of AA 3003 H14 alloy by the most possible range of process parameters of friction stir welding. Different welded specimens were produced by employing variable rotating speeds (1000, 1250, 1500, 2000 r.p.m.), and welding speeds (20, 40, 60, 80 mm/min).

FSW results

The friction stir welding joints were shown in Fig. 5. Visual inspection shows different results of welding shapes where some welds shows

presence of flash as shown in Fig.6. Because of the plunging depth of the tool this can be avoided by controlling it which must be little more than the plate thickness. Tunnel defect was found at the intersection of weld nugget and thermo-mechanically affected zone due to high rotational speed and travel speed. By optimizing rotational speed 1500 rpm and travel speed 80 mm / min this defects was avoided. Others show presence of pin hole this easily removed using filler and getting finer shape, Fig.6 presented the visual inspection of welding results. [20-21]



2000 rpm, 20 mm/min



1250 rpm, 40 mm/min



2000 rpm, 40 mm/min



1500 rpm, 40 mm/min



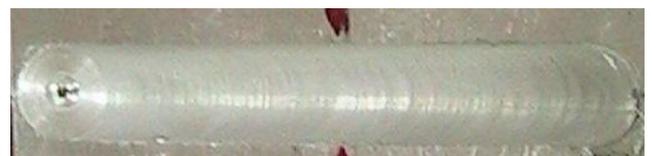
2000 rpm, 80 mm/min



1000 rpm, 20 mm/min



2000 rpm, 60 mm/min



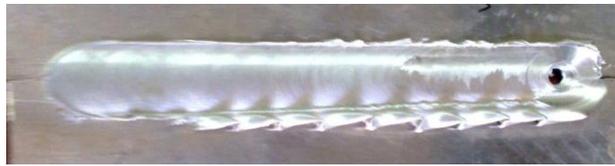
1250 rpm, 20 mm/min



1500 rpm, 20 mm/min



1500 rpm ,60 mm/min



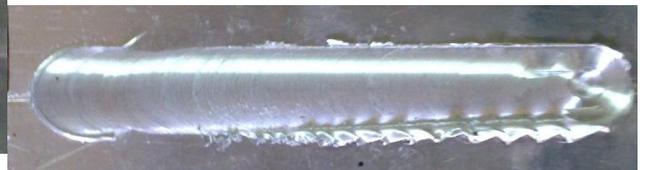
1000 rpm,60 mm/min



1000 rpm, 80 mm/min



1250 rpm ,60 mm/min



1250 rpm, 80 mm/min

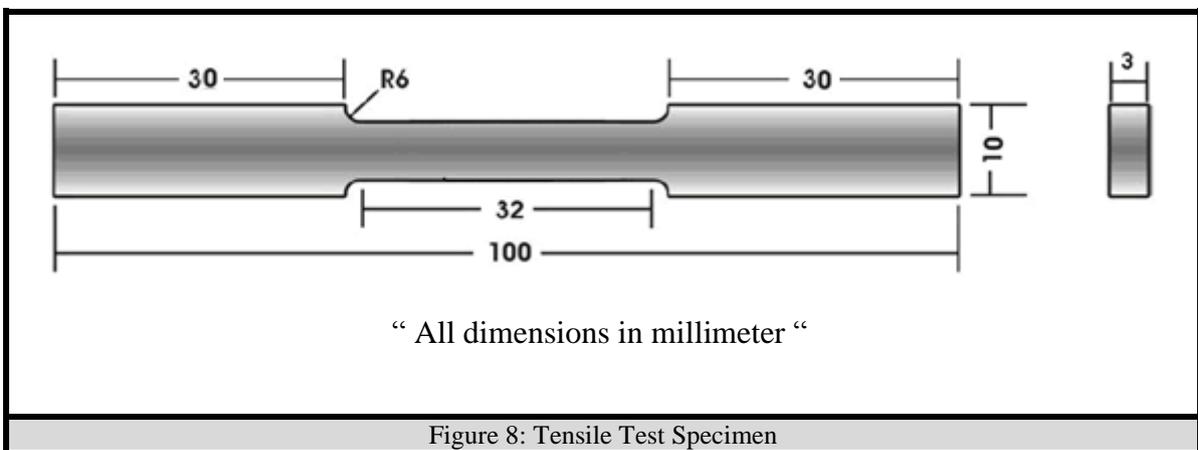
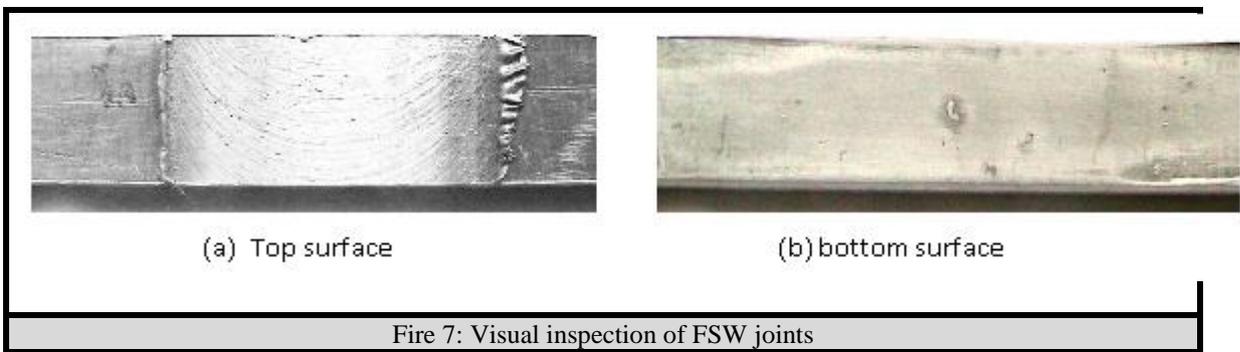
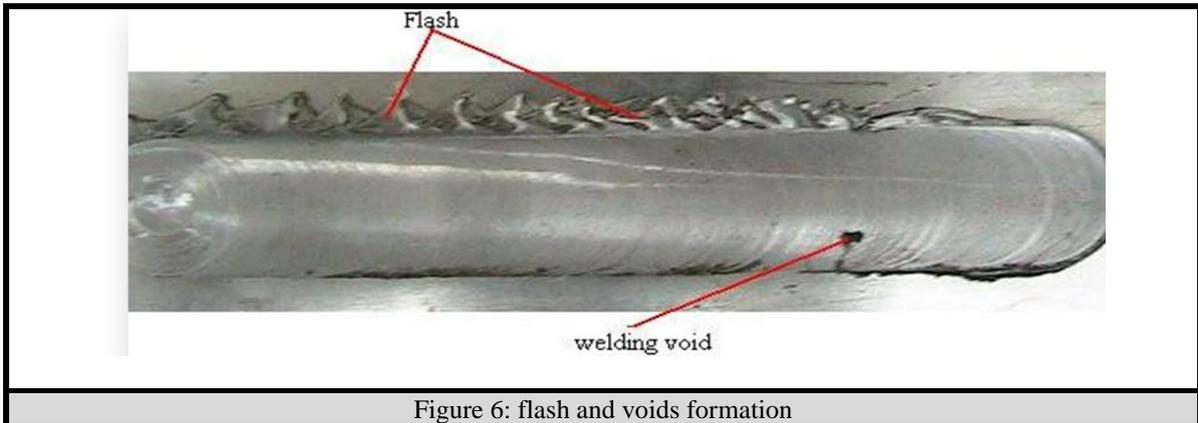


1000 rpm, 40 mm/min



1500 rpm, 80 mm/min

Figure 5 :The appearance of upper surface of welding beads of Al 3003-H14 plates produced with Friction Stir Welding.



A simple tensile test was carried away using a tensile testing device, the strain was read using a dial gauge to read the strain in load direction, the test specimens of 3003-H14 aluminum alloy were prepared according to the ASTM D638M-

89 standard specimen the geometry is shown in Fig.8

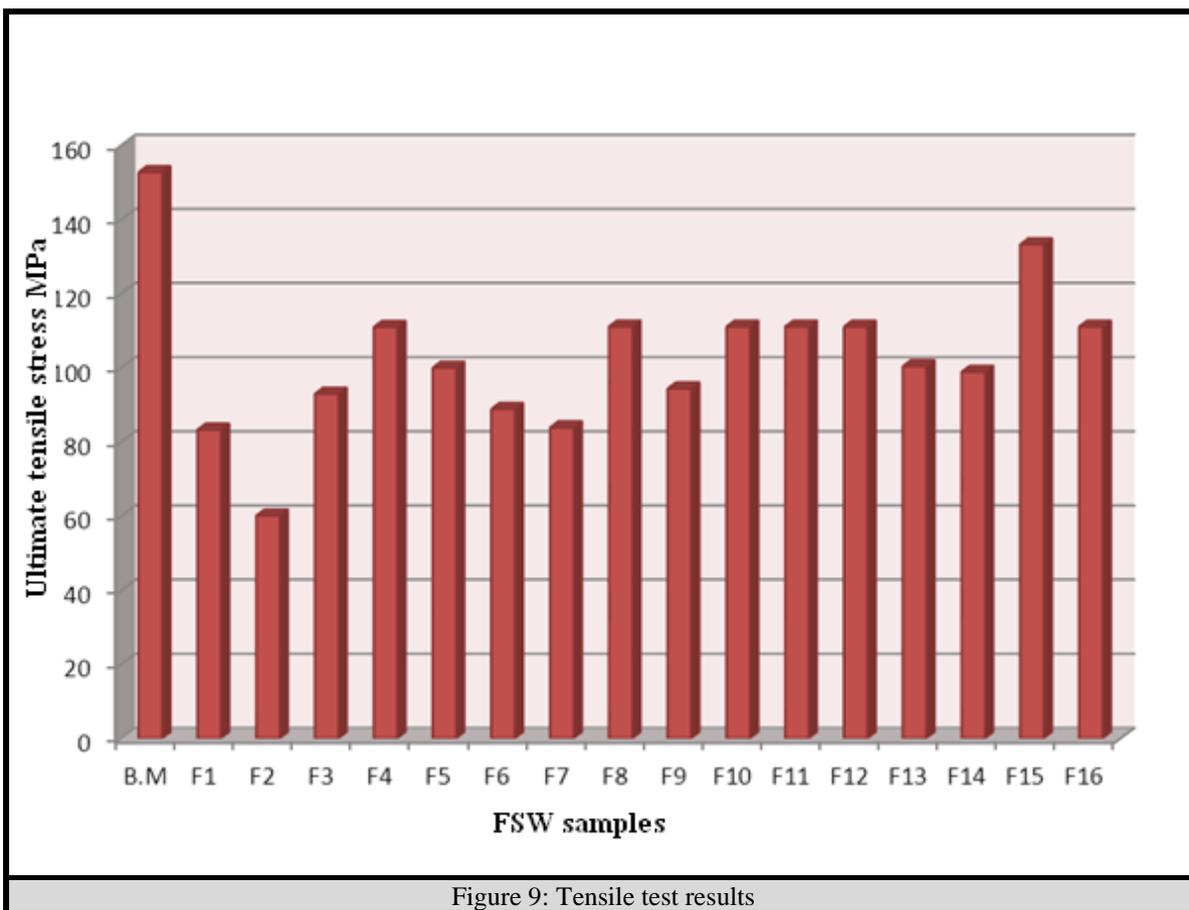


Figure 9: Tensile test results

Welding processes were carried out with four different Weld speeds and four different rotational speeds as shown in table 4.

Tensile and hardness tests for FS welds done at room temperature, tensile results shown in Fig 9. The best result obtained at 1500 rpm and 80 mm/min and the efficiency 89 % of the base metal Al 3003 H14.

Micro hardness test were prepared in order to characterize the hardness profile in the vicinity of

the weld affected area i.e. NZ, TMAZ, and HAZ in the FSW specimens.

Also the hardness profiles are extremely useful, as they can assist in the interpretation of the weld microstructure and mechanical properties. Each specimen was tested by dividing it into regions each point tacked 30 second with hardness Vickers (HV) then the reading has been recorded and measuring the other point respectively. The results are presented in Fig. 10

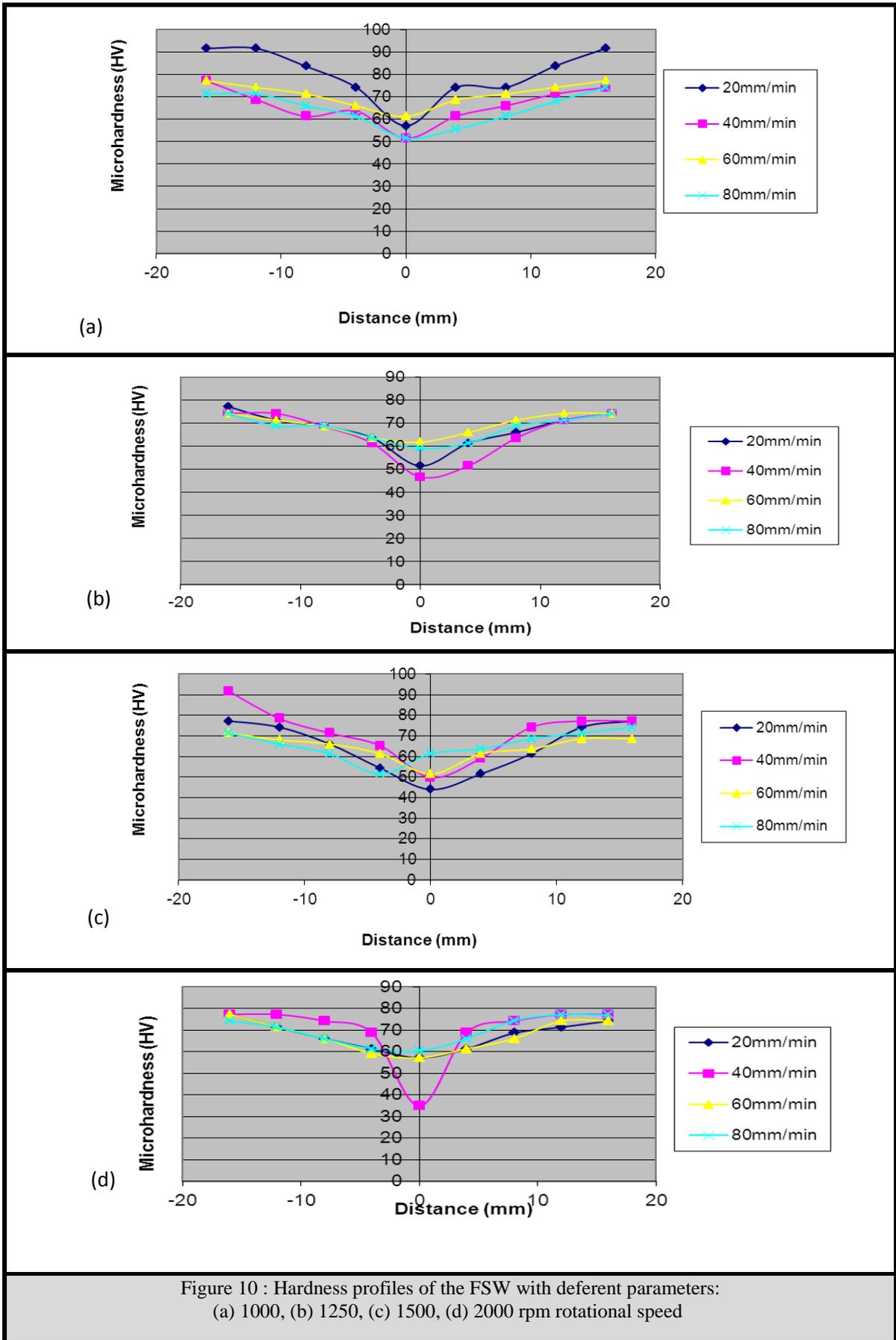
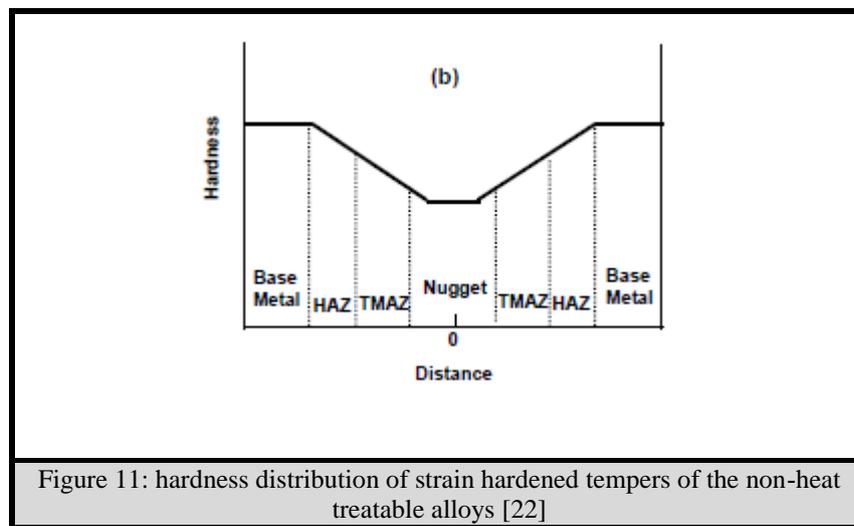


Figure 10 : Hardness profiles of the FSW with different parameters:
 (a) 1000, (b) 1250, (c) 1500, (d) 2000 rpm rotational speed

From Fig. 10 noted that results shows increasing in hardness from center to the parent metal and the lowest value is observed in the nugget zone because that Al 3003 is a strain hardened

tempers of the non-heat treatable alloys [22], Fig. 11 .



The hardness results shown that, in the strain hardened tempers of the non-heat treatable alloys, the recrystallization occurs in the nugget zone during FSW, would eliminate some or all of the cold work effects. This, in turn, would lead to nugget softening and the development of as welded hardness distributions are similar to that depicted in Fig. 11 which shows the hardness distribution of strain hardened tempers of the non-heat treatable alloys [22]. It should be noted that a local material softening occurs in the weld because of the thermal action of the welding process; in particular a localized softening in the NZ is observed. Note that results will show increasing in HV from center to the parent metal and the lowest value is observed in the nugget zone.

The joint strength was investigated with tensile tests, to give an average value of the ultimate tensile strength equal to the 89% of the UTS of the parent material, again fractures in many samples were occurred nearby the HAZ, in correspondence to the lowest values of micro-hardness the micro-hardness was obtained along the transverse joint section, indicating a strong improvement of the joint mechanical characteristics [23], but other samples occurs in the nugget zone at the center of the weld

. Conclusions

The influence of FSW parameters on the tensile and microhardness properties of FS-welded 3003 H14 Al alloy at various FSW conditions was examined in the present study.

1. Tunnel defect was found at the intersection of weld nugget and thermo-

2. The design of tool with tapered pin was suitable to avoid tool breakage
3. Mechanical properties of FS welded aluminum alloy 3003 H14 are influenced by process parameters. Hardness drop was observed in the weld region. The softening was mostly evident in the nugget zone because that Al 3003 is a strain hardened tempers of the non-heat treatable alloys. The optimum efficiency for joints of the using parameters of FSW founded at 80 mm/min weld speed and 1500 rpm rotation speed it reaches to efficiency 89% of the ultimate tensile stress of the base metal.

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