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The Frictions Stir Welding Tools with Different Composite Materials Using With CREO and ANSYS

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Abstract:

The 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. In this project we have designed circular tool by using creo-2 and then applied static (tool rotational velocity 1000 rpm) and thermal (temperatures' and convection on plates and tool also) boundaries conditions And calculated results like deformation stress and heat flux etc. Here we also designed 3 more tools hexagonal and tapered and truncated and applied same boundary condition with same material properties and calculated all results from all these results which tool can be used in the place of circular tool.

Keywords

Friction-stir welding, solid-state joining process pollution, softened metal, Welding Tools, creo-2, circular tool, ANSYS...

1. Introduction

The 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.

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.

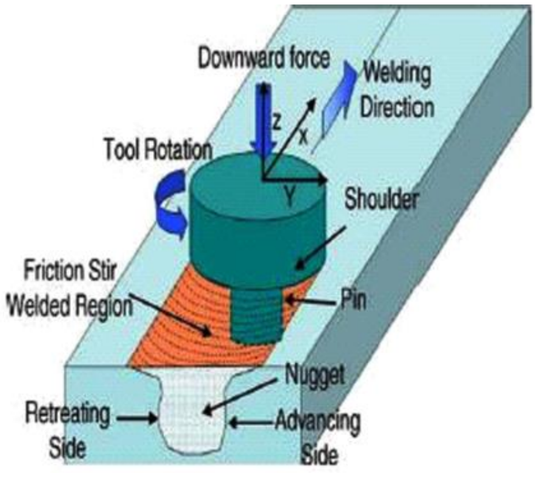

Figure. 1.1. Friction stir welding schematic diagram

As the pin is moved forward, a special profile on its leading face forces plasticized 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 plasticized tubular shaft of metal results in severe solid state deformation involving dynamic re-crystallization of the base material.

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 recrystallized 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 equated 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.

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.

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, solidification 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 materials 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:

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- 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.

2. Tool Based Design

Introduction to CREO

The CREO is a suite of programs that are used in the design, analysis, and manufacturing of a virtually unlimited range of product.

The CREO is a parametric, feature-based solid modelling system, “Feature based” means that you can create part and assembly by defining feature like pad, rib, slots, holes, rounds, and so on, instead of specifying low-level geometry like lines, arcs, and circle& features are specifying by setting values and attributes of element such as reference planes or surfaces direction of creation, pattern parameters, shape, dimensions and others. “Parametric” means that the physical shape of the part or assembly is driven by the values assigned to the attributes (primarily dimensions) of its features. Parametric may define or modify a feature’s dimensions or other attributes at any time.

For example, if your design intent is such that a hole is centred on a block, you can relate the dimensional location of the hole to the block dimensions using a numerical formula; if the block dimensions change, the centred whole position will be recomputed automatically.

“Solid Modelling” means that the computer model to create it able to contain all the information that a real solid object would have. The most useful thing about the solid modelling is that it is impossible to create a computer model that is ambiguous or physically non-realizable.

There are six core CREO concepts. Those are:

- Solid Modelling
- Feature Based
- Parametric
- Parent / Child Relationships
- Associative

Design Developed By Using Cad Tool (Creo-2)

1. Create rectangular 100*200mm with reference dimensions.

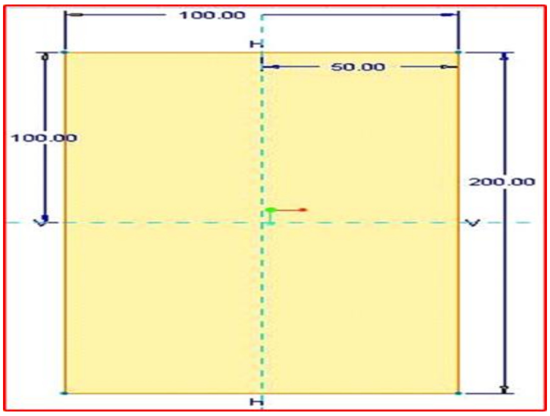

Figure.2.1. Plate dimensions

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.

2. Then extrude it 20mm ok button press on it.

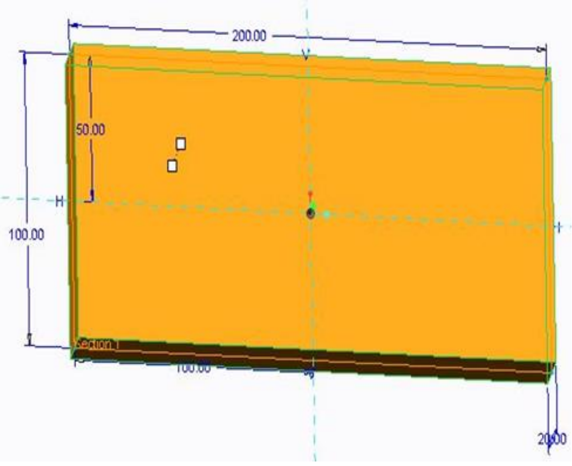

Figure.2.2. Extrude model

3. To create tool- create circle with 24mm dia-extrude

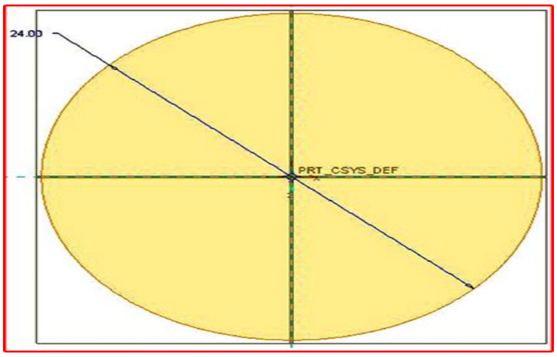

Figure.2.3.The Tool diameter

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4. Create extrude with 15mm thickness- ok
5. Create inner dia → 6mm → ok
6. Extrude- 5.5mm- ok
7. And create different tools by using same process.
8. Here we created hexagonal model with edge length 6mm and extrude height 5.5mm.

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 - then import into assembly window - make them assemble into single part.

Introduction to ANSYS

The ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms.

This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

The ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

The ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behaviour of the product, be it electromagnetic, thermal, mechanical etc.

3. Project Design

ANSYS Process

IMPORTING THE COMPONEENT FROM CAD (CREO) TOOL TO CAE TOOL (ANSYS)

Structural Analysis

1. Click on Ansys workbench
2. Static structural

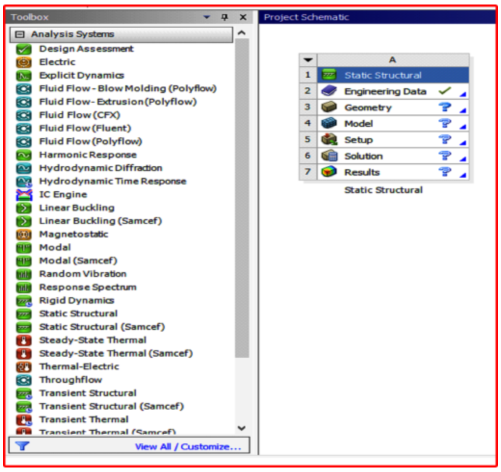

Figure.3.1. Structural Analysis

3. Engineering data → right click → enter values

FOR STEEL

Ex: - 2*10^11 Pa
Poison ratio : 0.3
Density : 7850 Kg/m^3
Yield strength: 250 MPa

FOR Al - 6061

Ex: - 68.9*10^9 Pa
Poison ratio : 0.33
Density : 2700 Kg/m^3
Yield strength: 276 MPa

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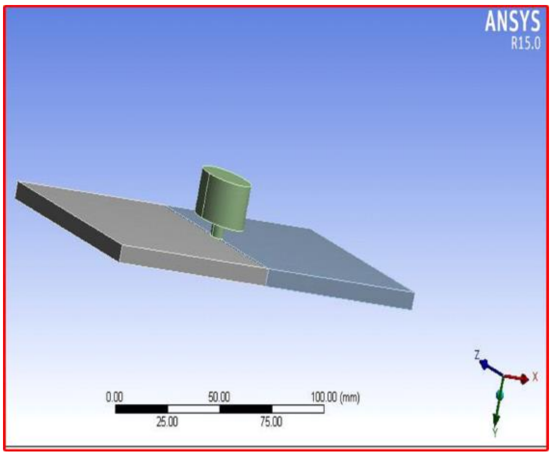

Figure.3.2. Model imported from pro-e tool in IGES format

4. Geometry-right click- import geometry- import iges format model

After importing model just click on geometry option then we will get selection of material. From engineering data here we already applied steel and al-6061 material properties. Now here we are selecting our tool material as steel and plate's material as AL-6061.

After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.

Meshing

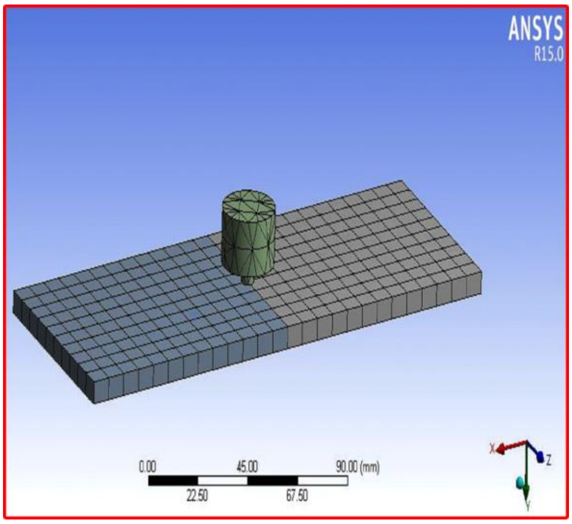

Figure.6.3. Meshing

After completion of meshing now we have to apply boundary conditions according to our requirement. Here we our plates will be fix in 4 directions to do this here we have to select fixed supports to all four sides. And our tool rotate with certain speed so here we have to apply inertial load conditions and that inertial conditions is rotational velocity with 1000 RPM.

Static structural → supports→ fixed support→ select all sides

Rotational velocity →1000RPM

After completion of boundary conditions here we have check results by solving. Just click on solve option and select results like deformation, strain, stress values for circular tool.

Solution → solve → deformation

Solution → solve → strain

Solution → solve → stress

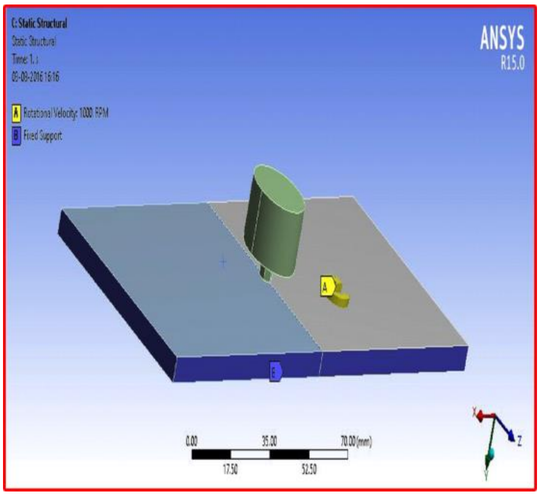

Figure.6.4. Boundary conditions

Results for (circular tool assembly)

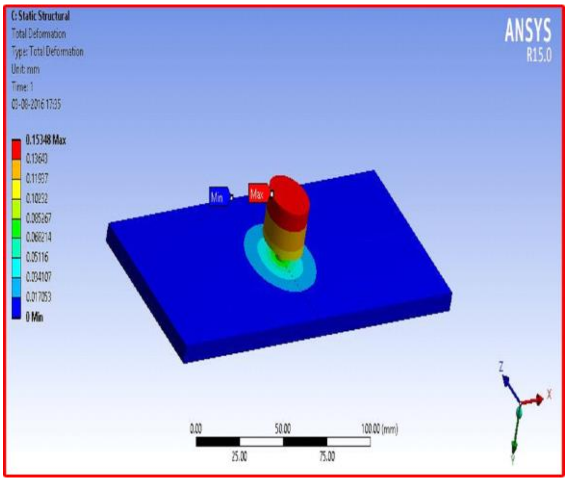

Figure.6.5. Deformation values for Circular tool assembly

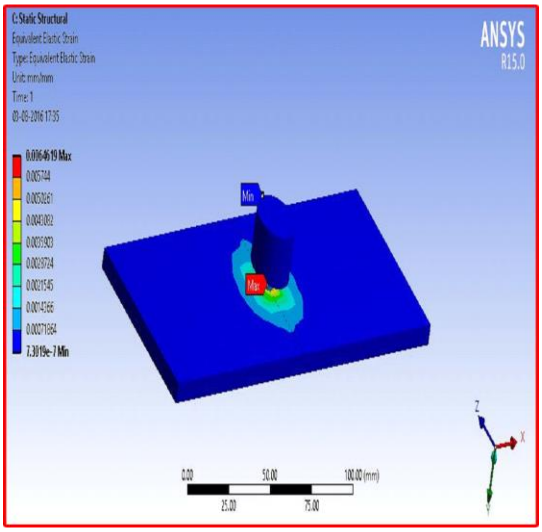

Figure.6.6. Strain Values for Circular Tool Assembly

The above figure shows the results of circular tool deformation for above applied boundary conditions. And here we have maximum deformation value is 0.15348mm which is shown in red colour and minimum value is 0mm which is shown in blue colour.

The above figure shows the results of circular tool strain values for above applied boundary conditions. And here we have maximum strain value is 0.0064619 which is shown in red colour and minimum value is 7.3019e-7 which is shown in blue colour.

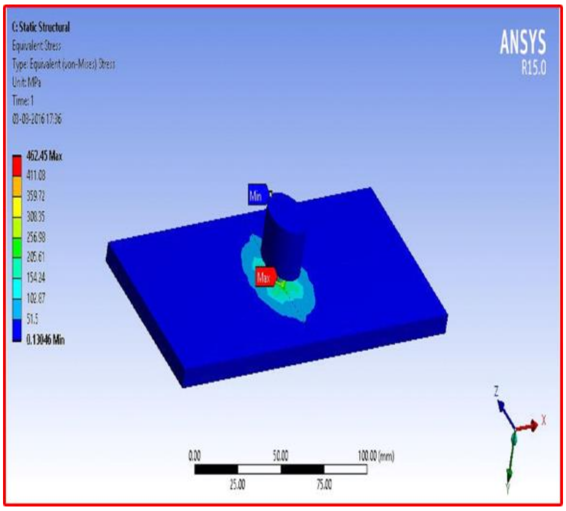

Figure.6.7. Stress Values for Circular Tool Assembly

The above figure shows the results of circular tool stress values for above applied boundary conditions. And here we have maximum stress value is 462.45Mpa which is shown in red colour and minimum value is 0.13046Mpa which is shown in blue colour.

Results for (hexagonal tool)

After completion of boundary conditions here we have check results by solving. Just click on solve option and select results like deformation, strain, stress values for circular tool.

Solution→solve→deformation
Solution→solve→strain
Solution→solve→stress

The below figure shows the results of hexagonal tool deformation for above applied boundary conditions. And here we have maximum deformation value is 0.14856mm which is shown in red colour and minimum value is 0mm which is shown in blue colour.

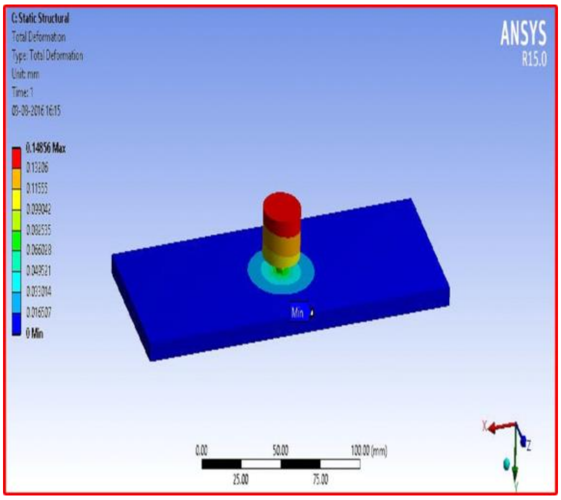

Figure.6.8. Deformation values for hexagonal tool

The above figure shows the results of hexagonal tool deformation for above applied boundary conditions. And here we have maximum deformation value is 0.14856mm which is shown in red colour and minimum value is 0mm which is shown in blue colour.

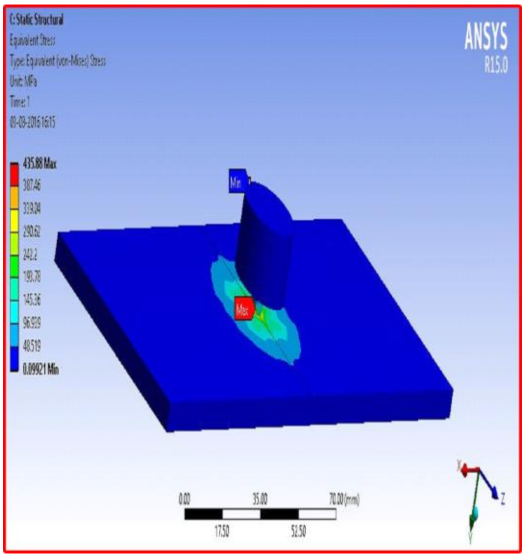

Figure.6.9. Stress values for hexagonal tool

The above figure shows the results of hexagonal tool stress for above applied boundary conditions. And here we have maximum stress value is 435.88Mpa which is shown in red colour and minimum value is 0.9921Mpa which is shown in blue colour.

From the above results here we have less stress values for hexagonal object.

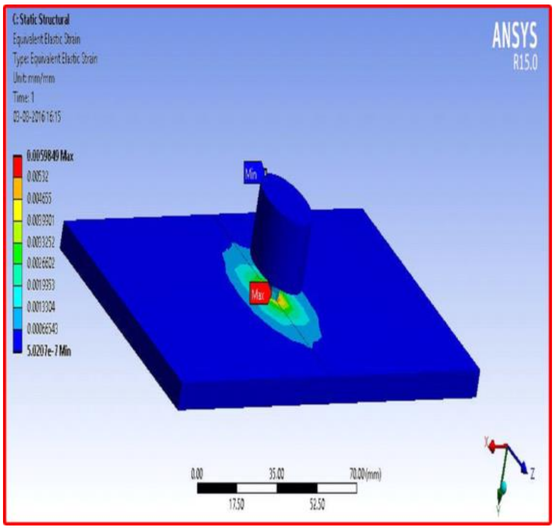

Figure.6.10. Strain values for hexagonal tool

The above figure shows the results of hexagonal tool stress for above applied boundary conditions. And here we have maximum strain value is 0.0059849 which is shown in red colour and minimum value is 5.0207e-7 which is shown in blue colour.

Results for (tapered tool)

After completion of boundary conditions here we have check results by solving. Just click on solve option and select results like deformation, strain, stress values for circular tool.

Solution→solve→deformation
Solution→solve→strain
Solution→solve→stress

Deformation

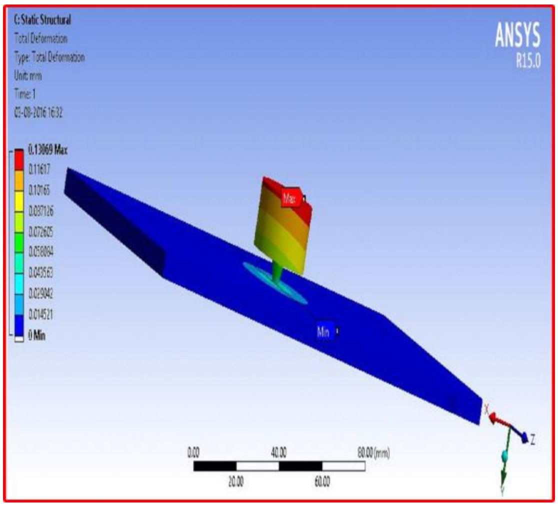

Figure.6.11. Deformation values for tapered tool

The above figure shows the results of tapered tool deformation for above applied boundary conditions. And here we have maximum deformation value is 0.13069mm which is shown in red colour and minimum value is 0mm which is shown in blue colour. Here we observe that the deformation value decreases for this tool compare with hexagonal tool.

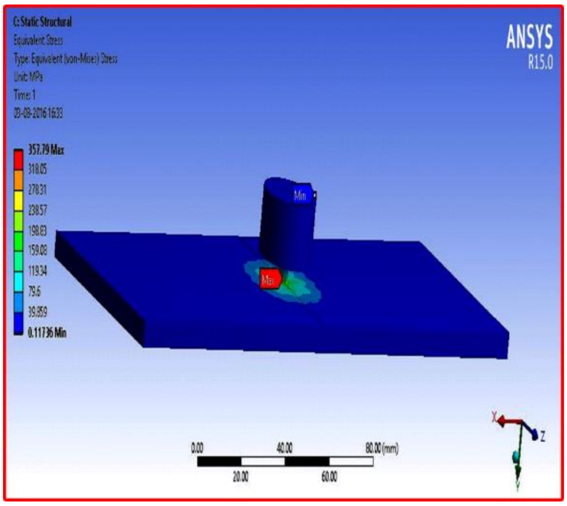

Figure.6.12.Stressvalues for tapered tool

The above figure shows the results of tapered tool deformation for above applied boundary conditions. And here we have maximum stress value is 357.79Mpa which is shown in red colour and minimum value is 0.11736Mpa which is shown in blue colour. Here we observe that the stress value decreases for this tool compare with hexagonal tool.

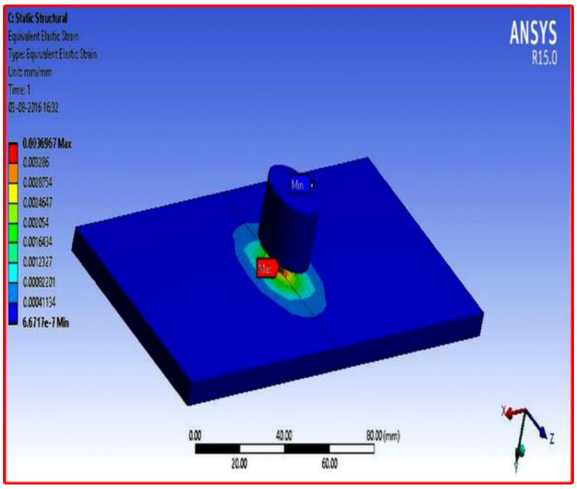

Figure.6.13.Strainvalues for tapered tool

The above figure shows the results of tapered tool strain values for above applied boundary conditions. And here we have maximum strain value is 0.0036967 which is shown in red colour and minimum value is 6.6717e-7 which is shown in blue colour. Here we observe that the stress value decreases for this tool compare with hexagonal tool.

Results for (truncated tool)

After completion of boundary conditions here we have check results by solving. Just click on solve option and select results like deformation, strain, stress values for circular tool.

Solution→solve→deformation
Solution→solve→strain
Solution→solve→stress

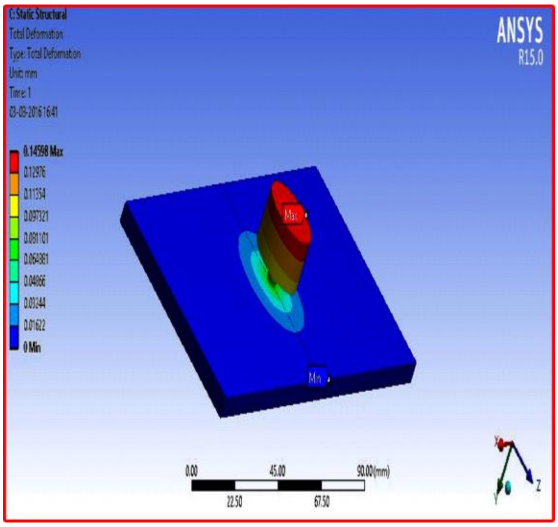

Figure.6.14. Deformation values for truncated tool

The above figure shows the results of truncated tool deformation for above applied boundary conditions. And here we have maximum deformation value is 0.14598mm which is shown in red colour and minimum value is 0mm which is shown in blue colour.

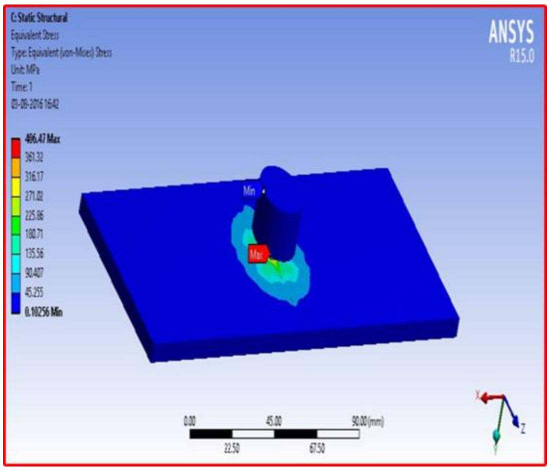

Figure.6.15. Stress values for truncated tool

The above figure shows the results of truncated tool stress for above applied boundary conditions. And here we have maximum stress value is 406.47Mpa which is shown in red colour and minimum value is 0.10256Mpa which is shown in blue colour. Here we got high stress values compare with tapered tool. And less stress values compare with existing circular tool.

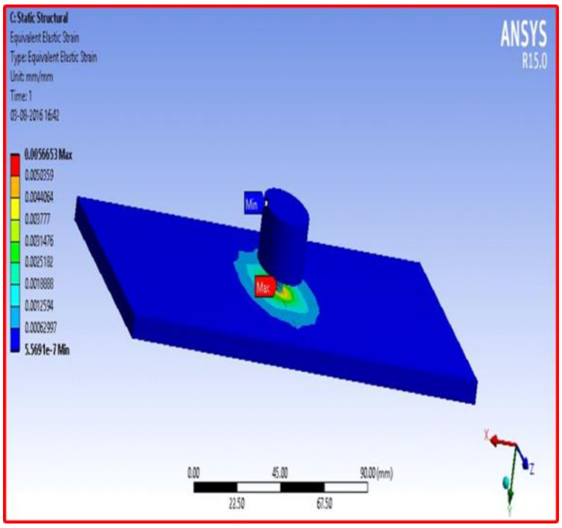

Figure.6.16. Strain values for truncated tool

The above figure shows the results of truncated tool strain for above applied boundary conditions. And here we have maximum strain value is 0.0056653 which is shown in red colour and minimum value is 5.5691e-7 which is shown in blue colour.

Tools	**Circular tool**	**Hexagonal tool**	**Tapered tool**	**Truncated tool**
Deformation(mm)	0.15348	0.14856	0.13069	0.14598
Stress (MPa)	462.45	435.88	357.79	406.47
Strain	0.0064619	0.0059849	0.0036967	0.0056653

4. 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 an 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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