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Effect of Rotational Speed on Friction stirdeformation of Al 6061 alloy

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ABSTRACT

Aluminium 6061 alloy is an eminent material for aerospace, transportation, construction and automotive industries, but its poor wear resistance has restricted its usage. Friction stir deformation (FSD) is a promising technique to enhance the mechanical properties of Al6061 alloys via microstructural modification. A mild steel tool was carefully chosen and fabricated to have uniform defect free stir zone. The present study aimed to optimise the process parameter of material via Friction stir deformation technique. The macrostructural observations of transverse cross-section were used to get an indication of the stir zone quality. From the present analysis defect free sound stir zone was observed at 1100 rpm rotational speed, 0.2 mm/min travelling speed and at 1.2 mm probe depth.

Keywords*: *Al6061 Alloy, Defect,Friction Stir Deformation

I INTRODUCTION

Al 6061 alloy is extensively used in aerospace, automobile and marine areas due to its high strength to weight ratio, but it shows inferior tribological properties in extensive usages**[1]**. Aluminium metal and its alloys are green engineering material due to its good specific properties which makes them applicable for variety of applications in aerospace and automotive industries. It adds excellent weight to strength ratio, good ductility, corrosion resistance and cracking resistance in adverse environment **[1]**. Among all the alloys of Al, Al 6061 has remarkable importance in aerospace industry. The major alloying elements are Mg and Si so it is also known as Mg-Si alloy. It is widely applicable in aerospace industry because of its good properties like formability, weldability, machinability and sufficient strength as compared to other alloys of aluminium **[2]**. Its typical compositions in weight% are Mg(0.8-1.2),Si(0.4-0.8),Fe(0-0.7),Cu(0.15-0.4),Cr(0.04-0.35),Zn(0-0.25) and Al(remainder)**[3].**In addition to its significance in aerospace industry it is quite usable for the transportation, construction and similar engineering industries. It shows excellent mechanical properties which make it to be machined quickly and economically **[4]**. In spite of all its properties it is reinforced with second phase hard reinforce particle for its better tribological and mechanical properties. Al based MMC shows improved strength, stiffness, hardness and good wear resistance properties **[3]**. Friction stir process (FSP) process is a novel metal forming technique that is based on the principle of 'Friction Stir Welding '(FSW). FSW was developed at The

Welding Institute (TWI) of UK in 1991 as a solid–state joining technique, and was initially applicable for aluminium alloys **[5]**. FSD/ FSW is a thermo mechanical deformation method that improves the mechanical properties of material through micro structural modifications **[6].**In FSD process a non- consumable tool of definite geometry rotates and transverse in to the material along an appropriate direction with a specific speed and probe depth. Due to frictional effect between the tool and work piece, frictional heat is generated which causes the plastic deformation in the stirring zone at an elevated temperature or below the melting point of material. Due to the intense plastic deformation grain refinement occurs in the stirring zone through dynamic recrystallization **Fig1[6-7].**In **Fig1** nugget zone is shown which is highly affected by frictional heat so this zone has refined grain as compared to base metal. Second zone is Thermo Mechanically Affected Zone (TMAZ), it consist two types of transition zones from DXZ zone on the advancing side and retreating . Advancing side(AS), where the tool rotates in the same direction of travelling speed and other side is where the tool rotates in the opposite direction of travelling speed is known as retreating side(RS).In TMAZ severe plastic deformation takes place due to shear induced by the tool rotation and its transverse motion. Third zone is Heat Affected Zone (HAZ), which is less affected by the thermal energy of deformation.

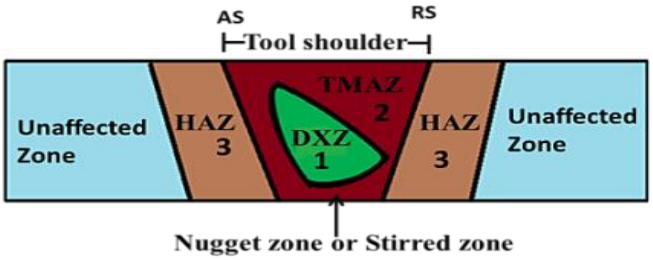
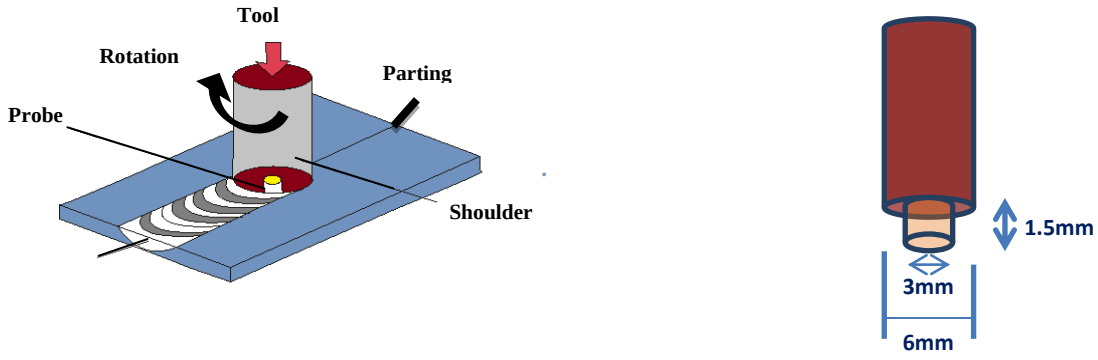


Fig. 1: Schematic representation of microstructural changes after Friction stir deformation

II. MATERIAL AND METHODS

2.1 Materials and Friction Stir deformation

Starting material utilizes cast Al6061 (Al - 96.50, Mg - 0.97, Si - 1.08 wt. %) alloy for the friction stir deformation (FSD). Friction stir processing was carried out on a rectangular sheet of cast Al6061 alloy of dimensions 10 mm × 15mm × 2mm using the Concept Mill 105 milling machine (7 HP spindle capacity of 1.1 kW, 5000 rpm and load capacity of 25 KN). A cylindrical mild steel tool (of dia 6mm, with protruding dia of 3 mm, and a protruding depth of 1.5 mm) was used for FSP. A schematic illustration of the FSP processing and rotational tool is shown in **Fig2** respectively. The FSD trials were done under varied tool rotational speed**Table1**.



(a) (b)

Fig.2: Schematic representation of: (a) Friction stir deformation (b) Rotating tool

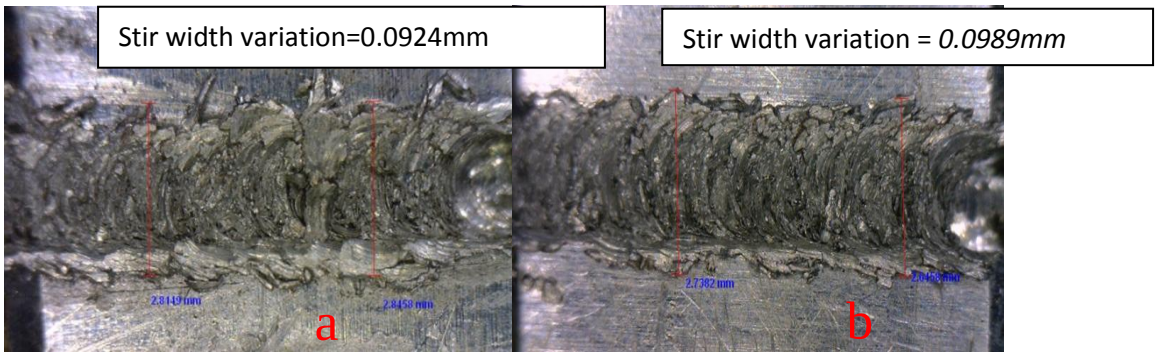
Table 1 Process parameters of aluminium 6061 for Friction stir deformation.

Rotational speed (rpm)	Travelling speed (mm/min)	Plunge depth (mm)
(1000-1400)	0.2	1.2

III FRICTION STIRDEFORMATION OF AL 6061 ALLOY

3.1 Stir width variation with different process parameter condition.

Friction stir deformation is a promising metal forming technique which is performed for microstructural modification. The main challenging aspect of this process is to optimise the process parameter for defect free stir zone. The important process parameter which affects the stir zone quality is rotational speed of tool as shown in**Fig3**. Stir width changes rapidly from **Fig3a** to **Fig3d** due to rapid frictional heating effect of tool. Also at higher rotational speed above 1500rpm there will be wear and tear effect of tool **Fig4.**



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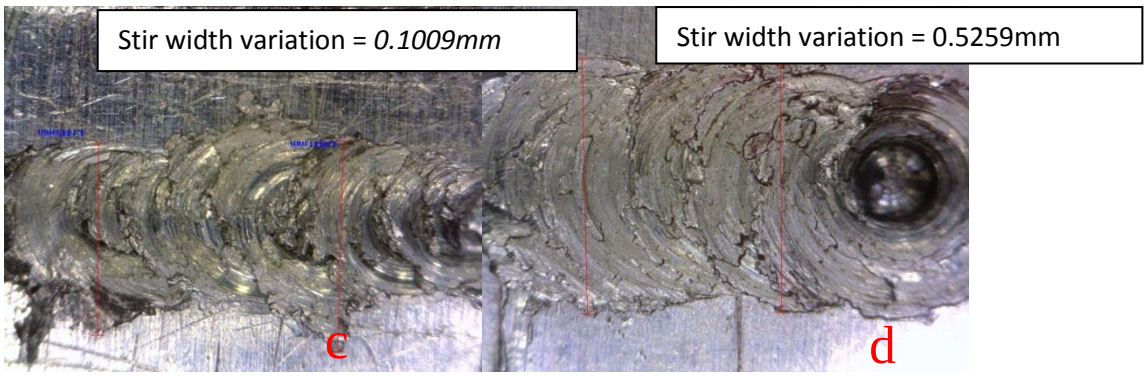

Fig3: Friction stir width variation at (a) 1000rpm (b) 1100rpm (c) 1200rpm (d) 1400rpm

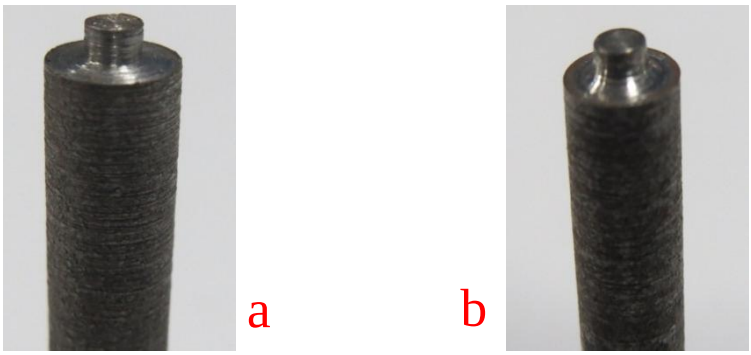

Fig4:(a) FSD mild steel tool(b) Tool Wear due to excessive heating effect of FSD

3.2 Optimum process parameter optimization for Friction stir deformation

Friction stir deformed materials are prone to many defects like pin hole, tunnel formation, piping defects, cracks etc. due to improper flow of metal and insufficient consolidation of metal in the FSD (nugget) region **[8,9]**. Numbers of experiments are carried out to optimize the friction stir process parameter condition. The process parameter like rotational speed, travelling speed and plunge depth need to be optimised for defect free sound stirring zone. In this analysis rotational speed was varied from 1000 rpm-1400 rpm and travelling speed and plunge depth were kept constant to 0.2 mm/min and 1.2 mm respectively. After the processing, macrostructures of all the samples were taken to reveal the quality of the stirring. The macrostructure of the stirred samples are illustrated in **Table 2**. Among all the condition, defect free and sound stirring condition was obtained under the condition of 1100 rpm, travelling speed 0.2 mm/min and plunge depth of 1.2 mm.

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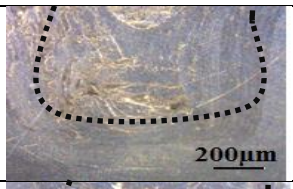
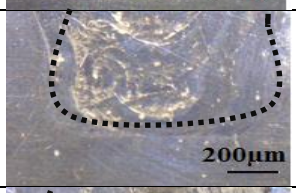
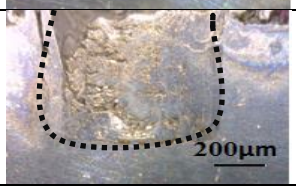
Table 2-Macrostructure images of friction stir deformed Al 6061 sample (travelling speed = 0.2 mm/min, plunge depth = 1.2 mm)

Rotational speed (rpm)	Macrostructure RS AS	Defect	Probable reason
1000		Tunnel defect	Insufficient heat input in stirring zone **[10]**.
1100		No defect	Adequate heat input and flow of the plasticized metal **[10]**.
1200		. Pin hole in ascending side	Excessive heat input and excessive stirring of material **[10].**
1400		Turbulent flow of material	Due to excessive heat generation material flow turbulently **[8]**.

IV CONCLUSION

Friction stir deformation of Al6061 is successfully done by using mild steel tool. Rotational speed is optimized to get defect free stir zone. Following conclusion is summarized from our study:

•Defect free stir zone was obtained at 1.2 mm probe depth, 0.2 mm/min travelling speed and at 1100 rpm rotational speed.

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