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# DESIGN AND ANALYSIS OF WELDED TEE-JOINT OF A THIN WALLED TUBE USING ANSYS WORKBENCH

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**Abstract:** There is no broad and complete approach for static and fatigue analysis for plate thicknesses of less than 3 mm in today's regulated welding regulations, nor at Saab. Only static and fatigue methods for plate thicknesses less than 3 mm are available from the British Standard Institute, according to standards such as the International Institute of Welding. Furthermore, they lack the range of joint classes required for complex tube welded junctions. This paper's goal is to qualify and evaluate existing standardized methods for forecasting static stress and fatigue life in thin-wall welded joints., methods provided by standard institutes of welding or methods found in literature surveys. Could a mechanism be developed to offer a conservative estimate of the static and fatigue life of tube welded joints with thicknesses of less than 3 mm? The structure that has been analyzed is a welded tubular T-joint with a thickness of 1.5 & 2 mm. The T-joint has been modeled in shell element model. And mild steel material is adopted as default and the result obtained at boundary condition for a load of 1000N in z direction the results shows better factors from 1st to last iteration.

**Index Terms:** T joint, ansys workbench, welding, finite element analysis (FEA), fatigue failure, static structure

## 1. INTRODUCTION

The welding is a process of joining two or more similar or dissimilar materials by the application of heat with or without the effect of pressure. Welding can be defined as the warming of metals to a required temperature, with or without any pushing factor, and with or without the use of an extra substance. A warmth source is used in combination welding to create and maintain a liquid pool of metal of the required size. Welding contact is a manufacturing process that uses heat to combine materials, usually metals or thermoplastics. Almost any advanced item requires the connecting of multiple independent portions. Welding is frequently used when a permanent connection is required.

Now a day's welding is needed in all computational ventures might be limited scale or aeronautical methodology. Almost certainly Thin-walled tubes, like all aluminum pipes, are steel and treated steel pipes with a divider thickness of up to 2 mm and a diameter of 42 mm or greater.

The term 'welded joint design' refers to the process of integrating or aligning metal selections with one another by using heat and created transition energy to soften and cement them together. The design of each joint has an impact on the final weld's quality and cost. Choosing the best joint plan for a welding position necessitates a great deal of thought and care.

According to the American Welding Society, there are five basic welding joint types that are commonly used in the industry i.e. Butt joint, Tee joint, Corner joint, Lap joint, Edge joint

## 2. TEE JOINT WELDING

When two components meet at a 90° angle, a T welding joint is formed. It's referred to as a computed T joint when the point is different. This results in the edges of a plate or segment meeting in a 'T' form at the focal point. When a cylinder or line is welded to a base plate, tee joints are generated similarly to fillet welds.

With this type of weld, one must always check for effective penetration through the weld's roof.

To make a tee joint, we can utilize one of these welding styles and they are plug weld, slot weld, bevel-groove weld, fillet weld, J-groove weld, melt-through weld, flare-bevel-groove welds.

With this type of weld, one must always check for effective penetration through the weld's roof.

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Tee joints aren't usually made with grooves, unless the base metal is thick and the welding on both sides can't support the weight the junction should support. Lamellar tearing is a common tee joint flaw that occurs as a result of the joint's restriction. Welders will regularly place a plug to prevent joint deformations to avoid this.

## 3. LITERATURE REVIEW

Welded joints are frequently crucial in defining a structure's service life. If the welding process is thoroughly understood, it is possible to extend the life of a welded part and save money. Numerical approaches, particularly the finite element method, can considerably aid the welding process when used to solve appropriate structural mechanics equations [1]. For the strength and durability analysis of weldments, detailed understanding of stress fields in crucial locations is required. The stress data is then utilized to determine where fatigue cracks may emerge and how quickly they may grow. The approach described below uses a specific finite element model to determine stress concentration factors and stress distributions in weldments [2] Spheres, cylinders, cones, ellipsoids, tori, and composites of these are typical shapes for pressure vessels. Pressure vessel cylinders are used in a variety of thermal applications in space and at sea depths, nuclear power reactors, process and chemical industries and industrial fluid supply systems [3] A welding junction is a point or edge that connects two or more pieces of metal or plastic. They are made by welding together two or more work parts (metal or plastic) in a specific geometry[4] The purpose of this research is to investigate the fatigue strength of welded joints using a fracture mechanics technique that takes into consideration welded joint fatigue behaviour. The methodology assists in determining the fatigue crack propagation rate as a function of the difference between the applied driving force and the material crack propagation threshold, which is a function of crack length[5]

## 4. BASICS OF FATIGUE FAILURE

Fatigue can be defined as the formation and propagation of small cracks on a welded structure due to continued application of stress. This failure takes place in two phases. The creation of cracks is the first step, and the spread of cracks is the second.

If appropriate measures are not taken following the initial formation phase, cracks can increase in size and propagate within a short period of time, thereby drastically reducing the load-carrying capacity and efficiency of the structure in part or as a whole.

Fatigue failure can affect just about any type of welded products including industrial, construction, agricultural, manufacturing, and mining equipment.

### 4.1 CAUSES OF FATIGUE FAILURE

The welding process, rather than the metal's strength, causes fatigue failure. Inadequate preheating, trapped hydrogen or slag, inadequate joint fusion, and joint porosity are all factors that might compromise the integrity of a welded connection.

**Inadequate preheating**

Preheating improves the structural characteristics of a weld, minimizes the risk of cracking, reduces weld brittleness, and decreases the amount of metal shrinkage, which can result in excessive stress and breakage.

**Trapped Hydrogen**

During the welding process, minuscule hydrogen ions can migrate from the weld joint and combine to generate hydrogen gas along the parent metal's fissures. The presence of hydrogen gas puts stress on the metal, increasing the chances of it cracking. Porosity

Gaseous impurities such as oxygen, nitrogen, and hydrogen can become trapped and freeze in the metal substrate, causing holes to appear on the weld. These holes may cause the metal framework to break down over time.

**Incomplete Joint Fusion**

When one side of a weld joint is not properly fused into the weld, this is known as incomplete joint fusion. As a result, the joint may develop a multitude of flaws that impair its load-carrying capacity.

**Mitigation of Fatigue Failure**

While all welded structures eventually succumb to wear and tear, weld enhancement procedures can extend the welded structure's life and reduce the risk of catastrophic breaking.

There are two types of weld improvement techniques: those that improve weld geometry and those that reduce residual stress.

**Weld Geometry Improvement**

Sharp corners, holes, and decreased cross-section areas may increase stress concentration. Techniques for improving weld geometry aim to reduce or control stress concentration at weld junctions.

Grinding the weld toe with a bur or disc grinding machine, re-melting the weld toe with Tungsten Inert Gas (TIG), and plasma treatment are all common geometry enhancement processes.

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**Residual Stress Reduction**

Residual stress results from thermal expansion caused by the temperature differential between the weld joint and the parental metal. Thermal stress reduction, vibratory stress relief, hammer peening, shot peening, and ultrasonic hammer peening are some of the techniques that can help to reduce the consequences of residual stress.

Welded joints will deteriorate over time as a result of stress, necessitating regular inspection and repair of metal structures. Even so, starting with excellent welding procedures can help reduce the risk of early and potential failure.

## 5. PROCEDURE

1.The specified workpieces are completely cleaned, which includes filing the edges, cleaning the rust, and removing the scales.
2.The electrode is inserted into an electrode holder, the ground clamp is secured to the welding plates, and the power is switched on.
3.Place the workpieces on the table to make a "Tee fillet joint."
4.To keep work parts from sliding during welding, tag welds are utilised on both ends of joining plates.
5.By leaving a 3mm gap between the plates and the welding rod, welding can be done on both sides of the work components.
6.After the slag is removed, the welded joint parts are allowed to air cool.
7.A wire brush is used to clean the weld joint areas.

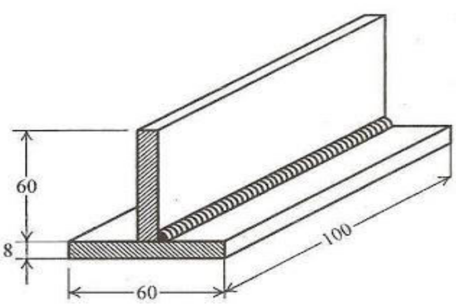



Fig. 1 Simple "T" Joint welding Technique

For thin walled tube the procedure will be same but the angle of welding varies.

## 6. ANALYSIS

The finite element method (FEM) is a numerical method for solving problems in engineering and mathematical physics. Structure analysis, heat transmission, fluid flow, mass transport, and magnetism potential are all typical areas of study in the field of drawbacks. The solution to partial differential equations' boundary pricing problems is commonly required for analytical resolution of those problems using the finite component technique. The situation is represented by a set of algebraic equations. The strategy produces approximation unknown values at a variety of sites across the domain. To decipher the situation, it breaks a large problem into smaller, less complicated aspects known as finite parts. The simple equations that represent these finite components are then combined into a larger system of equations that represents the entire disadvantage. FEM then performs an estimated response by reducing an associated error using variation in ways derived from pure mathematics of variations.

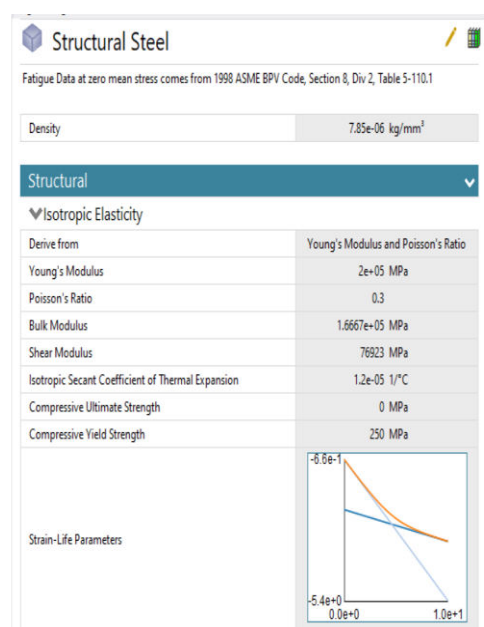
Studying or analyzing a development with FEM is usually named as finite component analysis (FEA).

### 6.1 PROCEDURE FOR ANSYS SIMULATION

1.To design and test failure sustains1000 N of load on the Thin tube.
2.I had created the design using CATIA v5 soft and converted the file to stp file to import into the ANSYS soft.
3.This time I will check the failure condition on the micro structure and also record the data at boundary condition.
4.After the simulation of the case results, I will try to minimize the failure by conducting the redesign methodology and again simulate the redesigned one. By performing welding around the tube joint

**Step 1-**

1st the first procedure of ANSYS is to select the material from its default library and import to the static structural Analysis system. The below shown fig illustrate the material mechanical properties of mild steel alloy.



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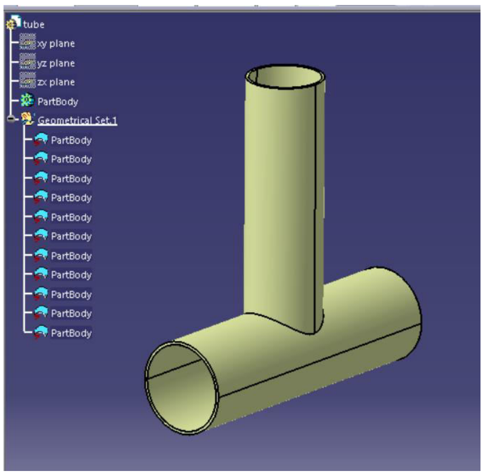
Material Mild Steel

Advantages of Mild Steel are -
Easily available, Low cost, High strength
Most common application like bicycle part, aerospace.

**Step 2**

2nd procedure is to import the geometry into the ANSYS Static structural analysis by selecting the patch location of IGES file.




CATIA v5 surface design 2mm thickness

Brace diameter = 40 mm
Chord diameter = 60 mm
Thickness = 2 mm

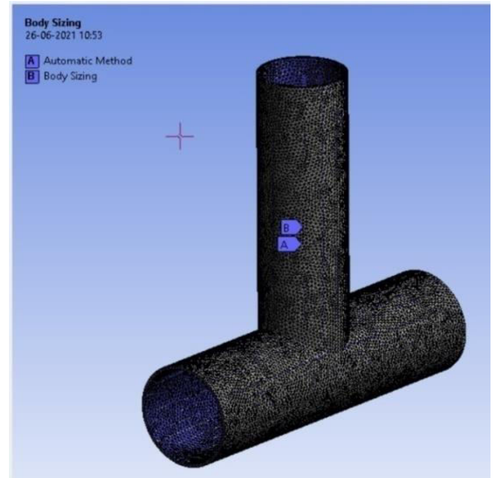
This type of joints is used in the various applications from thermodynamics heat exchanger to automotive products.

**Step 3**

3rd procedure is to create the mesh by selecting the patch configuration method to the required mesh shape and by providing the mesh sizing

Mesh Generation

ANSYS Meshing is a high-performance, general-purpose, intelligent, and automated product. It generates the most accurate and efficient mesh for multiphysics solutions. A mesh that is well suited for a certain analysis can be generated for all parts of a model with a single mouse click. For the advanced user who wishes to fine-tune the mesh, full control over the options used to generate it is provided. The power of parallel processing is automatically exploited to cut down on the time it takes to generate a mesh.




Mesh geo

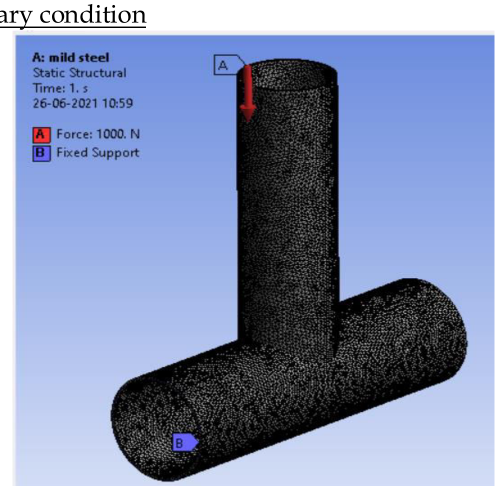
Patch configuration method with tetra and square mesh shape using 2 mm meshing size throughout the part.

| Statistics | |
|---|---|
| Nodes | 221449 |
| Elements | 119311 |

Node and elements at 2mm mesh size

ANSYS Meshing is familiar with the various solutions that will be utilised in the project and has established criteria for creating the best mesh feasible. Meshing is automatically integrated with each solver in the ANSYS Workbench environment. The construction of the best mesh possible is the foundation of engineering simulations. ANSYS Meshing is conversant with the solutions that will be used in the project and has defined criteria for producing the best mesh possible. Each solution in the ANSYS Workbench environment is automatically connected with ANSYS Meshing.

<u>Boundary condition</u>




Boundary condition

After the selection of material, importing geometry & mesh, The next procedure is to processes the boundary condition here the BC are tangential force and a fixed support as shown in the figure hear the maximum force to its failure is considered which is 100 kg in Z direction to study the welding process for thin tube part t joint.

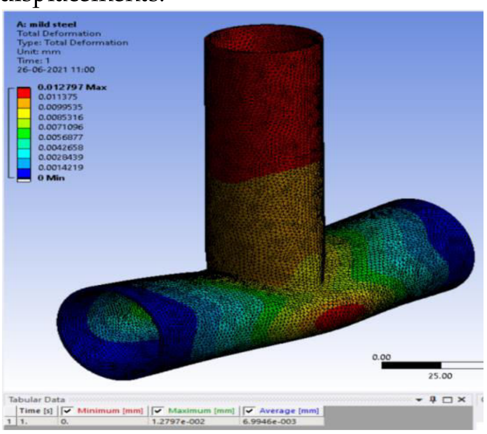
# 7. RESULTS

## 7.1 RESULTS WITHOUT WELDING

Total Deformation

Total deformation and directional deformation are phrases that are used interchangeably in finite element methods, regardless of the software employed. The movement of the system along a certain axis or in a defined direction is referred to as directional deformation.

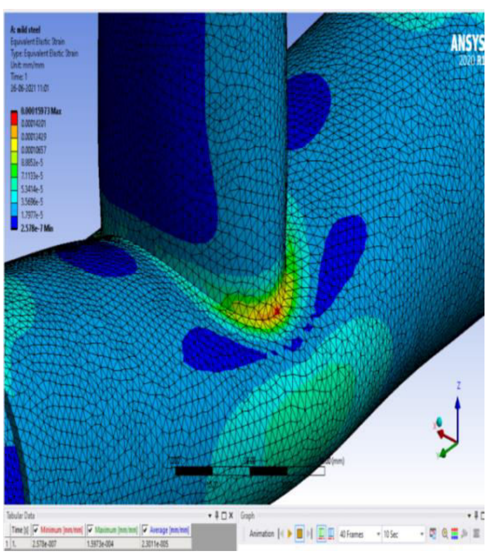
Total deformation is the vector sum of all system directional displacements.



Deformation

The deformation is low as we applied the force on the chord as we can see that it is 0.012797 mm max.

Strain



Strain

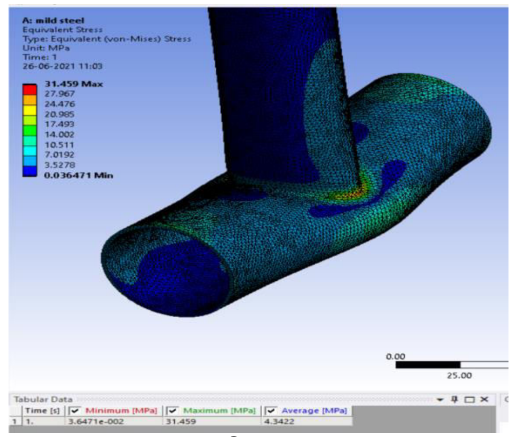
Because the stress concentration and strain factors are larger at the joint tabs, the corresponding strains for elastic, plastic, creep, and thermal stresses are computed in post processing using the von Misses equation.

$$\varepsilon_{eq} = \frac{1}{\sqrt{2}(1+v')}[(\varepsilon_x - \varepsilon_y)^2 + (\varepsilon_y - \varepsilon_z)^2 + (\varepsilon_z - \varepsilon_x)^2 + \frac{3}{2}(\gamma_{xy}^2 + \gamma_{yz}^2 + \gamma_{xz}^2)]^{\frac{1}{2}} \ldots\ldots\ldots\ldots\ldots(1)$$

Equivalent Stress

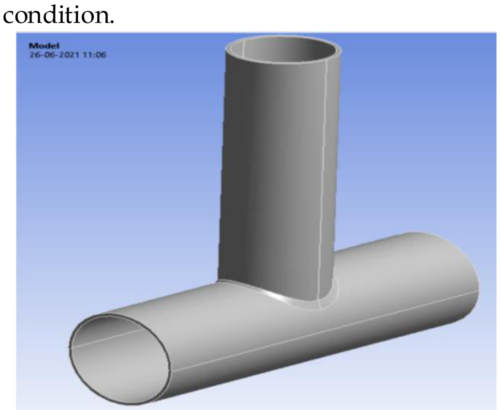
The below equation relates the equivalent stress to the primary stresses:

*σe = {[(σ1-σ2)2 + (σ2 −σ3 )2 + (σ3 - σ1 )2 ]/ 2}1/2 ……………………………(2)*



Stress

2nd iteration, welding has done the brace and chord and simulated the FEM solution and recorded the results at same boundary condition.



Welded joint

Parameters

Brace diameter = 60 mm

Chord diameter = 40 mm

Length of chord = 150 mm

Length of Brace = 150 mm

Throat thickness = 1.5 mm

6

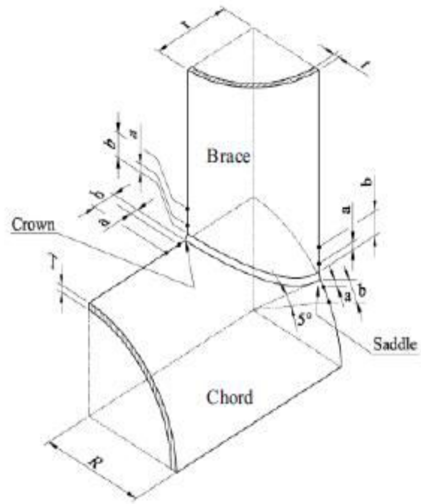
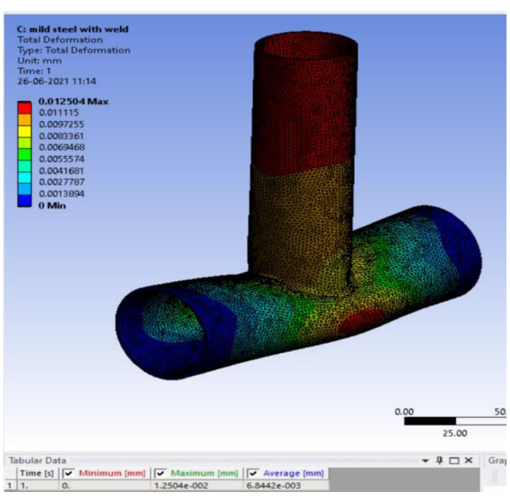



Fig 2. Diagram for chord and brace

| | |
|---|---|
| Along Brace surface normal to the weld toe crown & saddle position | |
| a | 0.2(r * t)1/2 |
| b | 0.65(r * t)1/2 |
| Along Chord surface normal to the weld toe crown position | |
| a | 0.2(r * t)1/2 |
| b | 0.45(r * t * R * T)1/4 |
| Along Chord surface normal to the weld toe saddle position | |
| a | 0.2(r * t)1/2 |
| b | 2пR 5/360* c *п*R/36 |

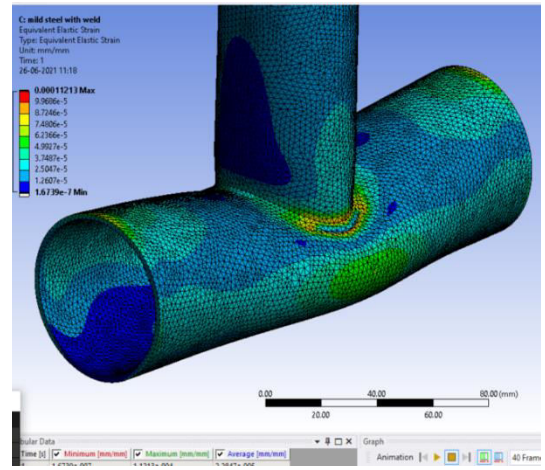
Table 1: distances a & b according to DNV

### 7.2 RESULTS FOR WELDING




Deformation

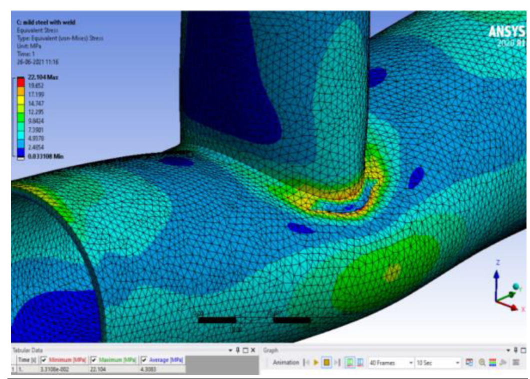
STRAIN



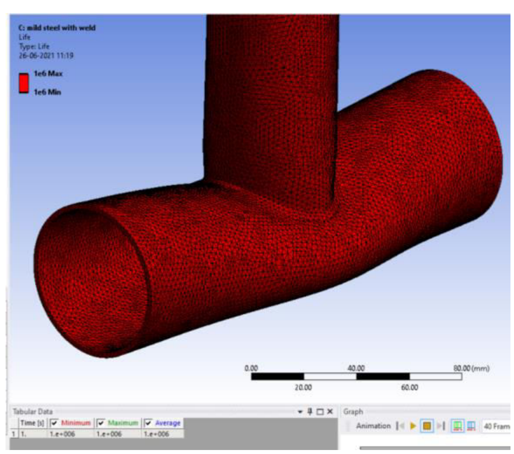

Strain

As the strain and stress factors are less at the join load so the process is decreasing in order so the jointed geometry has less strain as we compared the 1st& 2nd iteration

STRESS




Stress




Life

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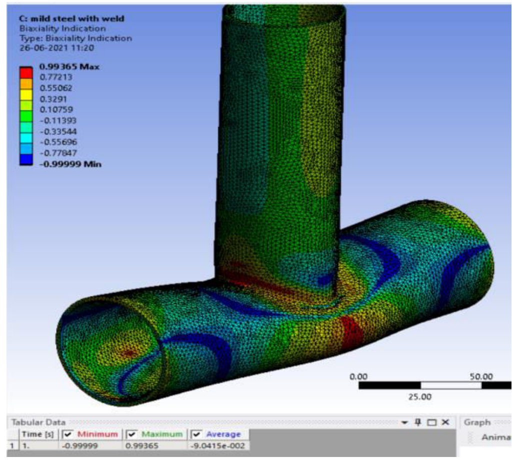
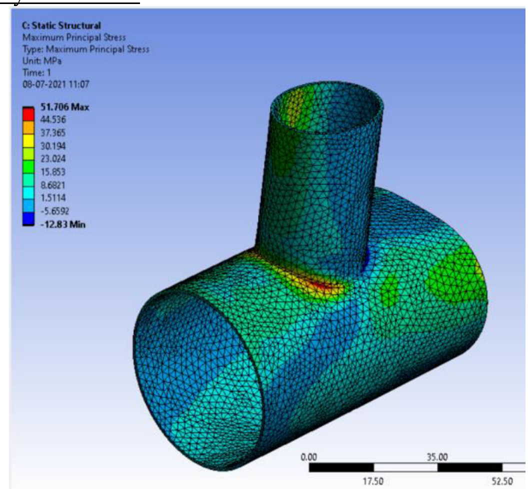
Goodman's theory equations for the product's life under the actual load condition

BI-AXILLARY INDICATION

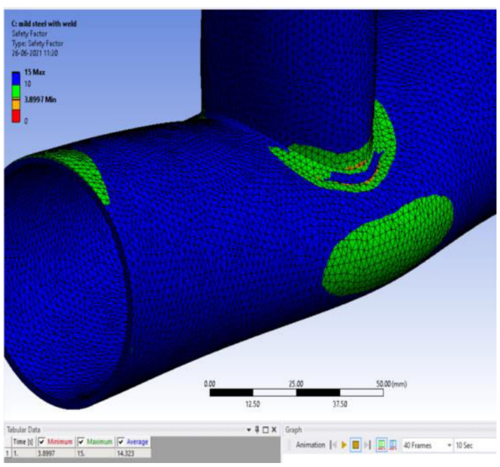


Bi-axillary indication

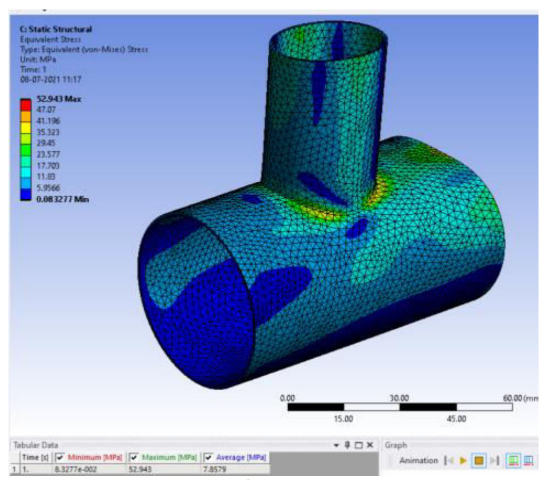
Boundary condition



Maximum principal stress



Factor of safety



Stress

Factor of safety to be considered to neglect the failure of the product as we can see the FOS as per the Goodman's theory

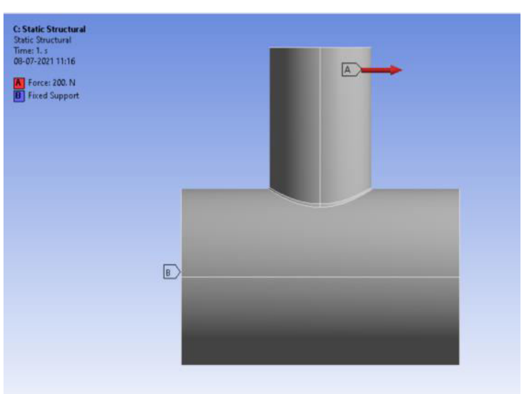


Fig 3. L-shaped welded joint

**Geometry description**

The tube analyzed for this report is a standardized T-joint shown in Figure 5. with dimensions.

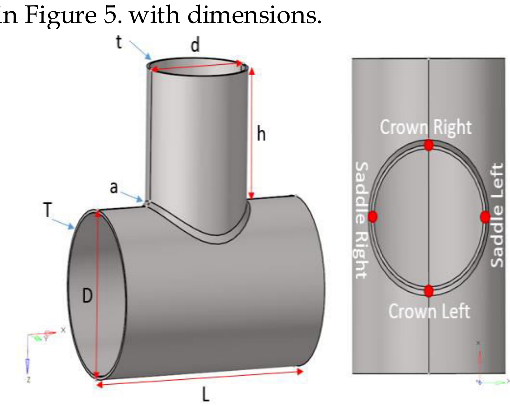



Fig 4. Geometry of T-joint and definition of right and left side of the tube.

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**Geometry of the T-joint.**
Description Notation Length (mm)

Diameter Chord D = 50.8
Diameter Brace d = 30.1
Thickness Chord T = 0.9144
Thickness Brace t = 0.9144
Throat thickness a = 0.9144
Length Chord L = 82.465
Height Brace h = 40.778

The weld is assumed to build a 45 ° angle with the T-joint at crown position according to Figure 5 and Saddle position has an angle of 71.8 ° due to the geometry of the Brace and Chord.

**Condition**

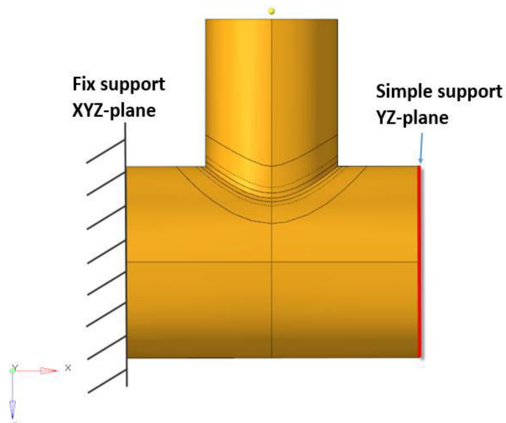
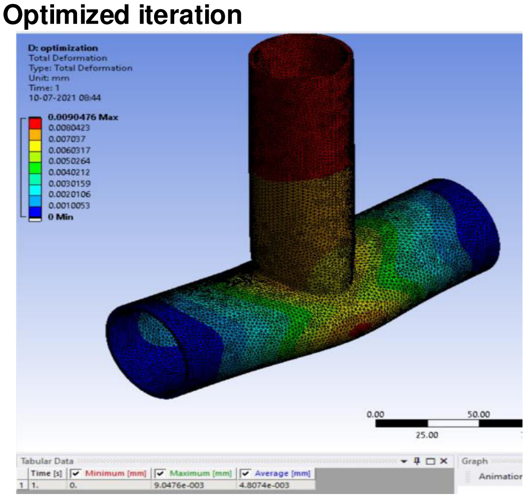



Fig. 5: The Boundy condition for T" joint. Fix supported at left end and while simple support at rigid end.

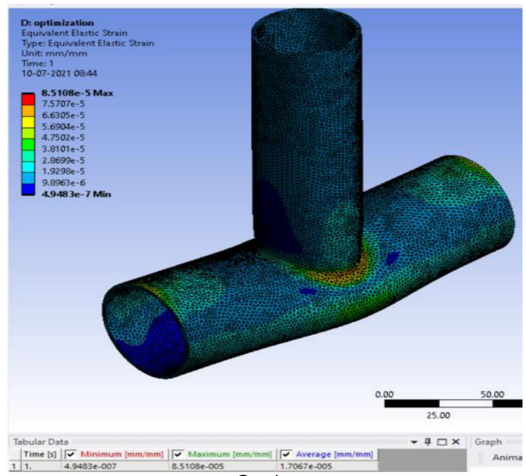
The obtained results were compared & the load condition applied at x-direction is as expected to theory simulation.

### 7.3 3rd Optimized iteration

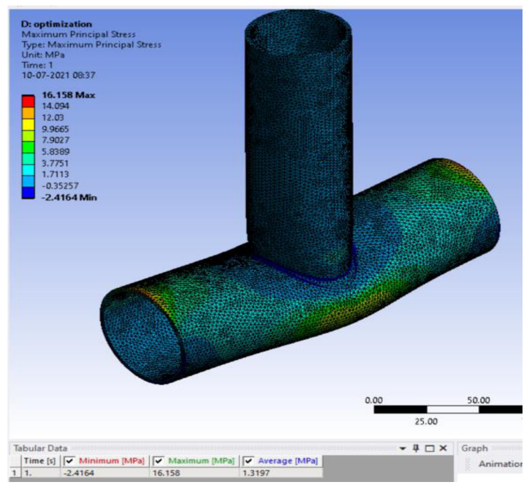



Deformation

The parameters are same but the throat thickness of weld is changed from 1.5 mm to 2mm thickness




Strain




Maximum-principal stress

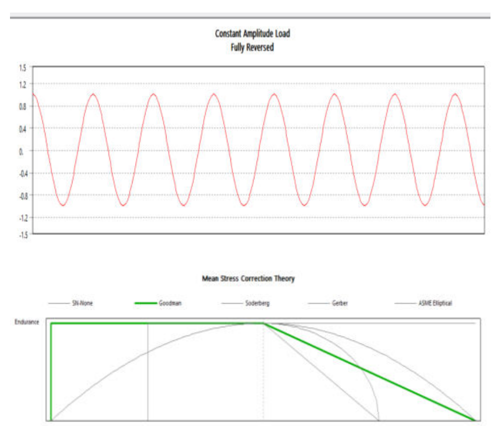
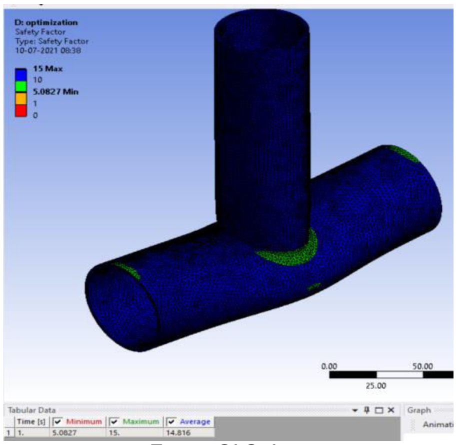



Fig 6. The mean stress correction theory yielding and ultimate according to Goodman's theory



Factor Of Safety

The factor of safety as per 2nd iteration the stress and FOS has been reduced as we can compare it

## 8. CONCLUSIONS

This paper refers the study the physical properties & fatigue factors of welded joint of T-cross-section Thin wall tube which are having thickness less than 3mm (<3mm). The first iteration of FEM solution is created using Static condition neglecting inertia and no time variation is considered. Linear loading and fatigue factors for fully reversed loading with a Goodman's theory procedure is followed.

The following factors are solved.

- Physical strength or properties.

(a.Total deformation, b. Equivalent Von-misses stress, c. Equivalent elastic strain.)

- Fatigue factors like

(i. life of the part, ii. Safety factor, iii. Damage, iv. Alternating stress, v. Biaxiality indication.)

FEM solution, iteration are followed as: (STATIC CONDITION)

1. The 1st iteration contains. Thin wall tube with no welded joint which can be created by the process of casting with an extra detailed procedure and results were recorded.

- Stress = 31.495 Mpa
- Deformation = 0.012797 mm
- Strain = 0.00015973

2. In 2nd iteration. Thin wall tube with welded joint, of a throat thickness 1.5mm at joining section and solved for the result, as we can see the result table it has much difference for a load condition of 1000 N in the negative z direction, for a fixed support condition as both end fixed & center load acting tangentially for all the cases in static system.

    - Stress = 22.104 Mpa
    - Deformation = 0.012504 mm
    - Strain = 0.00011213

3. The 3rd iteration was solved, for a case if we increase the throat thickness of weld joint to 2mm whether it can minimize the obtained factors solved in 2nd iteration? And the results are as expected.

    - Stress =16.168 Mpa maximum principal stress
    - Deformation = 0.0090476 mm
    - Strain = 8.5106e-5

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