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Charpy Impact Value of Friction Stir Welded 7020 and 7075 Aluminium Alloys at Different Tool Rotation and Transverse Speed

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Abstract

In this work, the effect of friction stir welding parameters such as tool rotation and tool transverse speed on the impact value of 7mm thick weldments of aluminum alloys 7020 and 7075 each alone at T6 and T9 temper conditions has been studied and investigated. Three tool rotation speed (280, 580, and 960 rpm) and five tool transverse speed (36, 76, 102, 146, and 216mm/min) were selected for the friction stir welding of each alloy condition. The resistance of weldments to sudden loading has been investigated using the Charpy impact test with standard V – notched specimens at room temperature. It has been observed during this work that the total impact energy increased in the friction stir welding of (medium strength) 7020 Al alloy for both temper conditions especially at 580 rpm and 102 mm/min with respect to the base metal while rotation and transverse speed have little effect on the impact value of (high strength) 7075 Al alloy and the results were very close to each other. Finally it is important to mention that the relation between rotation speed, transverse speed and input heat which affect on the impact value seems to be complex and depend on the material properties being welded.

تحديد قيمة صدمة جاربي لسبائك الالمنيوم 7020 و 7075 و الملحومة بطريقة اللحام الاحتكاكى المزجى عند سرع دوران ولحام مختلفة

الخلاصة

يتناول هذا البحث لحام صفائح المنيوم بسمك 7 ملم من سبيكتين مختلفتين من سبائك الالمنيوم 7020 و 7075 وفى حالتين مختلفتين T6 و T9 كل على انفراد بطريقة اللحام الاحتكاكى المزجي عند ثلاث سرع دوران مختلفة (960 ، 580 ، 280) دوره في الدقيقة وخمس سرع لحام (216، 146 ، 102 ، 76 ، 36) ملم / دقيقة ومن ثم تهيئة عينات الصدمة القياسية(V- notched standard specimens) لها واجراء التجربة عند درجة حرارة الغرفة . نتائج البحث تشير الى زيادة طاقة الصدمة للعينات الملحومة لسبيكة الالمنيوم 7020 (ذات المتانة المتوسطة) وعند الحالتين T6 وT9 وخصوصا عند سرعة دوران 580 دورة في الدقيقة وسرعة اللحام 102ملم/دقيقة مقارنة بالمعدن الاصلي في حين سرع الدوران واللحام لها تأثير قليل على مقاومة الصدمة لسبيكة الالمنيوم 7075 (ذات المتانة العالية) وكانت النتائج متقاربة في جميع الحالات تقريبا. وفي النهاية نود ان نشير بأن العلاقة بين سرعة الدوران وسرع اللحام والحرارة المتولدة اثناء اللحام والتي تؤثر على مقاومة الصدمة تبدو معقدة وتعتمد عن خواص المواد الملحومة .

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Introduction:

Friction stir welding (FSW) is a new developed solid state joining technique invented by the welding institute (TWI) in UK [1].

Due to the advantages of FSW over the traditional joining techniques such as no melting, versatile…etc, the process has been successfully applied to aerospace, ship manufacturing and automobile industries. Since the invention of FSW, many researchers have tried to investigate the mechanism of this new joining technology for its further development [1].

All studies have been conducted on FSW of precipitation hardening alloys with respect to microstructural characterization, and it is very important to know the effect of the welding parameters on mechanical properties and the microstructural evolution for high welding quality [1, 2], this is the reason why the welding parameters are investigated by Cavalier et al [3, 4], Elangovan et al [5], Peel et al [6]…etc.

The comprehensive studies by Cavaliere et al [3, 4] showed the close relations between the welding parameters and the resulted grain sizes, in fact the evolution of the microstructure in FSW can be directly affected by the temperature rises and material behaviors which are determined by the welding parameters [1].During FSW a rotating tool moves a long joint interface generate heat due to friction between the tool shoulder, tool pin and work piece surface resulting in recirculation flow of plasticized material near the tool surface. The softened material is subjected to extrusion by the tool pin rotational and traverse movements leading to formation of FSP (friction stir processing) zone which affected by the material flow behavior under the action of rotating tool [7, 8]. The aim of the present paper was to study the effect of FSW parameter (tool rotation and transverse speeds on the Charpy impact energy of two different Al alloys; a medium strength alloy (7020) and a high strength alloy (7075) and to evaluate the impact energy of welded joints, which usually depend on the orientation and direction of propagation of the crack in relation to the anisotropy of the material which depends on principal directions of mechanical working or grain flow and this effect has not been reported yet.

Experimental procedure:

Two different Al alloys of the 7000 series have been used in this study, the medium strength alloy 7020, and the high strength alloy 7075 at T6 and T9 temper conditions respectively. The measured and nominal chemical composition of these alloys is shown in table (1). Table 2 shows the procedures that are followed to put the two alloys in the T6 and T9 tempers as well as the mechanical properties of the two alloys. The FSW trials were carried out on a horizontal milling machine, A pair of work pieces of dimensions (150mm* 35mm* 7mm*) for both Al alloys were abutted and clamped rigidly on the backing plate for welding parallel to the rolling direction. The FSW tool has been fabricated from a tool steel and heat treated to have a hardness level of 52-54HRC. The tool had a concaved shoulder of 20mm diameter with chamfered edges, while the tool pin is made conical with right hand threads of 1mm pitch. The diameter of the pin at the base is 7mm and reduced to 4.8mm at the head with an overall height of 6.6mm making it slightly shorter than the plate thickness. The tool was rotating in the clock-wise direction and was tilting 2.5 degrees with respect to a vertical axis in order to maintain more pressure on the plasticized material behind the tool to produce high quality welds. In this work, three different tool rotational speeds of 280, 580, and 960rpm in conjunction with five different tool travel speeds of 36, 76, 102, 146, and 216 mm/min has been used. Impact testing of the welded joints in the transverse direction has been performed in order to evaluate the toughness of the materials in the as welded condition. For this purpose; sub-sized standard Charpy V-notched impact specimens 10x5x55mm, with 2mm deep and 45^o V-notch was prepared and tested in accordance with ASTM E23 standards using a standard pendulum impact tester. The specimens were prepared such that the V-notch lay at the center of the weld nugget facing the direction of welding as shown schematically in figure 1.

Results and discussion:

7020 Al alloy has received special attentions because it has long been realized that it has the greatest response to age hardening of all Al alloys also combines moderate strength with improved corrosion resistance and good weldability as compared with 7075 Al alloy, therefore its applications are more popular [9].

Fig.2 to fig.7 show the effect of the rotation speed and tool transverse speed on the impact value of 7020 and 7075 Al alloys at two conditions T6 and T9 respectively. The figures show and compare the Charpy impact energy of the base metal BM and the friction stir welded joints of the two alloys. Generally, there is a relationship between tool rotation speed, tool travel speed and the input heat generated by the friction between the tool shoulder and the base metal during FSW process. Input heat increased with increasing tool rotational speed (960 rpm) and decreased with high transverse welding speed (146 and 216 mm/min) (low input heat) which causes the intermittent metal flow and improper stirring action around the tool pin due to insufficient plasticization of the base metal under the tool shoulder, it means that stirring effect becomes weak when the transverse speed becomes higher (216mm/min). On the other side high input heat causes turbulent metal flow around the tool pin due to excess plasticization of base metal under the tool shoulder as shown at 960 rpm for both alloys. Both these conditions produced defective welds [7] (means low impact value). So 7020 can be plastically deformed very easily and the flow of plasticized metal around the non-consumable tool will also be uniform causing good impact value compared to metal with high strength and low impact value (7075 Al alloy). On the other hand the input heat affect on FSW grain size, when the grain size was found to increase with the increase of the tool rotation speed [10], since the input heat increases and theoretically, an increase in the feed rate may decrease the grain size due to the decrease in the input heat [10]. In this context Sato et al [11], show that at FSW of AA6063 Al alloy the increase of input heat as a function of tool rotation speed raises the temperature of the nugget zone and this could lead to static grain growth of dynamically recrystallized grains. So the increase in strength with the decrease in low rotation speed (280 rpm) is most likely to be due to decrease in grain size according to low input heat. Z. Zhang et al [1] show that lower transverse speed (2mm/sec) can lead to more sufficient material deformations near the welding tool, when the transverses speed is increased to 4mm/s friction stir welding failed due to the occurrence of the weld flaw near the bottom surface, This indicate reducing in impact value as shown at 216mm/min. According to above experimental results of Zhang and our paper it can be seen that, the transverse speed of FSW of 7020 Al alloy must not exceed 102mm/min due to good impact value at both condition T6 and T9 at rotation speed (580 rpm). In general 7075 Al alloy have lower impact values than 7020 Al alloy in both conditions and predicated output values were very close to each other, this is attributed to the frictional heating which effect on the growth, dissolution and re-precipitation of hardening precipitates [12]. Therefore improving in both impact value or impact strength and ductility can be obtained with reducing the size of the precipitates by controlling rotation speed and transverse speed during friction stir welding of Al alloys.

Conclusions:

From this investigation the following important conclusions can be derived:-

1. It has been found that the material with medium strength (7020 Al alloy) can be FSW easier than high strength (7075) Al alloy.
2. The impact test showed that the total impact energy increased in the FSW of 7020 Al alloy at T6 and T9 conditions compared to base metal and reduced in 7075 Al alloy.
3. The transverse speed of FSW of 7020 Al alloy must not exceed 102mm/min at rotation speed 580 rpm to give good impact value at both T6 and T9 conditions.
4. Both rotation speed and transverse speed have little effect on the impact value of 7075 Al alloys.
5. The relation between speed combination and the input heat which effect on the impact value is seems to be complex and depend on the material properties being welded.

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Table (1) Chemical composition of the base metals (wt. %).

Alloy	Elements	Cu	Mg	Mn	Zn	Fe	Si	Zr	Pb	Bi	Cr	Al
AA7020	Nominal [67]	0.2	1-1.4	0.05-0.5	4-5	0.4	0.35	0.08-0.2	-----	------	0.1-0.35	Bal.
	measured	0.2	1.2	0.33	4.5	0.4	0.35	0.05	---	----	0.25	Bal.
AA7075	Nominal [67]	1.2-2	2.1-2.9	0.3	5.1-6.1	0.5	0.4	----	----	----	0.18-0.28	Bal.
	measured	1.45	2.1	0.03	5.25	0.23	0.3	---	---	----	0.18	Bal.

++ The given nominal values for mechanical properties of the base alloys are in accordance with the specifications of European Aluminum Association EAA.

Table (2) Heat treatment procedures and the mechanical properties of the base materials.

Material	Solution heat treatment procedures	Mechanical properties	0.2% proof strength MPa	Ultimate tensile strength MPa	Elongation %	Hardness HV10 Kg/mm^2	Charpy V- notched impact value Joule
AA7020-T6	Solution treatment at 480°C for 30min, water quenched and artificially aged at 120°C for 24hrs.	Measured	290	365	24	103	8.2
		Nominal++	290-335	350-380	13	120	Not specified
AA7020-T9	Solution treatment at 480°C for 30min, water quenched and artificially aged at 120°C for 24hrs + 20% cold rolling and post cold rolling ageing at 160°C for 3hrs	Measured	320	385	20	114	7
		Nominal	No data available				
AA7075-T6	Solution treatment at 470°C for 30min, water quenched and artificially aged at 130°C for 12hrs.	Measured	455	524	15	152	3.5
		Nominal++	460-505	530-570	10	160	Not specified
AA7075-T9	Solution treatment at 470°C for 30min, water quenched and artificially aged at 130°C for 12hrs + 20% cold rolling and post cold rolling ageing at 160°C for 3hrs	Measured	490	575	10	162	3
		Nominal	No data available				

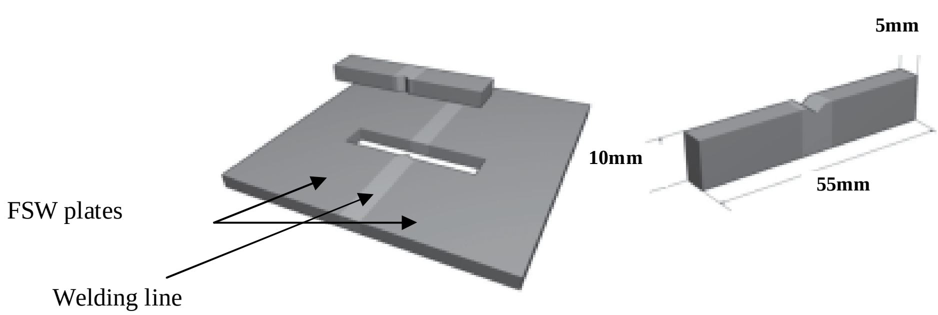

Figure (1) Scheme of the machining of the V-notch Charpy specimens from the FSW plates and dimensions of the sub-size specimens used in this work.

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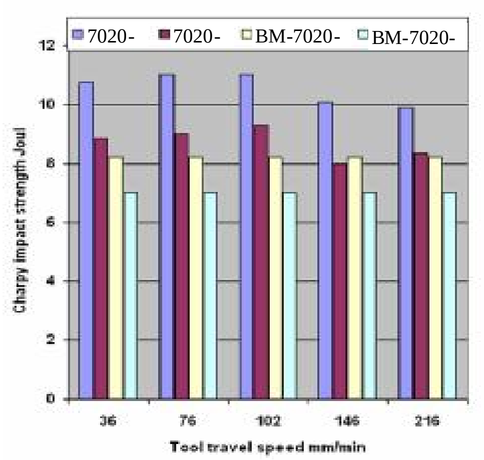

Figure (2) Charpy impact strength versus tool Travel speed for FSW of 7020-T6 at 280rpm.

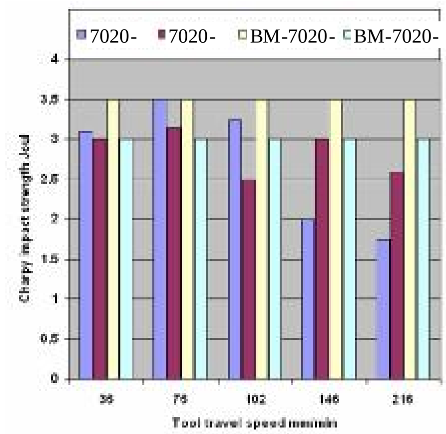

Figure (5) Charpy impact strength versus tool Travel speed for FSW of 7020-T9 at 280rpm.

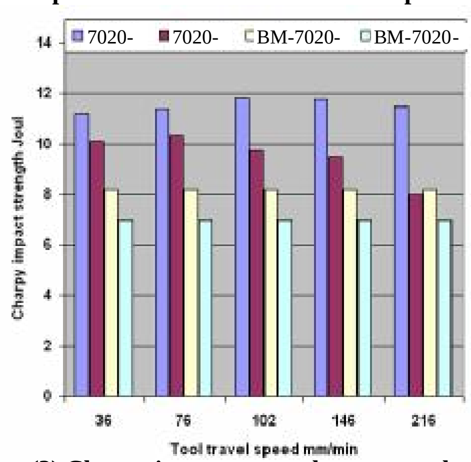

Figure (3) Charpy impact strength versus tool Travel speed for FSW of 7020-T6 at 580rpm.

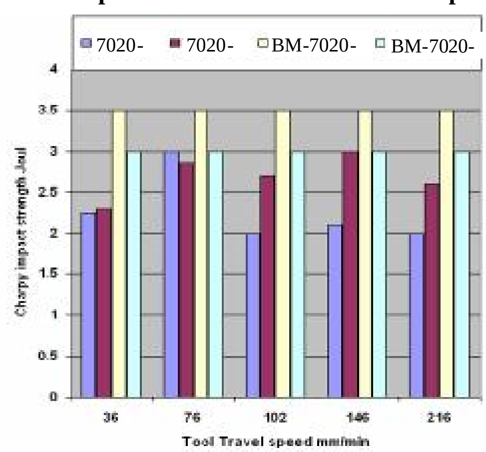

Figure (6) Charpy impact strength versus tool Travel speed for FSW of 7020-T9 at 580rpm.

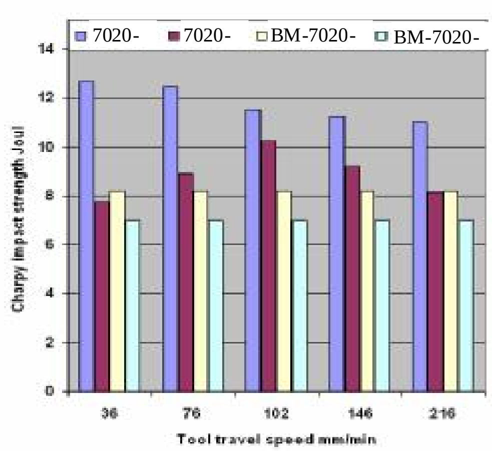

Figure (4) Charpy impact strength versus tool Travel speed for FSW of 7020-T6 at 960rpm.

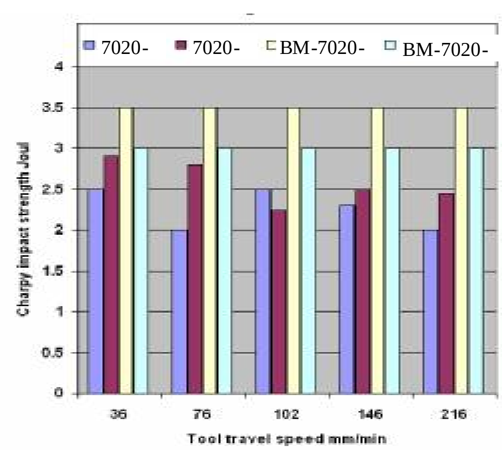

Figure (7) Charpy impact strength versus tool Travel speed for FSW of 7020-T9 at 960rpm.