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Friction Stir Welding Of Single Sided Aluminium Alloy (AA6063-O) Plates in Vertical Milling Machine

T. Pradeep Kumar[1], V.Kalaiyarasan[2], P.Vijayakumar[3]
[1]*Department of Mechanical Engineering, PRIST University, Thanjavur, Tamilnadu, India*
[2]*Department of Mechanical Engineering, PRCET, Thanjavur , Tamilnadu, India*
[3]*Department of Mechanical Engineering, PRIST University, Thanjavur, Tamilnadu, India*

Abstract: Friction stir welding is a process of joining two or more similar or dissimilar materials and coalescence is achieved by the relative motion between the tool and the work piece. The joint is established as a result of the heat that is generated due to the relative motion of the tool and the work piece. In the present study two AA6063-O work pieces are friction stir welded using H13 Tool steel in vertical milling machine. Initially the tool has low hardness value. Nitriding process is carried out to harden the tool steel. The four input process parameters are Tool rotational speed (560, 900 and 1400 rpm), Weld traverse speed(31.5, 63 and 100 mm/min), Tool tilt angle(0°,1°,2°) and Tool pin diameter(6 mm, 7 mm, 8 mm). Each process parameter has 3 levels. Taguchi L9 orthogonal array is used to optimize the total number of experimental runs from 81 welds to 9 welds.
Keywords: AA6063-O, FSW, Nitriding, Vertical milling machine, Taguchi L9 orthogonal array.

I. INTRODUCTION

Friction stir welding (FSW) is also one of the solid state joining process where the material to be welded is heated below or just up to the solidus. The formation of joint in FSW depends on direct conversion of mechanical energy into thermal energy without the use of heat from the conventional source. FSW can be employed to weld aluminium alloys, copper alloys thermoplastic polymers and even the materials that couldn't be welded using fusion welding. During FSW in vertical milling machine heavy vibrations are caused in the work piece so fixtures are used to constraint the movement of work pieces. The working tool is held in a rotating chuck where tool rotational speed (rpm) can be given as input. The chuck along with the tool is traversed along the work pieces at a particular weld traverse speed (mm/min). FSW is initiated by plunging the rotating tool chuck the shoulder of the tool is in complete contact with the work piece surface [1]. The traversing of rotating tool causes plastic deformation due to combined effect of frictional heat and strain. The material that is present in the leading side is sent to the trailing side as a result joint is established. The axial force applied on the tool against the work piece can be given as input value in friction stir welding machine but not in vertical milling machine. But the availability of FSW machine is not everywhere and easy. A vertical milling machine well equipped can able to well even thick materials easily [2]. Higher weld traverse speeds can be given as input in FSW machine than vertical milling machine. FSW also eliminates weld defects such as pores, hot cracking which is common problem during conventional welding [4]. FSW requires no filler electrodes as in arc welding. Emissions of harmful gases are also avoided in FSW.

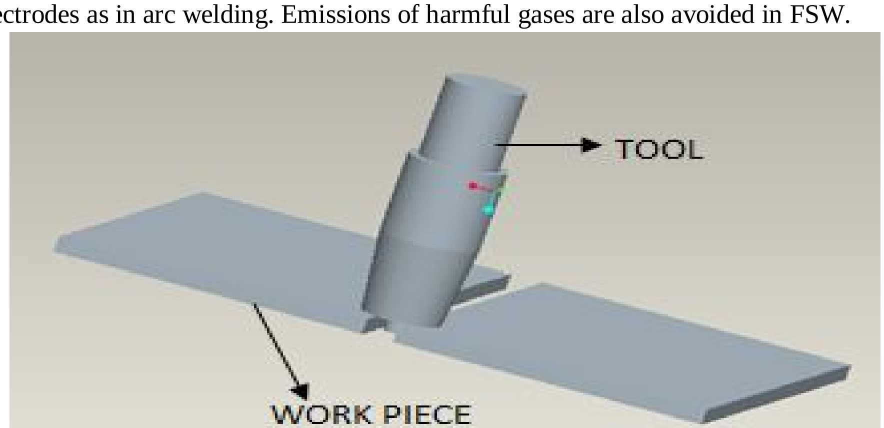

Fig 1: Arrangement of work pieces and tool for FSW.

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II. PROCESS PARAMETERS SELECTION

In fusion welding, many process parameters such as arc gas, shielding gas, voltage of the arc, wire feed should be controlled. In friction welding there are only fewer process parameters that needs to be controlled. Process parameters play a vital role in the outcome of weld joint. The available tool rotational speeds in vertical milling machines are 450 rpm, 560 rpm, 710 rpm, 900 rpm, 1120 rpm, 1400 rpm out of which 560 rpm, 900 rpm, and 1400 rpm are selected in order to have common interval. Ugender.et al., [3] observed that Low tool rotational speeds results in worm hole effect due to insufficient heat generation and insufficient metal filling during welding of magnesium alloy. High rotational speeds results in tunnel effect caused by excessive heat generation. Pin holes are formed due to low weld traverse speeds whereas high traverse speeds causes inadequate flow of metal. 31.5 mm/min, 63 mm/min, 100 mm/min are the weld traverse speeds chosen from the available traverse speeds of 8 mm/min, 10 mm/min, 12.5 mm/min, 16 mm/min, 20 mm/min, 25 mm/min, 31.5 mm/min, 40 mm/min, 50 mm/min, 63 mm/min, 80 mm/min, 100 mm/min for the study. In FSW the tool pin is completely inserted between the work pieces and traversed at a small swaying angle called tool tilt angle which is the third process parameter selected. Tool tilt angle values for the study are 0°, 1°, 2°. Tool pin diameter has an impact on mixing of metals as the rotating effect of the pin causes the formation of advancing side and rotating side and the metal flows around the tool pin. Tool pin diameter values are 6 mm, 7 mm, 8 mm. Taguchi method uses a special set of arrays which sets out a way of conducting minimum number of experiments. Taguchi L9 orthogonal array is a right choice for understanding the effect of 4 independent factors provided each process parameters has 3 levels. In the present study this method is used to reduce the experimental runs from 81 (3*3*3*3) to 9. Aluminium AA6063-0 alloy flat work pieces procured and were cut of required dimensions of 150 mm X 100 mm X 6 mm. Facing operation is done on their edges before FSW.

Table 1: Process parameters of FSW

EXPERIMENTAL RUNS	TOOL ROTATIONAL SPEED (rpm)	WELD TRAVERSE SPEED (mm/min)	TOOL TILT ANGLE (degrees)	TOOL PIN DIAMETER (mm)
1	560	31.5	0	6
2	560	63	1	7
3	560	100	2	8
4	900	31.5	1	8
5	900	63	2	6
6	900	100	0	7
7	1400	31.5	2	7
8	1400	63	0	8
9	1400	100	1	6

III.SELECTION OF TOOL

A. TOOL NOMENCLATURE

The working tool should possess factors such as elevated temperature strength, wear resistance, good machinability and fracture toughness. H13 tool steel is finalised as the tool material after validation of factors. The tool was bought in cylindrical form with a diameter of 30 mm, tool length of 100 mm and subjected to turning operation such that shoulder has a diameter of 25 mm, shank of 28 mm and 25 mm diameters. Three working tools with pin diameters of 6 mm, 7 mm, 8 mm were prepared. Tool pin length is 5.7 mm. The shank has been given tapered form in order to improve the load bearing capacity. The pin can be threaded in order to have better mixing of metal.

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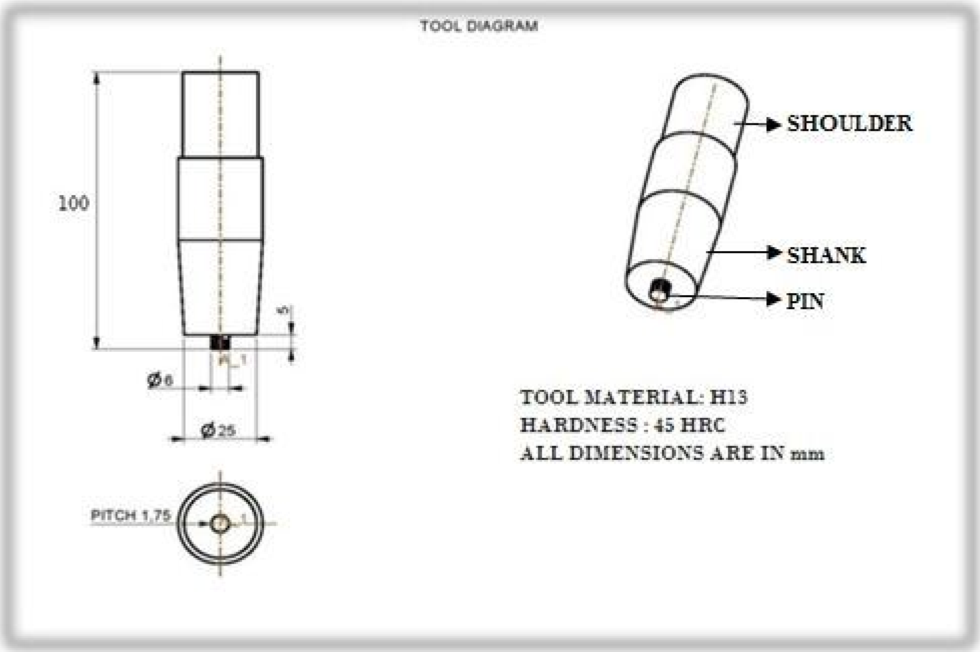

Fig 2: Tool Nomenclature.

B. Nitriding

In FSW, it is desirable that the tool has high hardness at the surface and the core of the tool need not require high hardness. Nitriding is one such surface heat treatment done to achieve it. In nitriding, the nitrogen atoms get diffused along the surface of the steel. Initially the H13 tool steel has hardness of 20 HRC. The tool steel is heated and maintained at 570^0 C for 50 hours in a gas tight chamber and ammonia gas is allowed to circulate as a result, nitrogen atoms gets absorbed on the surface of tool steel. Post nitriding, hardness measured in Rockwell hardness machine and it got increased to 45 HRC.

Fig 3: Tool before Nitriding, Hardness: 20 HRC.

Fig 4: Tool after Nitriding, Hardness: 45 HRC

IV. RESULTS AND DISCUSSIONS

A total number of nine experimental runs of FSW are carried out in vertical milling machine. As a result, 9 joints of aluminium alloy (AA6063-O) plates are obtained.

A. Nine weld joints of aluminium alloy (AA6063-O) plates are obtained.
B. Weld joints are found to be free from weld defects such as pores, cracks.
C. The images of the weld joints are listed in Fig 4.

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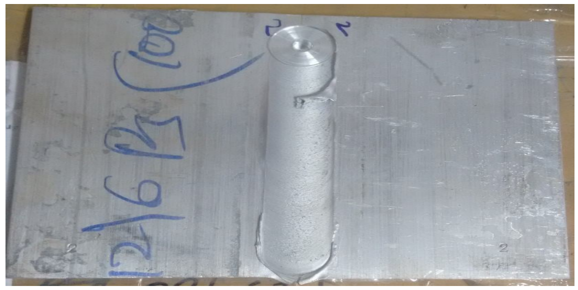
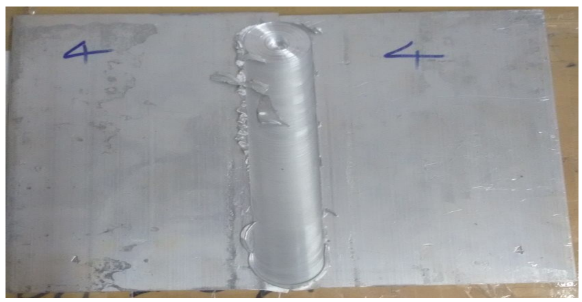


Fig 4: Friction stir welded joints 2, 4 and 6.

Rotational Speed: 560 rpm
Traverse Speed: 63 mm/min
Tool Tilt Angle: 1 deg
Tool Pin Diameter: 7 mm



Rotational Speed: 900 rpm
Traverse Speed: 31.5 mm/min
Tool Tilt Angle: 1 deg
Tool Pin Diameter: 8 mm

Rotational Speed: 900 rpm
Traverse Speed: 100 mm/min
Tool Tilt Angle: 0 deg
Tool Pin Diameter: 7 mm

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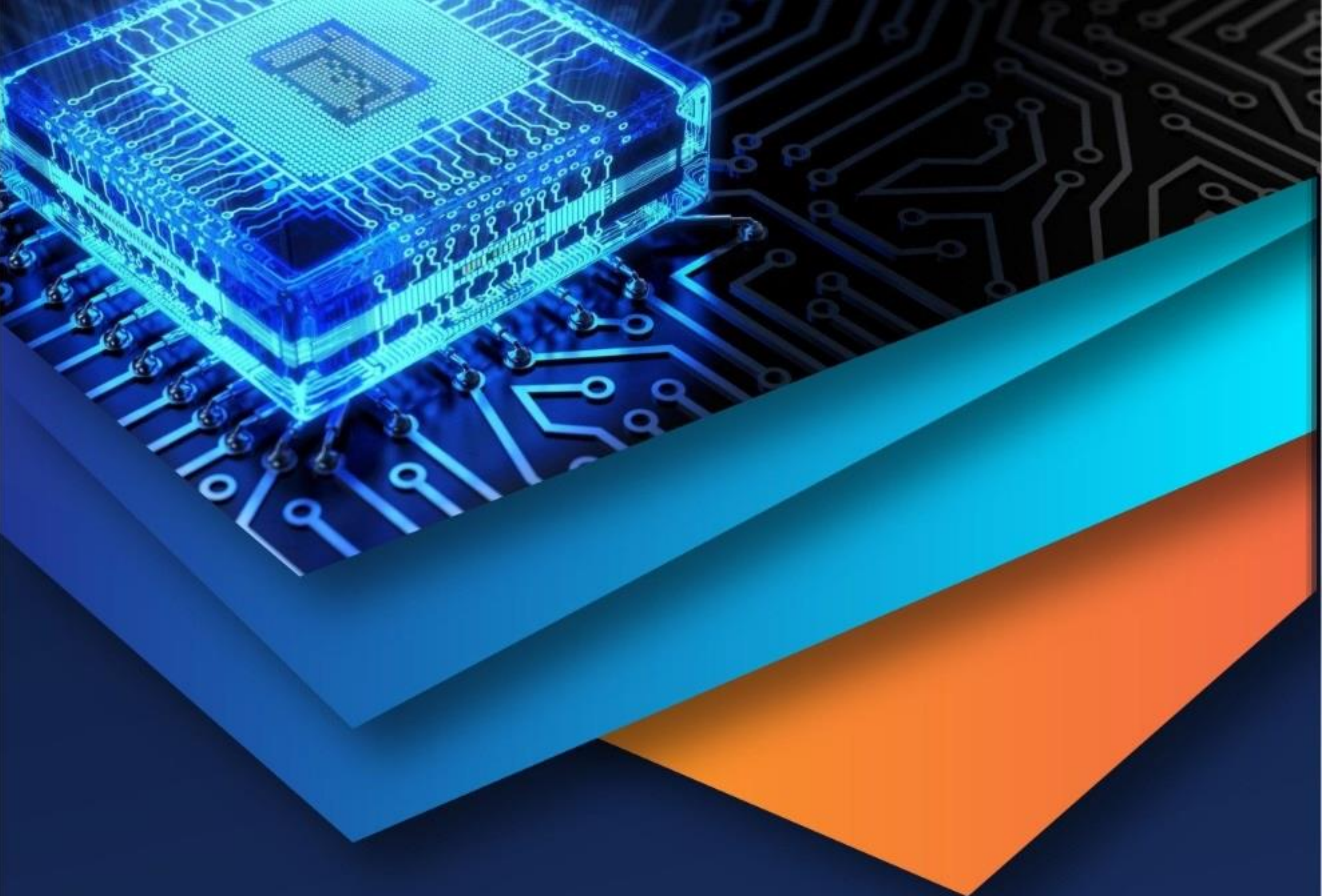

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