Investigations of Analysis and Fabrication of butt joint using friction stir welding of A319 Aluminum Alloy

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Abstract- Friction stir welding (FSW) is a new and promising welding process that can produce low-cost and high-quality joints of heat-treatable aluminum alloys because it does not need consumable filler materials and can eliminate some welding defects such as crack and porosity. In this paper the effect of welding speed and tool pin profile on FSP zone formation in A319 alloy has been studied. Different tool pin profiles are used to fabricate the welding joints. Those profiles are round, round taper, square and treaded, and the Finite Element Analysis (FEA) process coupled field analysis on different tool pin profiles to verify the temperature distribution, thermal flux, gradient and stresses have been studied. The experimental results showed that thermal gradient is less for round cutting tool and it was found around 577.4 K/mm and thermal flux is also less which around 7.507 W/mm2.

Keywords: Friction stir welding, Aluminum319 alloy, thermal flux.

I. Introduction

Friction-stir welding (**fsw**) is a solid-state joining process (meaning the metal is not melted during the process) developed by twi in 1991[1] and is used for applications where the original metal characteristics must remain unchanged as far as possible. This process is primarily used on aluminum, and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics.

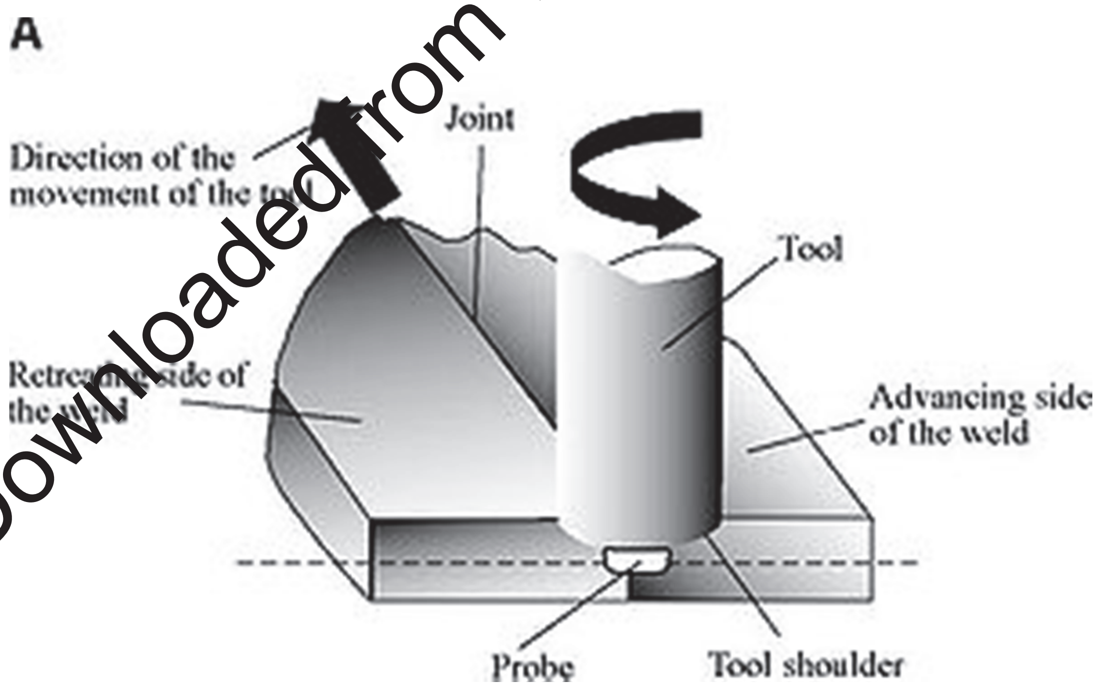

Fig 1.a. Schematic diagram of the FSW process: (A) Two discrete metal work pieces butted together, along with the tool (with a probe).

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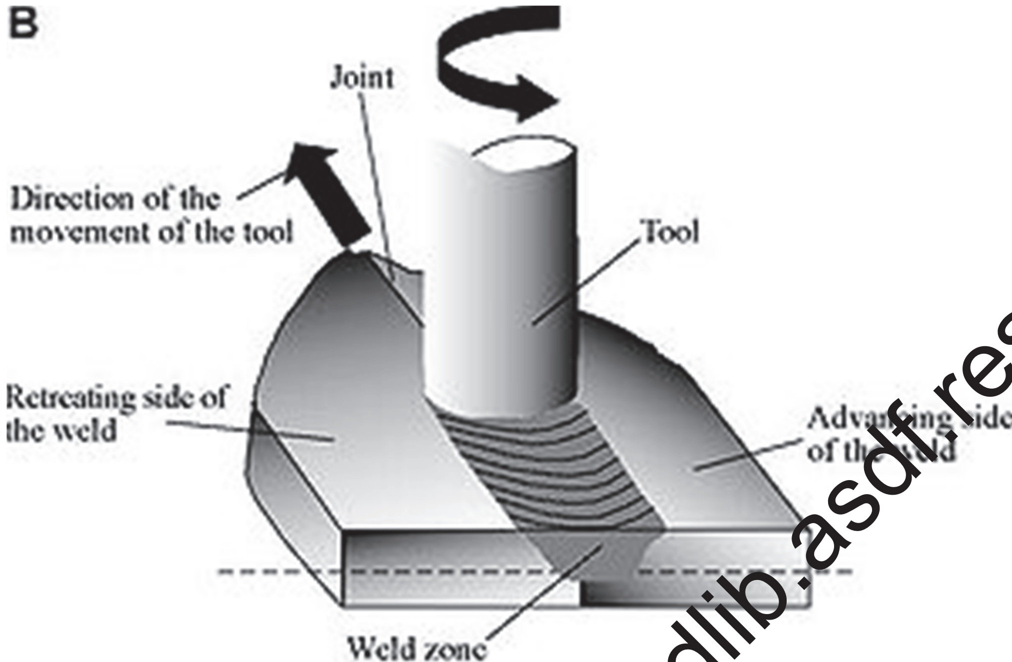

Fig 1.b. The progress of the tool through the joint, also showing the weld zone and the region affected by the tool shoulder

In FSW, a cylindrical-shouldered tool, with a profiled threaded/unthreaded probe (nib or pin) is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of sheet or plate material, which are butted together [2]. The parts have to be clamped rigidly onto a backing bar in a manner that prevents the abutting joint faces from being forced apart. The length of the nib is slightly less than the weld depth required and the tool shoulder should be in intimate contact with the work surface. The nib is then moved against the work, or vice versa. Frictional heat is generated between the wear-resistant welding tool shoulder and nib, and the material of the work pieces. This heat, along with the heat generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without reaching the melting point (hence cited a solid-state process), allowing the traversing of the tool along the weld line in a plasticised tubular shaft of metal. The amount of heat conducted into the workpiece determines the quality of the weld, residual stress, distortion of the workpiece and the microstructure of the metal [4, 5]. As the pin is moved in the direction of welding, the leading face of the pin, assisted by a special pin profile, forces plasticised material to the back of the pin while applying a substantial forging force to consolidate the weld metal. The welding of the material is facilitated by severe plastic deformation in the solid state, involving dynamic recrystallization of the base material.

II. Experimental Procedure

Friction stir butt welded joints of A319 alloy, with a thickness of 6 mm and chemical composition of Al 87.2%, Si 5.8%, Cu 3.51%, Fe 0.68%, Mn 0.25%, Zn 0.9%, Cr 0.1%, Ti 0.16%, Ni 0.12%, Sn 0.02% & Pb 0.03% were selected in the present study. Friction stir welding was carried out using 3-Axis Vertical CNC Milling Machine with the position of the tool fixed relative to the surface of the Sheet as shown in fig.1. The work piece was firmly clamped to the bed and specially made tool was plunged in to the selected area of the material sheet for the sufficient time in order to plasticize around pin. After adequate plasticization tool is traversed across the surface the material for a single pass. Different tool pin profiles are used to fabricate the welding joints. Those profiles are round, round taper, square and treaded used in the present investigation.

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough and hard wearing, at the welding temperature. Further it should have a good oxidation resistance and a low thermal conductivity to minimise heat loss and thermal damage to the machinery further up the drive train. Hot-worked tool steel such as AISI H13 has proven perfectly acceptable for welding aluminium alloys within thickness ranges of 0.5 – 50 mm but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composites or higher melting point materials such as steel or titanium. The experimental work for 5 different tools round tool, round tapered, Square tool, triangle tool and Treaded were modeled in Pro/ENGINEER Wildfire which is the standard in 3D product design. Coupled field analysis for both cutting tools and welding plates are done using ANSYS is general-purpose finite element analysis (FEA) software package.

III. Results and Discussions

The round cylindrical tool and two plates was modeled using ProE by taking the dimensions of the tool 18mm as shoulder Diameter, 6mm as the pin diameter 5.7 as the length of the pin and 80mm as the length of the tool and the plates were modeled with dimensions 50 mm x 100 mm and the thickness was taken of 6mm.

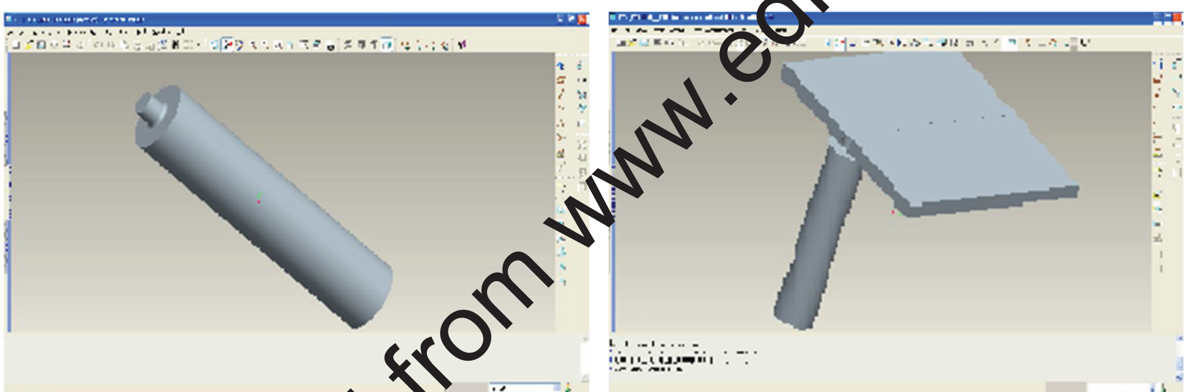

Fig 2.Round Tool and plates for friction stir welding

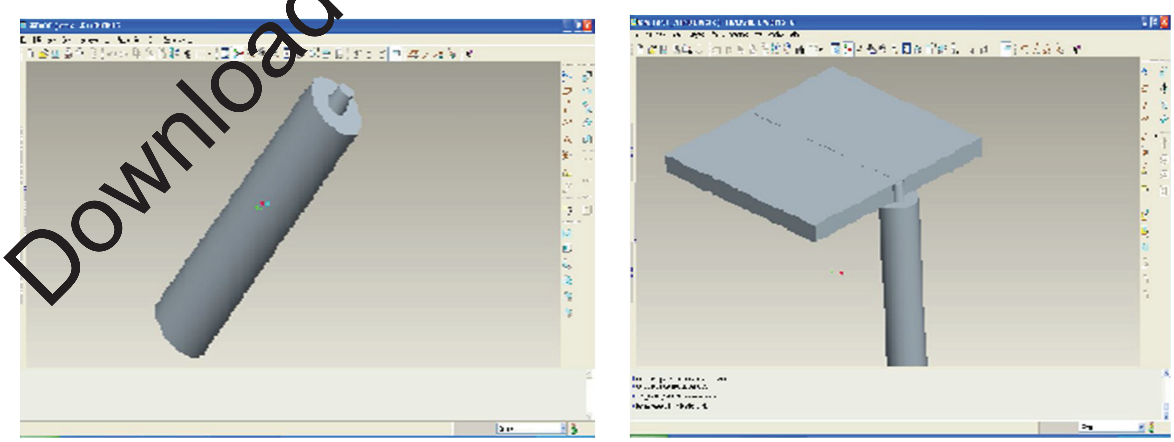

Fig 3.Round taper Tool and plates for friction stir welding

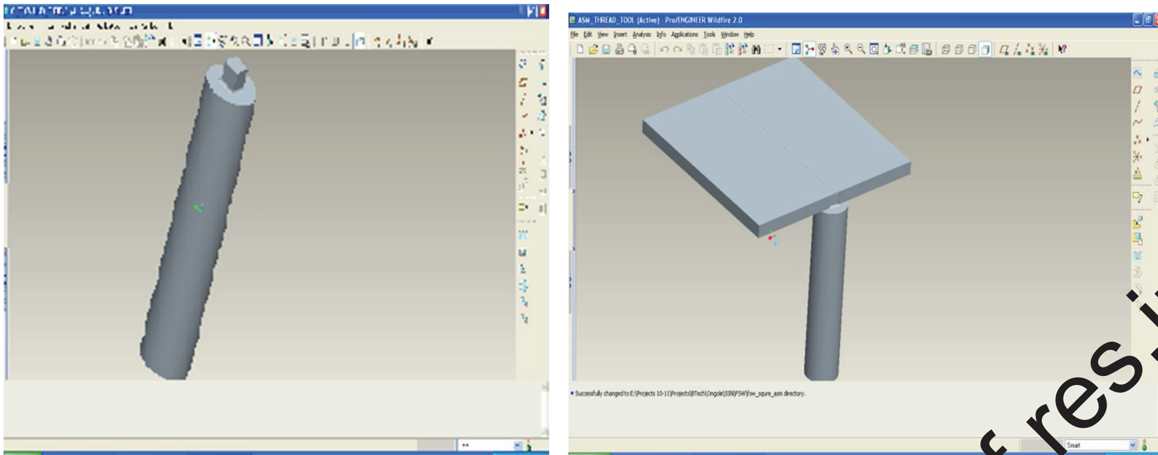

Fig 4.Square Tool and plates for friction stir welding

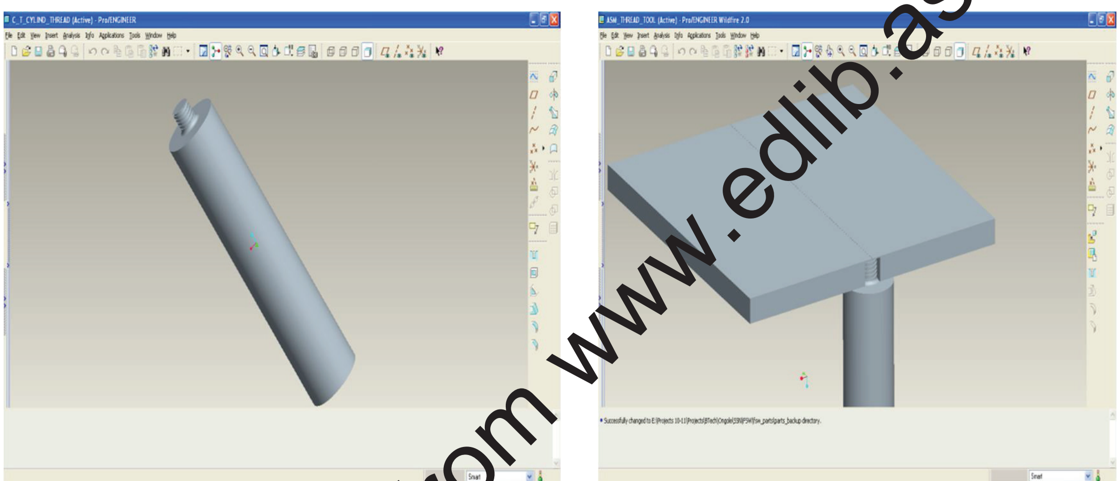

Fig 5.Threded Tool and plates for friction stir welding

Coupled field Analysis was carried out for the all designed tools the fig 6 shows the various the simulation result can help select the material used for FSW tool and the proper welding parameter for its application.

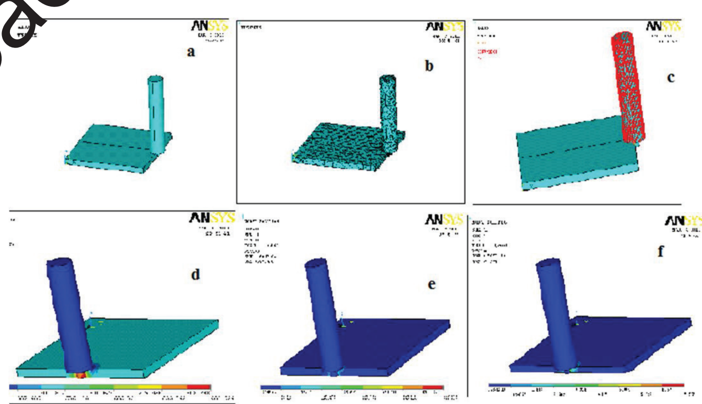

Fig 6 a) shows the imported Model from Pro/Engineer b) shows the meshed tool and plate taking Solid 20 node 90 c) Temperature loads d) nodal temperature e) Thermal Gradient f) Thermal Flux

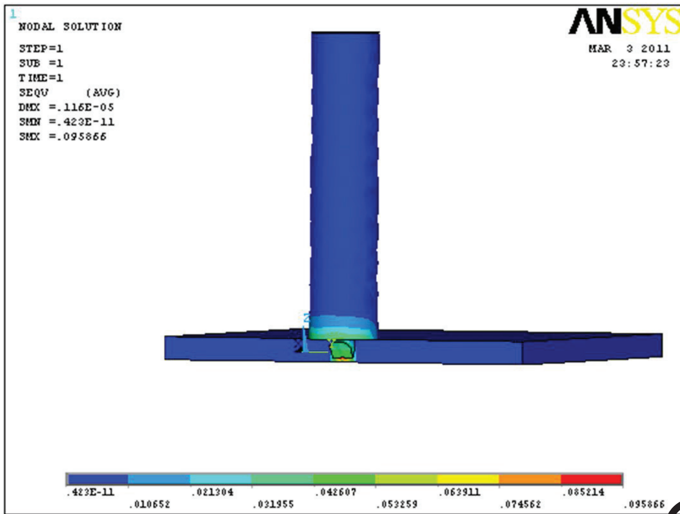

Fig 7 Stress distribution of round tool

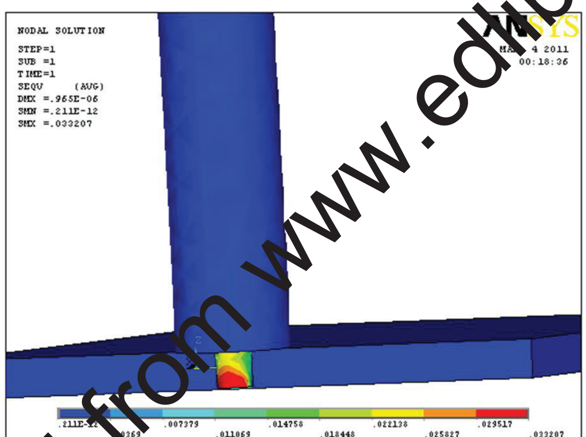

Fig 8 Stress distribution of round taper tool

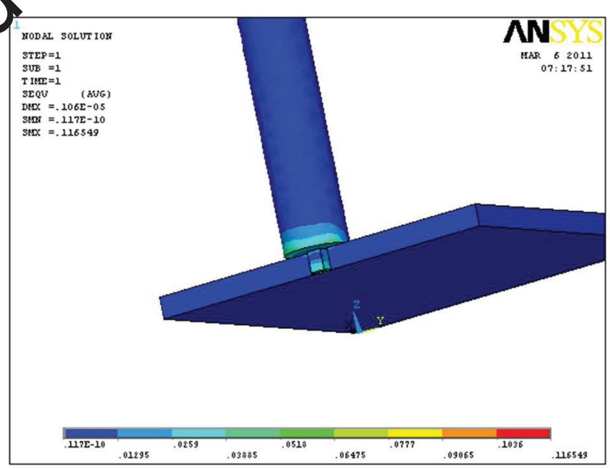

Fig 9 Stress distribution of square tool

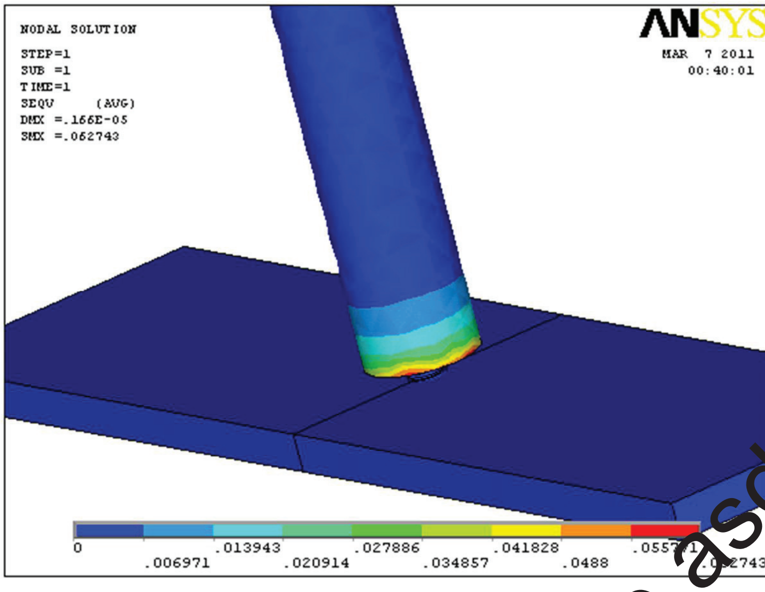

Fig 10 Stress distribution of treaded tool

Table 1: The analysis results

	ROUND TOOL	ROUND TAPER	SQUARE	THREAD
NODAL TEMPEARATURE (K)	982.654	987.792	983.049	973
THERMAL GRADIENT (K/mm)	577.438	1002	761.38	790.393
THERMAL FLUX (W/mm^2)	7.507	23.056	14.176	10.275
DISPLACEMENT (mm)	0.116e^{-5}	0.857e^{-6}	0.106e^{-5}	0.166e^{-5}
STRESS (N/mm^2)	0.95866	0.33207	0.116549	0.062743

IV. Conclusions

- In our project we have designed 4 types of cutting tools Round, Round taper, Square, and Thread for doing Friction Stir Welding.
- We have conducted FEA process coupled field analysis on tools Round, Round taper, square and treaded to verify the temperature distribution, thermal flux, gradient and stresses.
- By observing the results, thermal gradient is less for round cutting tool and thermal flux is also less. Temperature is also produced for required melting point of plates.
- So for using Friction Stir Welding, round cutting tool is more effective than other cutting tools from FEA results.
- By conducting experimental work also, it is proved that round cutting tool produces effective welding.

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