International Journal of Research
Available at
https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 14
October2016

Investigation Parametric Model of Friction Stir Welding

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ABSTARCT:

A computational fluid dynamics (CFD) model is presented for simulating the material flow and heat transfer in the friction stir welding (FSW) of 6061-T6 aluminum alloy (AA6061). The goal is to utilize the 3-D, numerical model to analyze the viscous and inertia loads applied to the FSW tool by varying the welding parameters. To extend the FSW process modeling, in this study, the temperature-dependant material properties as well as the stick/slip condition are considered where the material at the proximity of the FSW tool slips on the lower pressure regions. A right-handed one-way thread on a tilted FSW tool pin with a smooth, concaved shoulder is, additionally, considered to increase the accuracy of the numerical model. In addition, the viscous and frictional heating are assumed as the only sources of heat input. In the course of model verification, good agreements are found between the numerical results and the experimental investigations.

INTRODUCTION:

FRICTION-STIR WELDING

friction-stir welding (FSW) is a solid-state joining process (the metal is not melted) that uses a third body tool to join two facing surfaces. Heat is generated between the tool and material which leads to a very soft region near the FSW tool. It then mechanically intermixes the two pieces of metal at the place of the joint, then the softened metal (due to the elevated temperature) can be joined using mechanical pressure (which is applied by the tool), much like joining clay, or dough. It is primarily used on aluminium, and most often on extruded aluminium (non-heat treatable alloys), and on structures which need superior weld strength without a post weld heat treatment.

It was invented and experimentally proven at The Welding Institute UK in December

1991. TWI holds patents on the process, the first being the most descriptive.

1.1.1 Principle of operation

A constantly rotated non-consumable cylindrical-shouldered tool with a profiled probe is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. Frictional heat is generated between the wear-resistant welding components and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward, a special profile on its leading face forces plasticised material to the rear where clamping force assists in a forged consolidation of the weld. This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid state deformation involving dynamic re-crystallization of the base material.

1.1.2Micro structural features

The solid-state nature of the FSW process, combined with its unusual tool and asymmetric nature, results in a highly characteristic microstructure. The microstructure can be broken up into the following zones:

- The stir zone (also nugget, dynamically recrystallised zone) is a region of heavily deformed material that roughly corresponds to the location of the pin during welding. The grains within the stir zone are roughly equiaxed and often an order of magnitude smaller than the grains in the parent material. A unique feature of the stir zone is the common occurrence of several concentric rings which has been referred to as an "onion-ring" structure. The precise origin of these rings has not been firmly established, although variations in particle number density, grain size and texture have all been suggested.
- The flow arm zone is on the upper surface of the weld and consists of material that is dragged by the shoulder from the retreating side of the weld, around the rear of the tool, and deposited on the advancing side.
- The thermo-mechanically affected zone (TMAZ) occurs on either side of the stir zone. In this region the strain and temperature are lower and the effect of welding on the microstructure is correspondingly smaller. Unlike the

stir zone the microstructure is recognizably that of the parent material, albeit significantly deformed and rotated. Although the term TMAZ technically refers to the entire deformed region it is often used to describe any region not already covered by the terms stir zone and flow arm.[citation needed]

- The heat-affected zone (HAZ) is common to all welding processes. As indicated by the name, this region is subjected to a thermal cycle but is not deformed during welding. The temperatures are lower than those in the TMAZ but may still have a significant effect if the microstructure is thermally unstable. In fact, in age-hardened aluminium alloys this region commonly exhibits the poorest mechanical properties.

1.1.3 Advantages and limitations

The solid-state nature of FSW leads to several advantages over fusion welding methods as problems associated with cooling from the liquid phase are avoided. Issues such as porosity, solute redistribution, solidificatio n cracking and liquation cracking do not arise during FSW. In general, FSW has been found to produce a low concentration of defects and is very tolerant of variations in parameters and materials.

Nevertheless, FSW is associated with a number of unique defects. Insufficient weld temperatures, due to low rotational speeds or high traverse speeds, for example, mean that the weld material is unable to accommodate the extensive deformation during welding. This may result in long, tunnel-like defects running along the weld which may occur on the surface or subsurface. Low temperatures may also limit the forging action of the tool and so reduce the continuity of the bond between the material from each side of the weld. The light contact between the materials has given rise to the name "kissing-bond". This defect is particularly worrying since it is very difficult to detect using non-destructive methods such as X-ray or ultrasonic testing. If the pin is not long enough or the tool rises out of the plate then the interface at the bottom of the weld may not be disrupted and forged by the tool, resulting in a lack-of-penetration defect. This is essentially a notch in the material which can be a potential source of fatigue cracks.

A number of potential advantages of FSW over conventional fusion-welding processes have been identified:

- Good mechanical properties in the as-welded condition
- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables — A threaded pin made of conventional tool steel, e.g., hardened H13, can weld over 1 km (0.62 mi) of aluminium, and no filler or gas shield is required for aluminium.
- Easily automated on simple milling machines — lower setup costs and less training.
- Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
- Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
- Can use thinner materials with same joint strength.
- Low environmental impact.
- General performance and cost benefits from switching from fusion to friction.

However, some disadvantages of the process have been identified:

- Exit hole left when tool is withdrawn.
- Large down forces required with heavy-duty clamping necessary to hold the plates together.
- Less flexible than manual and arc processes (difficulties with thickness variations and non-linear welds).
- Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required.

1.1.4 Important welding parameters

Tool design

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 be 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.

Improvements in tool design have been shown to cause substantial improvements in productivity and quality. TWI has developed tools specifically designed to increase the penetration depth and thus increasing the plate thicknesses that can be successfully welded. An example is the "whorl" design that uses a tapered pin with re-entrant features or a variable pitch thread to improve the downwards flow of material. Additional designs include the Triflute and Trivex series. The Triflute design has a complex system of three tapering, threaded re-entrant flutes that appear to increase material movement around the tool. The Trivex tools use a simpler, non-cylindrical, pin and have been found to reduce the forces acting on the tool during welding.

The majority of tools have a concave shoulder profile which acts as an escape volume for the material displaced by the pin, prevents material from extruding out of the sides of the shoulder and maintains downwards pressure and hence good forging of the material behind the tool. The Triflute tool uses an alternative system with a series of concentric grooves machined into the surface which are intended to produce additional movement of material in the upper layers of the weld.

Widespread commercial applications of friction stir welding process for steels and other hard alloys such as titanium alloys will require the development of cost-effective and durable tools. Material selection, design and cost are important considerations in the search for commercially useful tools for the welding of hard materials. Work is continuing to better understand the effects of tool material's composition, structure, properties and geometry on their performance, durability and cost.

1.1.5 Tool rotation and traverse speeds

There are two tool speeds to be considered in friction-stir welding; how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle. The relationship between the welding speeds and the heat input during welding is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool. If the material is too cold then voids or other flaws may be present in the stir zone and in extreme cases the tool may break.

Excessively high heat input, on the other hand may be detrimental to the final properties of the weld. Theoretically, this could even result in defects due to the liquation of low-melting-point phases (similar to liquation cracking in fusion welds). These competing demands lead onto the concept of a "processing window": the range of processing parameters viz. tool rotation and traverse speed that will produce a good quality weld. Within this window the resulting weld will have a sufficiently high heat input to ensure adequate material plasticity but not so high that the weld properties are excessively deteriorated.

DESIGN

Create rectangular plate by using Aluminium 100*200mm with reference dimensions

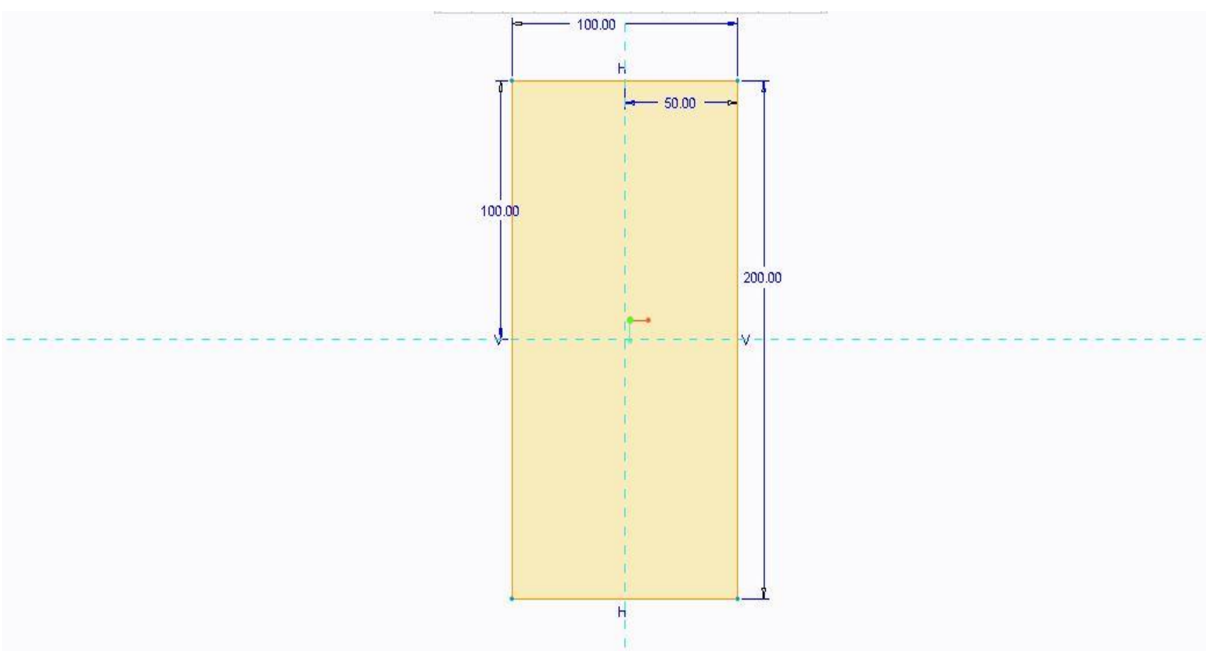

Figure 3.1 Plate dimensions

The above sketch should follow 3 conditions those are the sketcher should be closed and there should be no open end there should be no over lapping. By following these conditions we have to create our model. After completion of sketch click ok and we will get below model.

Then extrude it to 200mm after click ok

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 14
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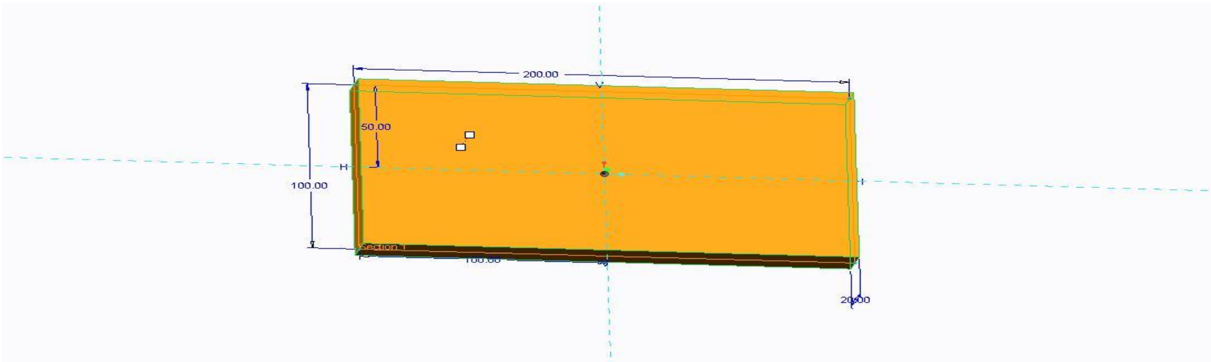

Figure 3.2 Extrude model

To create tool extrude the circle with 24mm diameter

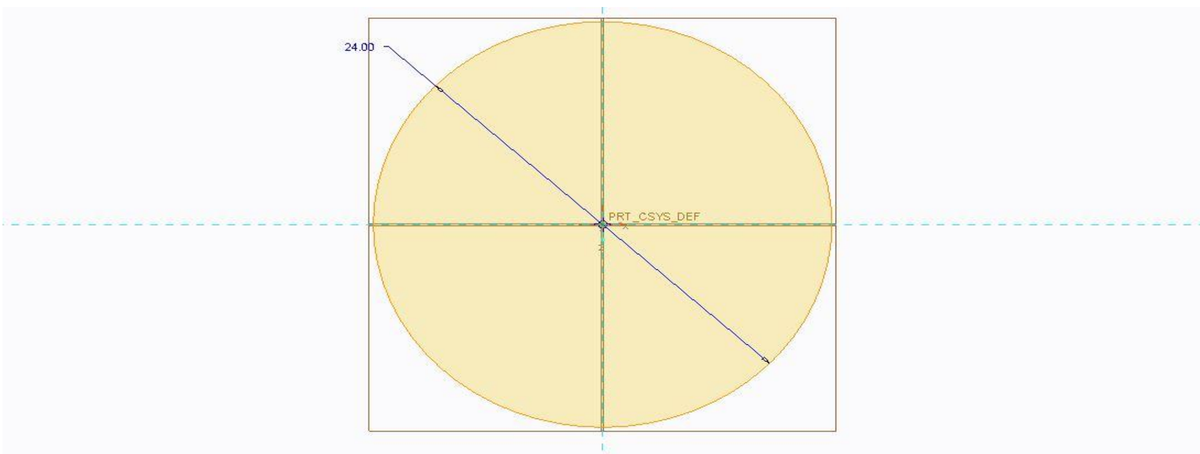

Figure 3.3 Tool diameter

Create extrude with 15mm thicknes ok

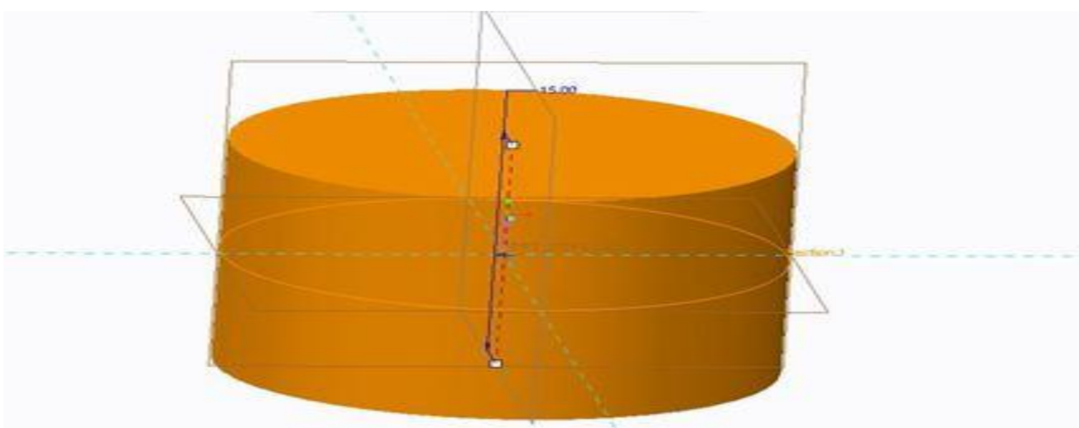

Figure 3.4 Extrude tool

Create inner diameter by using the 6mm

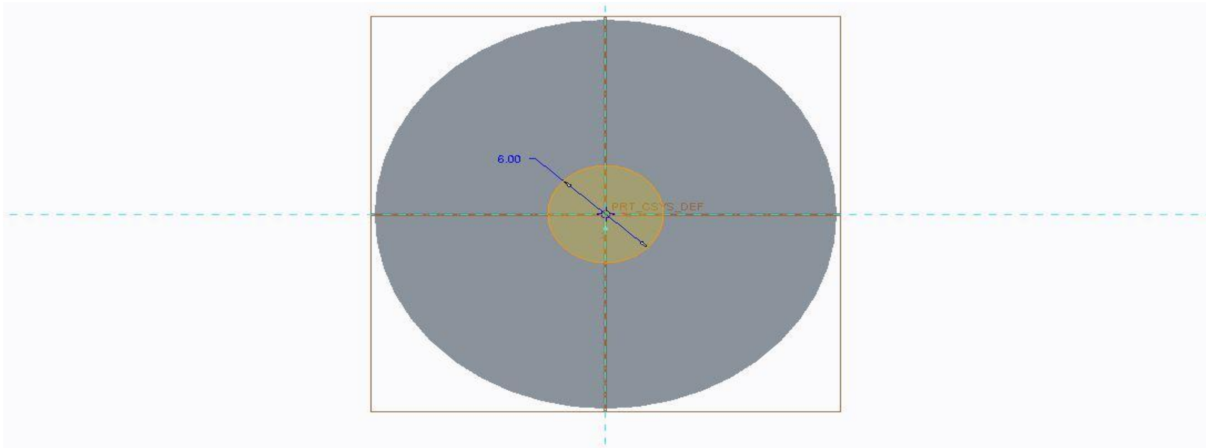

Figure 3.5 Circular tool dimensions

Extrude the circular tool by using the

5.5mm

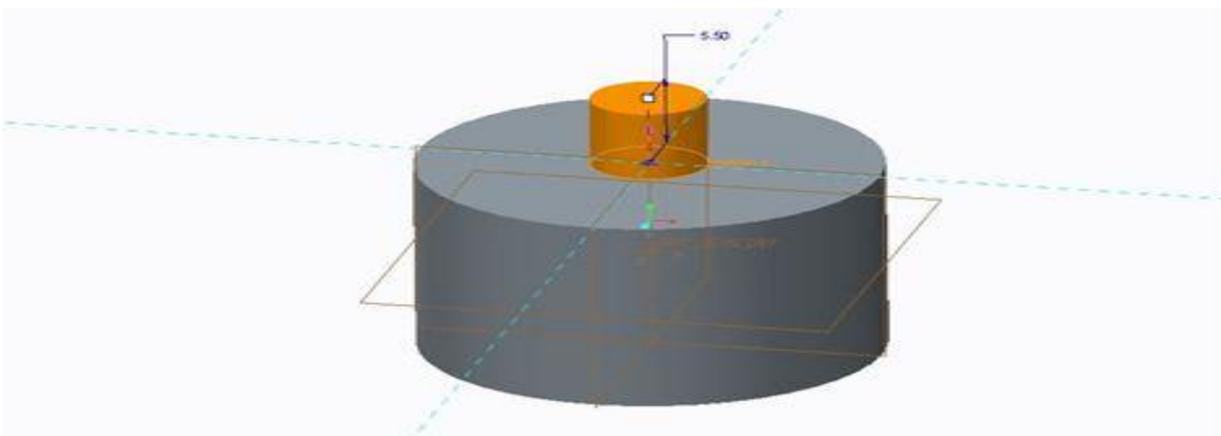

Figure 3.6 Extrude tool

Figure 3.7 Circular Complete tool

The above circular tool has been created with dimension of circular diameter 6mm and tool height is 5.5mm and based on this we are going to crate different tools with same dimensions but different shapes and those shapes are hexagonal,tapered,truncated tools.

And create different tools by using same process

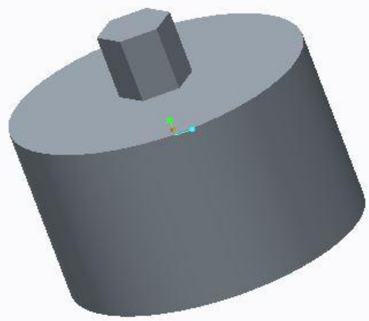

Figure 3.8 Hexagonal tool

Here we created hexagonal model with edge length 6mm and extrude height 5.5mm

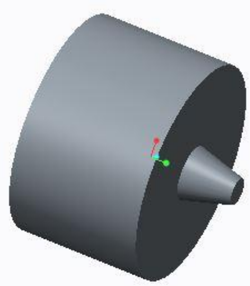

Figure 3.9 Tapered tool

The above tapered tool was created by using blend option and here we have complete two different circular diameters are there those are 6mm and 4mm follows.

Figure 3.10 Truncated conical tool

Here truncated model also created by same blend option which we were used in above tapered shape but here we taken minimum diameter is 5mm and maximum diameter is 6mm and height is 5.5mm. save all these files individual after completion of all designs here we assembling our objects.

Save all individual files and then import into assembly window after make them assemble into single part

Import rectangular base plate first into assembly window then select default option this default option makes object planes coincide with assembly planes. Then import other plate also and place it contact with other plate. Here we are using only coincide constraint option for all these constraints. And then import circular tool and place at middle of the plates and we created complete assembly model by using only constraint option only.

CONCLUSION

In our project we have designed 4 types of cutting tools Round, hexagonal and tapered and truncated for doing Friction Stir Welding of two dissimilar materials Aluminium alloy 6061for plates and steel (tool) running at speed of 1000 rpm. And we conducted static analysis on it, in this project the round tool is considered as a existing tool and also we analysed other 3 tools with same boundary conditions and material. from the results when we were using circular tool it has been produces 462Mpa stress on the plate but the tapered tool produces 357.79Mpa only

After that we have conducted FEA process thermal analysis on all tools Round and hexagonal and tapered and truncated tool to verify the temperature distribution, thermal flux, and stresses at different transverse speed. By observing the results, thermal flux and thermal gradient is more for circular tool and the stresses produced are more than tapered tool. Temperature is also produced for required melting point of plates. So for using Friction Stir Welding, we can also use tapered tool.

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