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Structural Analysis Of Tig Welded Joints Of Inconel 718 Using Ansys

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Abstract:

Welded joints have wide applications in construction industries as well as in engineering constructions such as bridges, boilers, pressure vessels, piping systems, ships, and Automobile industries. In spite of having wide applications major challenges with welded joints are welded structures may weak at joint due to stress concentration factor and knowing properties at welded joints.

In this regard welded joints of aluminium and steel alloys materials are analysed so far. Hence in the present study Inconel 718 of T- joint and butt joints investigated using ANSYS. The finite element method is used for the analysis of T joints and butt joints in the plane stress conditions, under static load. Stresses in Inconel-718 welded joints are calculated by using Ansys.

Keywords—*Inconel 718; T- Joint and Butt Joints; Solid works; ANSYS; TIG Welding*

Introduction

Inconel is a family of austenitic nickel-chromium-based super alloys. Inconel alloys are oxidation- and corrosion-resistant materials well suited for service in extreme environments subjected to pressure and heat. When heated, Inconel forms a thick, stable, passivating oxide layer protecting the surface from further attack. Inconel retains strength over a wide temperature range, attractive for high temperature applications where aluminium and steel would succumb to creep as a result of thermally induced crystal vacancies. Inconel's high temperature strength is developed by solid solution strengthening or precipitation hardening, depending on the alloy.

The Inconel family of alloys was first developed in the 1940s by research teams at Wiggin Alloys (Hereford, England), which has since been acquired by SMC, in support of the development of the Whittle jet engine.

Inconel alloys are oxidation- and corrosion-resistant materials well suited for service in extreme environments subjected to high pressure and kinetic energy. When heated, Inconel forms a thick and stable passivating oxide layer protecting the surface from further attack. Inconel retains strength over a wide temperature range, attractive for high-temperature applications where aluminium and steel would succumb to creep as a result of thermally induced crystal vacancies (see Arrhenius equation). Inconel's high temperature strength is developed by solid solution strengthening or precipitation strengthening, depending on the alloy. In age-hardening or precipitation-strengthening varieties, small amounts of niobium combine with nickel to form the intermetallic compound Ni_3Nb or gamma prime (γ'). Gamma prime forms small cubic crystals that inhibit slip and creep effectively at elevated temperatures. The formation of gamma-prime crystals increases over time, especially after three hours of a heat exposure of 850 °C, and continues to grow after 72 hours of exposure.

Inconel is a difficult metal to shape and machine using traditional techniques due to rapid work hardening. After the first machining pass, work hardening tends to plastically deform either the work piece or the tool on subsequent passes. For this reason, age-hardened Inconel such as 718 are machined using an aggressive but slow cut with a hard tool, minimizing the number of passes required. Alternatively, the majority of the machining can be performed with the work piece in a solutionized form, with only the final steps being performed after age hardening.

External threads are machined using a lathe to "single-point" the threads or by rolling the threads in the solution treated condition (for harden able alloys) using a screw machine. Inconel 718 can also be roll-threaded after full aging by using induction heat to 1,300 °F (704 °C) without increasing the grain size. Holes with internal threads are made by thread milling. Internal threads can also be formed using a sinker EDM (electrical discharge machining)

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Cutting of a plate is often done with a water jet cutter. New whisker-reinforced ceramic cutters are also used to machine nickel alloys. They remove material at a rate typically eight times faster than carbide cutters. Apart from these methods, Inconel parts can also be manufactured by selective laser melting. More often than machining, water-jet or laser, grinding is a preferred and economical method for forming Nickel alloy components to shape and finish. Due to the hardness of the abrasives used, the grinding wheels are not as affected by the material work hardening and remain sharp and durable.

Welding of some Inconel alloys (especially the gamma prime precipitation hardened family, *e.g.* Wasp alloy and X-750) can be difficult due to cracking and micro structural segregation of alloying elements in the heat-affected zone. However, several alloys such as 625 and 718 have been designed to overcome these problems. The most common welding methods are gas tungsten arc welding and welding. Innovations in pulsed micro laser welding have also become more popular in recent years for specific applications.

Inconel is often encountered in extreme environments. It is common in gas turbine blades, seals, and combustors, as well as turbocharger rotors and seals, electric submersible well pump motor shafts, high temperature fasteners, chemical processing and pressure vessels, heat exchanger tubing, steam generators and core components in nuclear pressurized water reactors, natural gas processing with contaminants such as H_2S and CO_2, firearm sound suppressor blast baffles, and Formula One, NASCAR, NHRA, and APR, LLC exhaust systems. It is also used in the turbo system of the 3rd generation Mazda RX7, and the exhaust systems of high powered rotary engine Norton motorcycles where exhaust temperatures reach more than 1,000 degrees C. Inconel is increasingly used in the boilers of waste incinerators. The Joint European Torus and DIII-D (fusion reactor) tokomaks vacuum vessels are made in Inconel. Inconel 718 is commonly used for cryogenic storage tanks, down hole shafts and wellhead parts.

Welding is a process of joining two metal pieces by the application of heat. Welding is the least expensive process and widely used now a days in fabrication. Welding joints different metals with the help of a number of processes in which heat is supplied either electrically or by mean of a gas torch. Different welding processes are used in the manufacturing of Auto mobiles bodies, structural work, tanks, and general machine repair work. In the industries, welding is used in refineries and pipe line fabrication. It may be called a secondary manufacturing process.

TIG WELDING

Gas tungsten arc welding (GTAW),also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it. A constant current welding power produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.

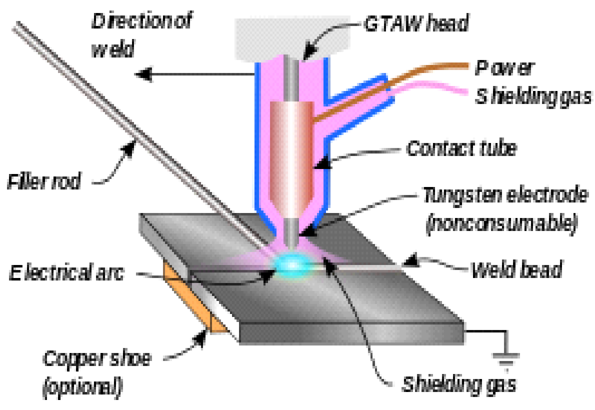

Fig. 1 TIG welding machine

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal and gas metal, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

SOLID WORKS

Solid Works is the state of the art in computer-aided design (CAD). Solid Works represents an object in a virtual environment just as it exists i.e., having volume as well as surfaces and edges. Complex three-dimensional parts with contoured surfaces and detailed features can be modelled quickly and easily with Solid Works. Then, many parts can be assembling virtual environment to create a computer model of the finished product. In addition, traditional engineering drawings can be easily extracted from the solid models of both the parts and the final assembly. This approach opens the door to innovative design concepts, speeds product development, and minimizes design errors. The result is the ability to bring high-quality products to market very quickly. Solid modelling represents objects in a computer as volumes, rather than just as collections of edges and surfaces.

FINITE ELEMENT ANALYSIS

Finite element analysis was first developed for the use of aerospace and nuclear industries where the safety of structure is critical. Today growth in the usage of method is directly attributable to the rapid advances in computer technology. Thus, commercial finite element packages exist that can solve the most sophisticated problems, not just in structural analysis, but for a wide range of phenomena such as steady state and dynamic temperature distributions, fluid flow and manufacturing processes such as injection molding and metal forming.

The purpose of a finite element analysis is to model the behavior of a structure under a system of loads. To do so, all influencing factors must be considered and determined whether their effects are considerable or negligible on the result. Many software's are used for this purpose. ANSYS, Pro-E, Uni Graphics, NISA, MSC, NASTRAN, etc.

VARIOUS STAGES OF ANSYS

(a).Pre-processor

The pre-processor stage in ANSYS package involves the following:

- Specify the title, which is the name of the problem.
- Set the type of the analysis to be used, i.e., structural, thermal, fluid, or electromagnetic, etc.,
- Create the model - The model is drawn in 1-D, 2-D, or 3-D space in the appropriate units (m, mm, in, etc.). The model may be created in pre-processor, or it can be imported from another CAD drafting package through a neutral file format9 like IGES, STEP, ACIS, Para solid, DFX, etc. Define the element type, this may be 1D, 2D or 3D, and specify the analysis type being carried out.
- Apply mesh - Mesh generation is the process of dividing the analysis continuum in to several discrete parts or finite elements. The finer mesh, the better result, but the longer the analysis time. Therefore, the compromise between accuracy and solution speed is usually made.

Assign the properties - Material properties (Young's Modulus, Poisson's ratio, density, and if applicable coefficient of expansion, friction, thermal conductivity, damping effect, specific heat, etc.,) must be defined.

(b). Meshing

In manual meshing the elements are smaller at joint. This known as mesh refinement, and it enables the stress to be captured at the geometric discontinuity. Manual meshing is long and tedious process for models with any degree of geometric complication, but with useful tool emerging in pre-processes, the task is becoming easier.

Free & Mapped Mesh:A free mesh is one that has no restrictions in terms of element shapes, and no specific pattern applied to it. Compared to a free mesh, a mapped mesh is restricted in terms of the element shape it contains and the pattern of the mesh. A mapped mesh contains only quadrilateral (area) or only hexahedron (volume) elements. If this type of mesh is desired, the user must build the geometry as series of fairly a regular volumes and/or areas that can accept a mapped mesh.

Meshing Controls

The default meshing controls that the program uses may produce a mesh that is adequate for the model we are analyzing. In this case, we need not specify any meshing controls. However, if we do use meshing controls we must set them before meshing the solved model

Meshing controls allow us to establish the element shape, midsize node placement and element size to be used in meshing the solid model, this step is one of the most important of the entire analysis for the decisions we make at this stage in the model development will profoundly affect the accuracy and economy of the analysis.

(c). Post-Processor

In this module, the results of the analysis are read and interpret. All postprocessor includes the calculation of stress and strain in the entire X, Y, Z directions or indeed in the direction at an angle to the co-ordinate axes. The principle stress and strain may also be plotted.

LITERATURE SURVEY

Welded joints have wide applications in construction industries as well as in engineering constructions such as bridges, boilers, pressure vessels, piping systems, ships, and Automobile industries. The influence of parameters like plate thickness, initial crack length and reinforcement angle on fatigue strength of butt-welded joints can be analyzed [1].

The structural stress concepts described first are based on a linearization of the stress distribution across the plate thickness or along the anticipated crack path and, alternatively, on the structural stress 1 mm in depth below the weld toe [2].

The fatigue effects become even more important in presence of welded joints and the fatigue assessment of welded joints becomes more complex in presence of a multi axial stress state as demonstrated by Susmel. The aim of this study is the application of an energy-based approach for the fatigue assessment of base material and welded joints, made of S690QL steel IR camera was used for detecting the temperature during the fatigue tests in order to apply an energy-based approach [3].

Welded joints are subjected to many types of loading and these loadings have different axial components with different phases. However, the structural integrities are evaluated according to design codes based on theoretical and experimental investigations under a uniaxial loading condition. Most of these codes are based on the S-N curves approach [4].

Crack propagation tests were carried out on large centre cracked tension (CCT) specimens and on small compact tension (CT) specimens. The main difference between the two typs of specimens concerned the residual stresses, which were not present in the CT specimens, due to their reduced dimensions [5].

Fatigue strength of Welded joints has the following factors: stress concentration at weld toe, internal defects and welding process method. The material used in this study was a steel sheet called DOMEX 600 DC .Butt welded specimens using MAG welding process were submitted to cyclic loading in servo hydraulic machine [6].

Aluminium alloys are use in wide areas because of the superiorities such as low weight, high strength, and excellent resistance to corrosion compared to other materials. Welding is an economical and feasible manufacturing method. Laser beam welding has been applied widely in the industry due to its advantages such as narrow heat affected zone, small distortion and relatively high welding speed. Welded joints fatigue stress find out by using fracture mechanics for laser beam welded Al-alloy joints under stationary variable amplitude loading [7].

Gas metal arc welding (GMAW) is one of the most used joining method in the industry. However, one of the main problems of this process is the generation of residual stresses (RS). There are different approaches to predict the fatigue life of welded joints, but in general, these approaches do not consider the real value of RS. Therefore, the current approaches to estimate fatigue life of welded components are conservatives. Fatigue strength of Welded joints are calculated by using Ansys software.

MODELING OF T-JOINT AND BUTT JOINT USING SOLID WORKS

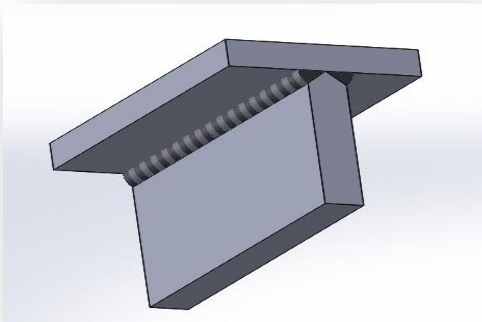

Fig.2 Model of T joint

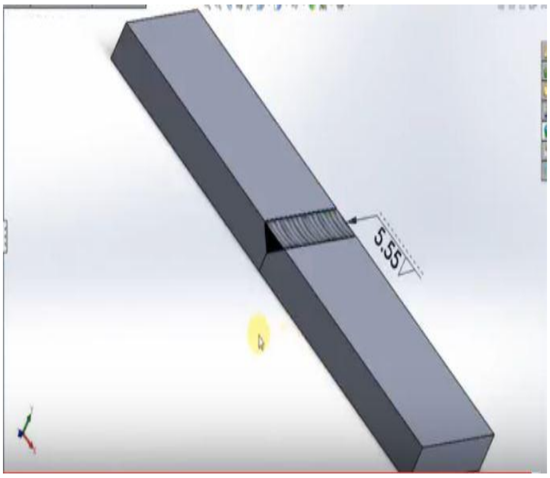

Fig.3 Model of Butt joint

MESHING OF T-JOINT AND BUTT JOINT USING ANSYS

T-joint and Butt joints are exported into the Ansys workbench to study the stress concentration factor.

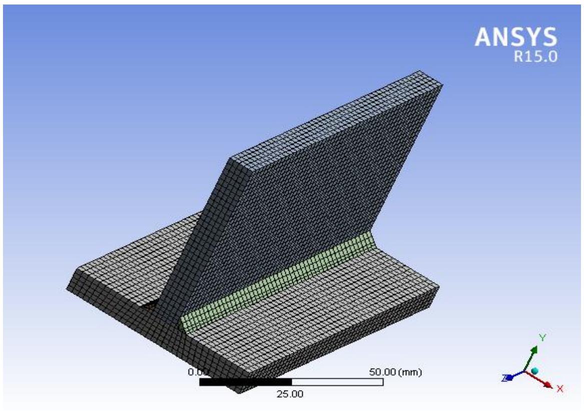

Fig.4. Meshing of T-Joint

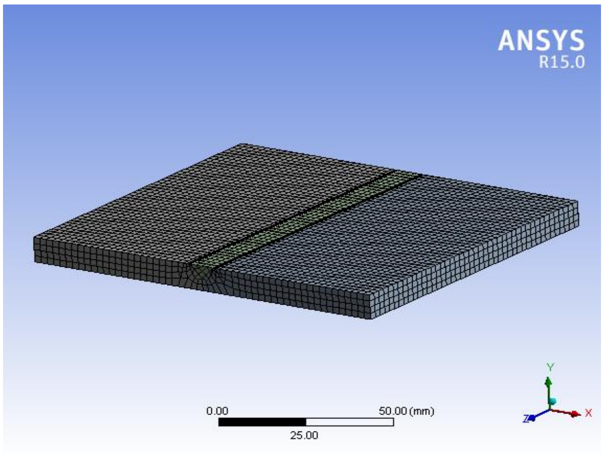

Fig.5 Meshing of Butt joint

APPLYING LOADS ON FIXED EDGES

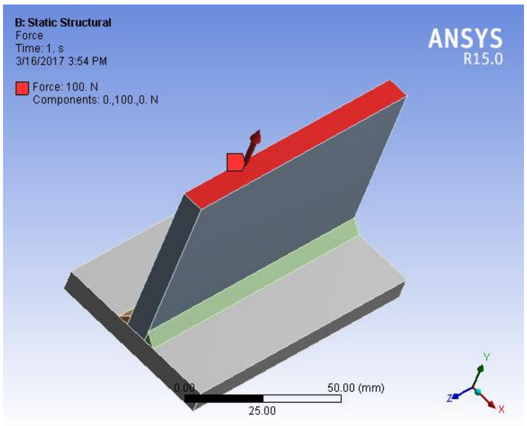

Fig. 6 applying load on T-joint

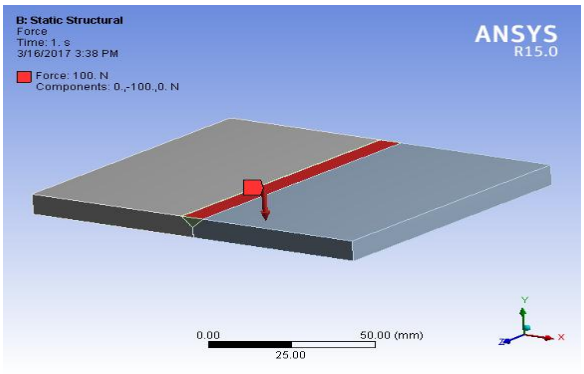

Fig.7 Applying load on butt joint

Static Structural Analysis of T- Joint

Structural analysis is probably the most common applications of the finite element method.The engineering constructions such as bridges, boilers, pressure vessels, piping systems, ships, and Automobile industries, Structural analysis is available in the ANSYS multi physics, ANSYS mechanical, ANSYS structural and ANSYS professional programs only.

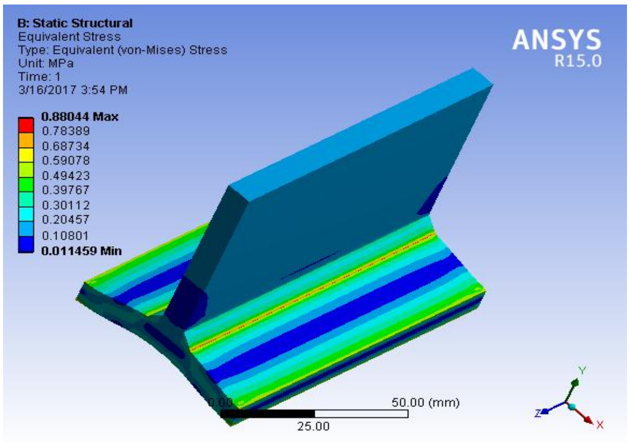

Fig.8 Equivalent Stress

The load 100N is applied on the surface area of T joint. For the T joint material is Inconel 718 alloy the Equivalent Stress obtained maximum value 0.88044 MPa and minimum value 1.1459e-002 Mpa.

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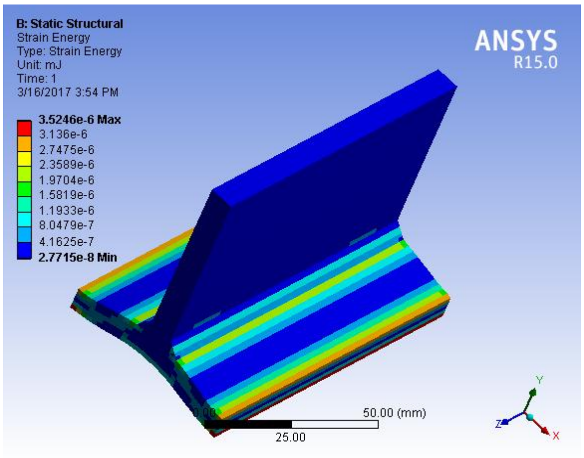

Fig.9 Strain Energy

The load 100N is applied on the surface area of T joint. For the T joint material is Inconel 718 alloy the Total Deformation maximum value1.4193e-004 mm and minimum value 0. mm.

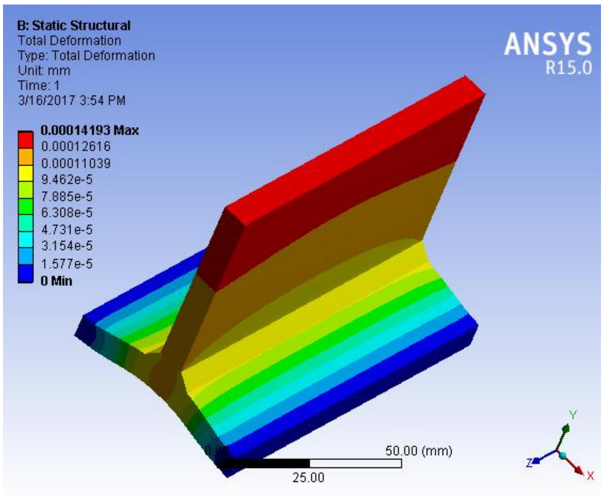

Fig.10 Total Deformation in T-joint

The load 100N is applied on the surface area of T joint. For the T joint material is Inconel 718 alloy the Total Deformation maximum value1.4193e-004 mm and minimum value 0. Mm.

RESULTS OF T-JOINT

Table 1: Showing the Minimum and Maximum values in different stages

	Total Deformation	Equivalent Elastic Strain	Equivalent Stress	Strain Energy	Maximum Principal Stress
Minimum	0. mm	5.7585e-008 mm/mm	1.1459 e-002 Mpa	2.7715e -008 mJ	-0.19802 MPa
Maximum	1.4193e -004 mm	4.4023e-006 mm/mm	0.8804 4 Mpa	3.5246e -006 mJ	0.99574 MPa

Static Structural Analysis of BUTT Joint

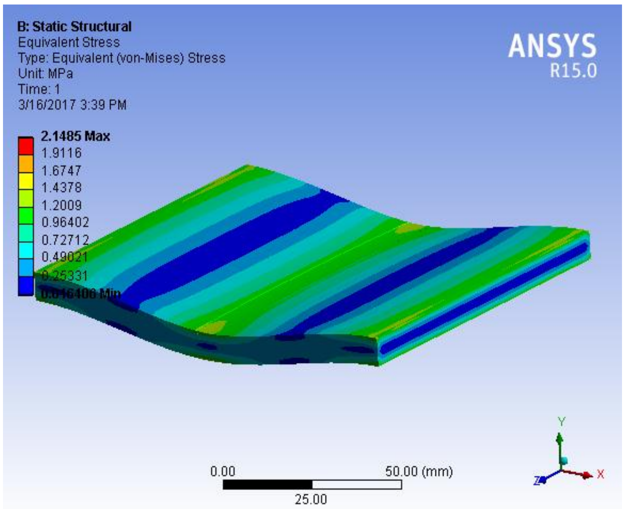

Fig.11 Equivalent stress

The load 100N is applied on the surface area of butt joint. For the butt joint material is Inconel 718 alloy the Equivalent Stress obtained maximum value 2.1485 Mpa and minimum value 1.6406e-002 Mpa.

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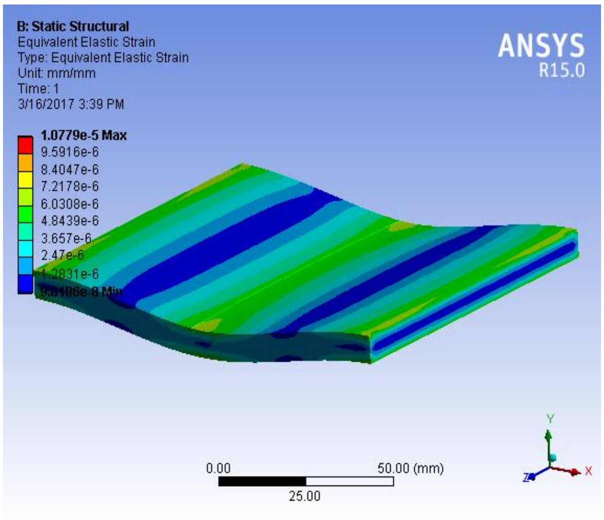

Fig.12 Equivalent Elastic Strain

The load 100N is applied on the surface area of butt joint. For the butt joint material is Inconel 718 alloy the Strain Energy obtained maximum value1.0779e-005 mm/mm and minimum value 9.6186e-008 mm/mm

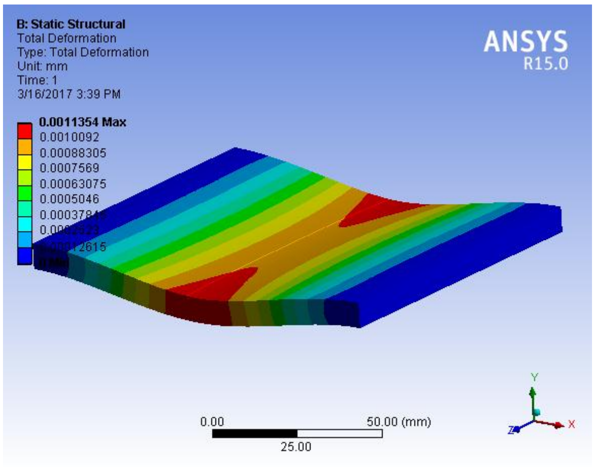

Fig.13 Total Deformation in butt joint

The load 100N is applied on the surface area of butt joint. For the butt joint material is Inconel 718 alloy the Total Deformation maximum value1.1354e-003 mm and minimum value 0.mm

RESULTS OF BUTT JOINT

Table 1: Showing the Maximum and Maximum values in different stages.

Stress	Total Deformation	Equivalent Elastic Strain	Equival-ent Stress	Strain Energy	Maximum Principal Stress
Minimum	0. mm	9.6186e-008 mm/mm	1.6406 e-002 Mpa	6.1077e-009 mJ	0. mm
Maximum	1.1354e-003 mm	1.0779e-005 mm/mm	2.1485 Mpa	2.666 e-005 mJ	1.1354 e-003 mm

CONCLUSION

It is concluded from the results that stress concentration factor and strain energy of Inconel 718 TIG welded joints are more than aluminium and stain less steel. Further it is concluded that T joint is more efficient than the Butt joint of Inconel 718.

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