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Influence of Tool Material on Mechanical Properties of AA6061-O during the Friction Stir Welding Process

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Abstract: *Friction stir welding (FSW) is a latest solid state joining process for similar or dissimilar metals. It has wide application in several industries. In friction stir welding, selection of tool material and design of tool plays an important role for weld quality. In this experimental work, two different tool materials were used with straight cylindrical pin profile i.e. High carbon High chromium Steel (D3) (HcHcr) and High Speed Steel (H.S.S).The aim of this work is to analyze the effect of each tool on mechanical properties of weld metal.*
Keywords: *Friction Stir Welding, Tool material, Mechanical Properties.*

I. Introduction

Friction stir welding (FSW) is relatively new solid state joining process. Friction stir welding process invented at The Welding Institute (TWI) U.K in 1991 [1, 2]. The FSW is suitable for the materials which are hard to weld by conventional welding process. Fsw is not only limited for joining of Aluminium Alloy [3, 4], but it is suitable for other materials like Titanium Alloy [5, 6], Magnesium Alloy [7, 8] and many metal matrix composites [9, 10].In friction stir welding technique a specially designed non–consumable rotating tool which is inserted in to the workpiece to be joined and the rotating tool moves along the line of the joint (as shown in figure 1.1)

In FSW there is no melting of metal, as the tool travels the heat is generated by friction between workpiece and tool. This frictional heat is generated due to high normal pressure and shearing action of tool shoulder, due to this plastic deformation occurs in the material at stir zone. The high heat and strain during stirring causes the dynamic re-crystallization of parent metal and thus formation of new grain in the weld zone [11, 12].

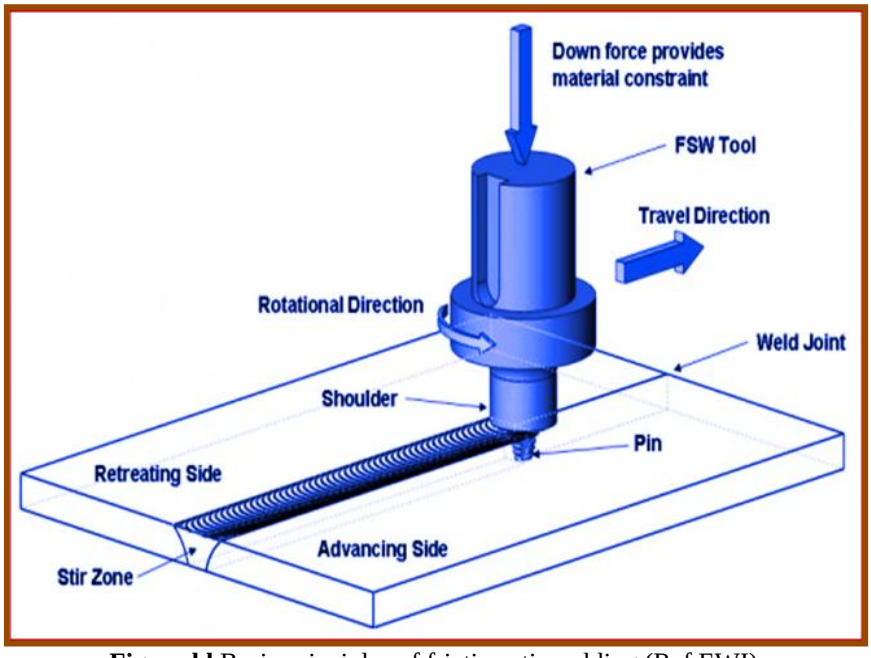

Figure l.l Basic principles of friction stir welding (Ref.EWI)

II. Material and experimental procedure

In this experimental work, aluminium alloy plate (AA 6061-O) was used as work piece material. The dimensions of a work piece were 120mm x 100mm x 6mm. Chemical composition (%) of base material is shown in Table-2.1

Table 2.1: Chemical Composition (%) of Specimen

Components	Percentage
Si	0.94
Fe	1.51
Cu	0.97
Mn	0.228
Mg	0.329
Cr	0.051
Ni	0.029
Ti	0.018
Al	93.70

2.1 Tool Material

In this experimental work, there was two different tool materials were used.
The Tool materials are -
1. High Speed Steel (H.S.S)
2. High Carbon High Chromium steel (D_3) (HcHcr)

After selection of tool material the desired machining operation is performed on the centre lathe machine. After machining of tools the required oil hardening was done on both the tools for desired output. In this study materials of tool are different but dimensions of tool that is design of tool was same for both the tools.

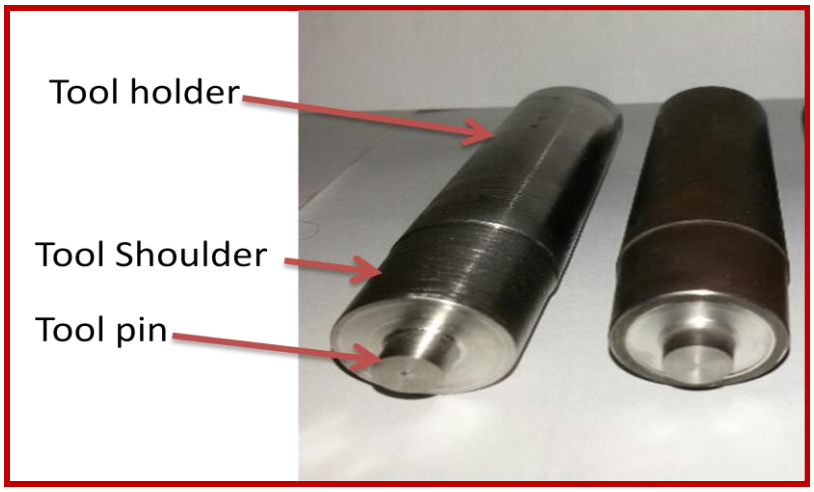

Figure 2.1 showing complete machined tools

Table 2.2: FSW process parameters and tool nomenclature

Rotational speed (rpm)	320,464
Feed rate (mm/min)	50,70
Pin length (mm)	5.7
Tool shoulder diameter (mm),D	19
Pin diameter (mm)	6.8
Tool holder diameter (mm)	20
Tool materials	H.S.S, HcHcr
D/d Ratio of tool	2.79
Tool Profile	Straight cylindrical

After the preparation of setup for friction stir welding, first of all the welding fixture was properly clamped on the bed of Universal Milling Machine and after that workpiece was clamped on the welding fixture with the help of top clamps provided. Side supporting plates are used to support the workpiece or to restrict the movement of workpiece during the welding operation.

After clamping of workpiece on welding fixture, tool was clamped in the spindle then starts the machine and impinge the tool in to the workpiece up to the desired depth after that feed was provided to the bed and friction stir welding was performed.

Figure 2.2 showing the friction stir welding

Total eight experiments were performed at different Rotational speed (rpm) and different welding speed (mm/min). The tool rotational speed is taken as 320 and 464 r.p.m and feed rate is selected as 50, 70 mm/min.

Table 2.3 showing the input and output parameters

SL.No	WELDING PARAMETER			MECHANICAL PROPERTIES		
	Tool	Speed (r.p.m)	Feed (mm/min)	UTS (N/mm^2)	Joint Efficiency (%)	Hardness, Brinell
1	H.S.S.	320	50	104.64	79.96	35
2	H.S.S.	320	70	111.24	85.00	37
3	H.S.S.	464	50	71.94	54.97	33
4	H.S.S.	464	70	120.99	92.45	36
5	Hchcr	320	50	121.64	92.95	31
6	Hchcr	320	70	122.29	93.45	33
7	Hchcr	464	50	121.64	92.95	32
8	Hchcr	464	70	123.64	94.48	34

III. Results and discussions

After the successful performance of friction stir welding on AA -6061-O with various tool materials such as H.S.S (T_1) , HcHcr (T_2) at various tool rotational speed (s , r.p.m) with various feed rate (f , mm/min), the various results were obtained. In this present work total 08 experiments were performed and these results are discussed below.

3.1 Hardness

In this experimental work the effect of tool material on hardness of weld zone was analyzed. The hardness of welded area was measured by Brinell hardness tester.

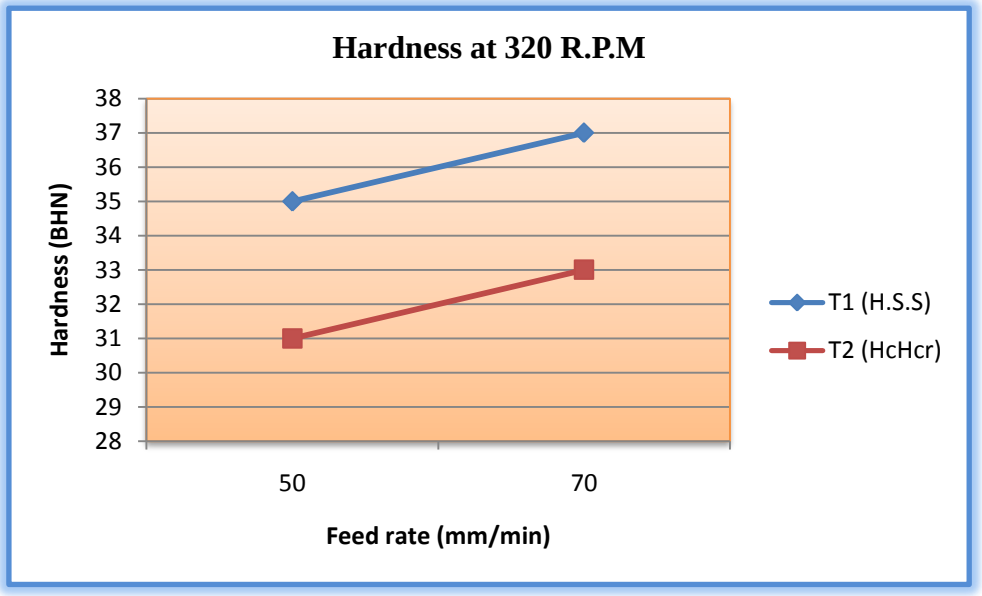

Fig: 3.1 showing the graph for the hardness (BHN) at 320 r.p.m and 50 , 70 mm/min feed rate

The hardness of the parent metal was **27** BHN. From (fig.3.1) the graph it is observed that as the feed rate increases from 50 mm/min To 70 mm/min. at 320 r.p.m of spindle, the hardness of weld zone increases through both tool. But it was also observed that through the H.S.S Tool hardness obtained is comparatively high.

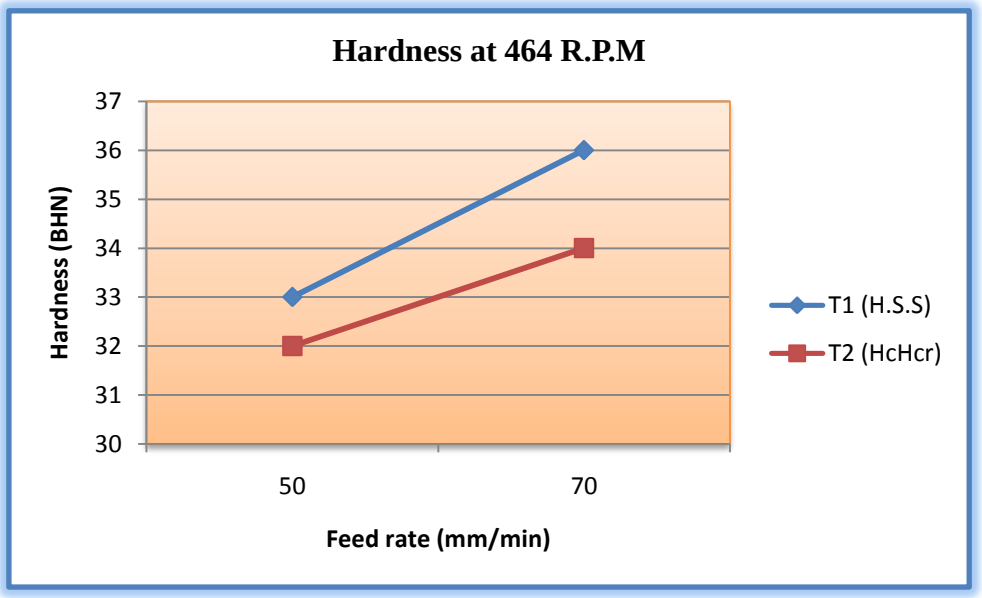

Fig: 3.2 showing the graph for the hardness BHN) at 464 r.p.m and 50 , 70 mm/min feed rate.

From (fig.3.2) the graph it is observed that as the feed rate increases from 50 mm/min To 70 mm/min at 464 r.p.m of spindle, the hardness of weld zone increases through both tool. But it was also observed that through the H.S.S Tool hardness obtained is comparatively high.

3.2 Ultimate Tensile Strength

In this present work the effect of tool material on ultimate tensile strength (UTS) of weld zone was analyzed. The ultimate tensile strength of parent metal was observed that 130.86 N/mm^2.

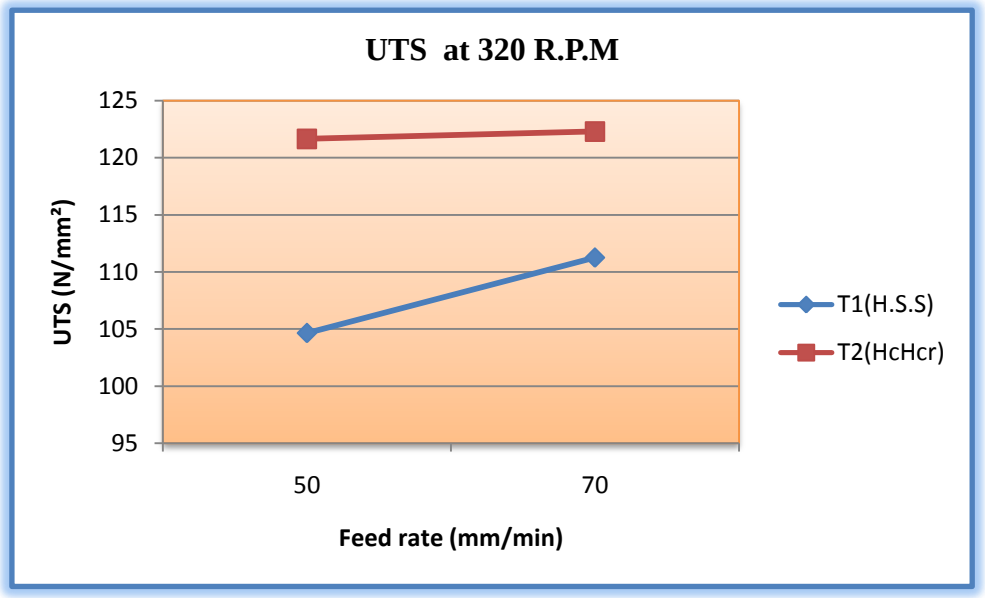

Fig: 3.3 showing the graph for UTS (N/mm^2) at 320 r.p.m and 50, 70, mm/min feed rate.

From the (fig. 3.3) graph it was observed that with HcHcr tool very slight change is observed in UTS at this stage .But UTS of weld zone is high with HcHcr tool.

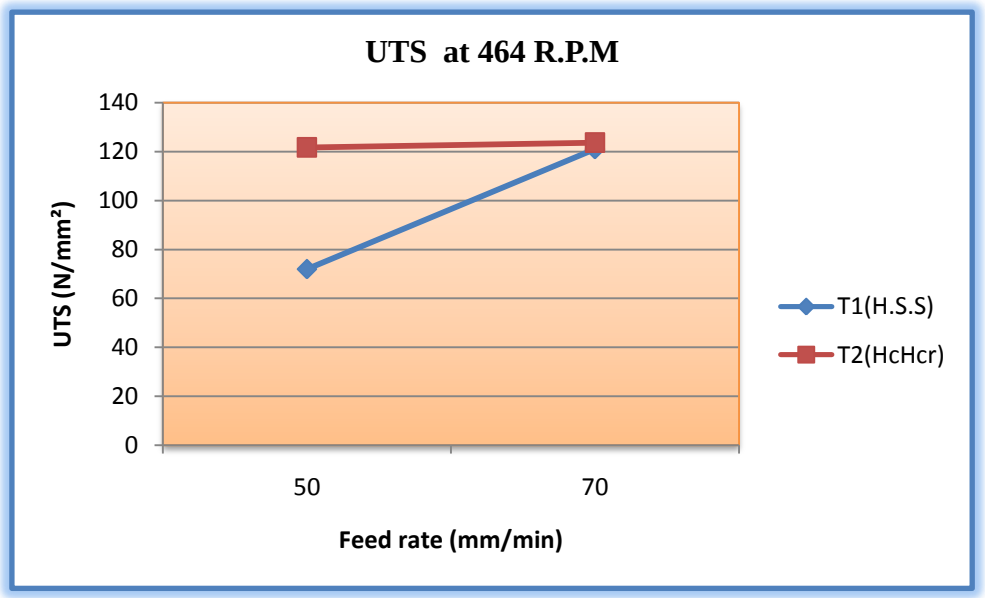

Fig: 3.4 showing the graph for the UTS (N/mm^2) at 464 r.p.m and 50, 70, mm/min feed rate.

From the (fig. 3.4) graph it was observed that with H.S.S tool the UTS of weld zone rapidly increases as the feed rate increases from 50 mm/min to 70 mm/min. And it was also observed that with HcHcr tool very slight change is observed in UTS at this stage but with Hchcr tool UTS is 123.64 (maximum) at 464 r.p.m ,70 mm/min feed.

IV. Conclusions

In the friction stir welding process selection of tool material and design of tool is an important task. So this study was focused on effect of tool material on mechanical properties of weld metal.

From this study it was observed that Hchcr Tool gives better performance than the H.S.S tool. So it is concluded that for AA6061-O material at these parameters Hchcr tool gives better output as compared to H.S.S. tool.

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