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FATIGUE 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 -250 to -1500 N in z direction the results shows better factors from 1st iteration and cyclic loading 1000 to 10000 N for maxi failure for structural steel in 2nd iteration

Keywords*: 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 [1]. A warmth source is used in combination welding to create and maintain a liquid pool of metal of the required size [15].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 [1]

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 [37,39].

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 [38]. 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 [40, 41].

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 [2]. When a cylinder or line is welded to a base plate, tee joints are generated similarly to fillet welds [33]. 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 [34], J-groove weld [3], melt-through weld, and flare-bevel-groove weld [35]

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 [12, 27]. 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.

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3. LITERATURE REVIEW

For the strength and durability analysis of weldments, detailed understanding of stress fields in crucial locations is required. The stress data is then utilised to determine where fatigue cracks may emerge and how quickly they may grow [30]. 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. [36]. A welding junction is a point or edge that connects two or more pieces of metal or plastic. They're made by welding two or more work parts together in a specific geometry. In this article, we looked at the microscopic and macroscopic behaviour of a few specific and regularly used joints in the industry when they were subjected to various forms of loading [43]. 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 behavior [47].

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 [3, 4, 6].

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[47, 52].

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 [14]. 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 [7].

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 [44].

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 [46].

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 [11]. Techniques for improving weld geometry aim to reduce or control stress concentration at weld junctions [13].

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 [43].

Residual Stress Reduction

Residual stress results from thermal expansion caused by the temperature differential between the weld joint and the parental metal [8, 10, 16]. 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 [18, 20-21].

Welded joints will deteriorate over time as a result of stress, necessitating regular inspection and repair of metal structures [25, 26]. 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.

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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.

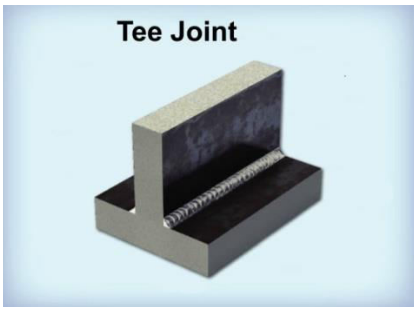


Fig. 1 Simple "T" Joint welding Technique

For thin walled tube the procedure will be same but the angle of welding varies [29].

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 [42]. 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 [9]. The simple equations that represent these finite components are then combined into a larger system of equations that represents the entire disadvantage [31]. FEM then performs an estimated response by reducing an associated error using variation in ways derived from pure mathematics of variations. The term "fatigue" was initially used to describe the failure of a structure or structural part due to cyclic loading in the nineteenth century [28]. August Wohler was the first to study fatigue when he looked into the failure of train axles [17]

Studying or analyzing a development with FEM is usually named as finite component analysis (FEA) [3].

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 setup 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.

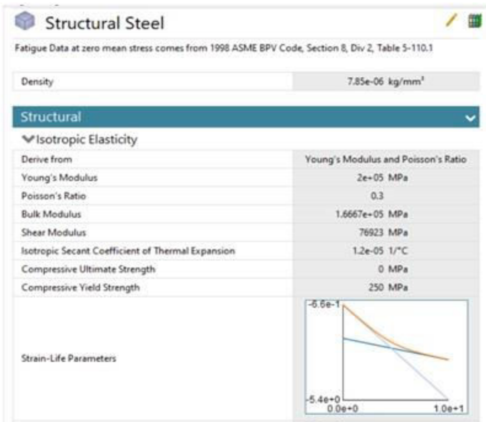


Fig. 2 Material Mild Steel

Advantages of Mild Steel are easily available, Low cost, high strength, [4-6, 19, 20]
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, welding has done the brace and chord and simulated the FEM solution and recorded the results at same boundary condition.

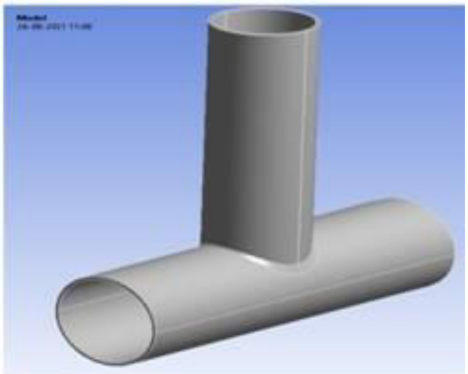


Fig. 3 Welded joint

Parameters
Brace diameter = 60 mm
Chord diameter = 40 mm
Length of chord = 150 mm
Length of Brace = 150 mm
Throat thickness = 1.5 mm

7. RESULTS

Boundary Condition for structural analysis

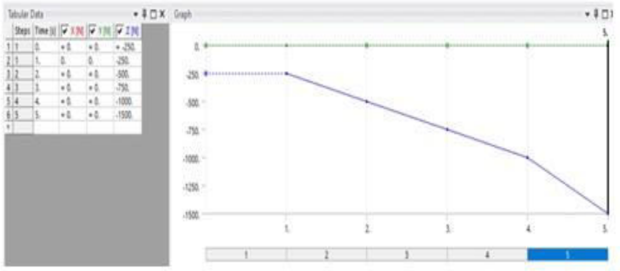


Fig. 4 Cyclic loading with time function for 5 sec

Cyclic load of -250N to -15000 in z direction downwards [22-24]

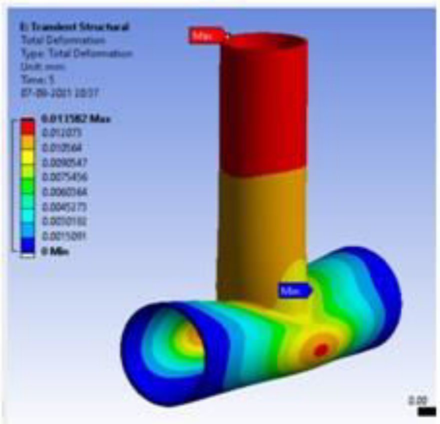
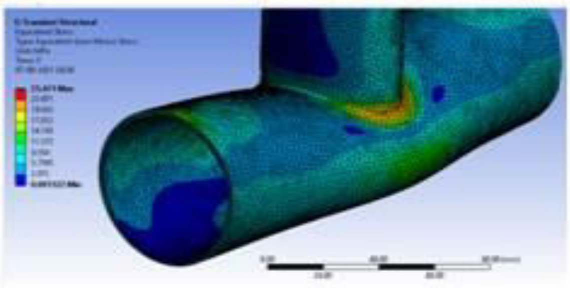


Fig. 5 Deformation at applied boundary condition

Total Deformation at applied boundary conditions is 0.013582 mm



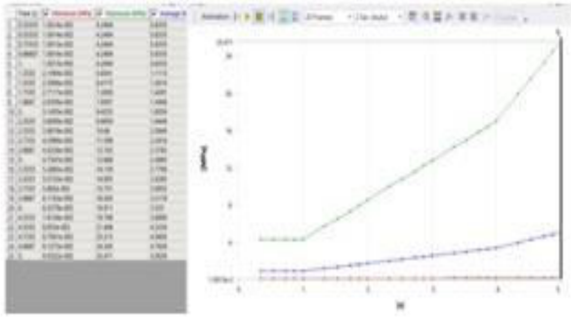


Fig. 6 Stress at applied boundary condition

The maximum stress induced is at the joint of the product. The red colour indicates maximum stress which is 25.471Mpa

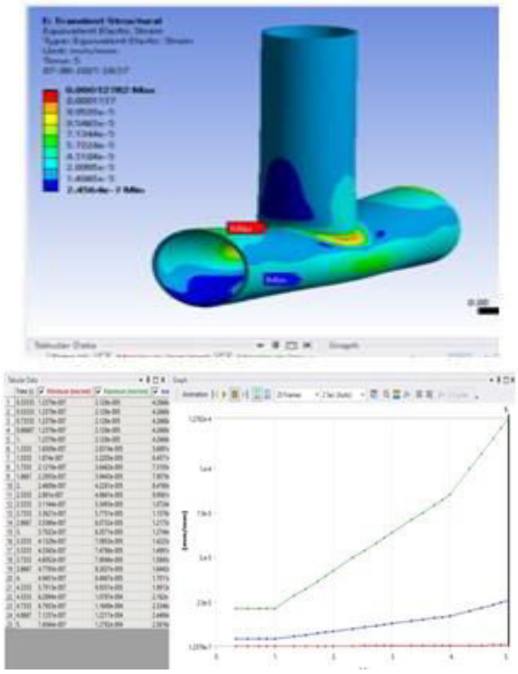


Fig. 7 Strain at applied boundary condition

The maximum equivalent elastic strain induced is at the joint of the product. The red colour indicates maximum strain which is 0.0001278

Fatigue analysis

Fatigue factors like life of the part, Safety factor, Damage, Alternating stress, Biaxiality indication [32].

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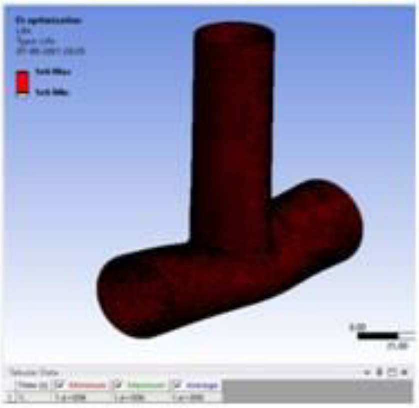

Fig. 8 Life for applied boundary condition

The available life for a certain fatigue analysis is referred to as fatigue life. Fatigue Life can be applied over the entire model or to specific portions, surfaces, edges, and vertices.

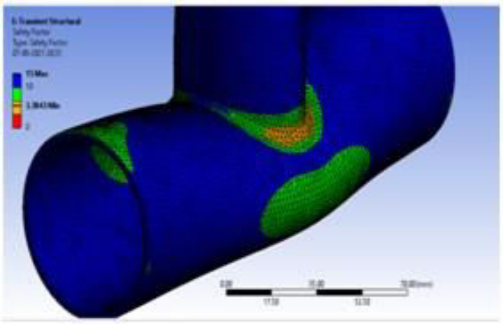

Fig. 9 Safety Factor for applied boundary condition

At a specific design life, fatigue failure occurs. The maximum safety factor is 15. Values less than one for Fatigue Safety Factor indicate failure before the design life is achieved, represents the number of loading blocks that must be completed before failure. Here the safety factor of whole body is 10 and at the joint are 3.348

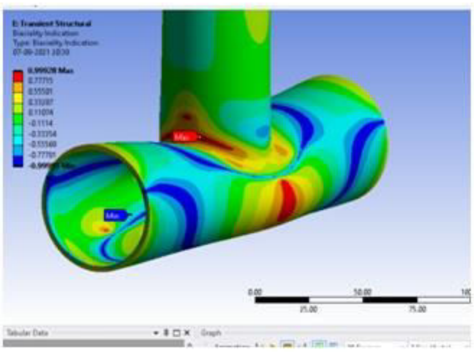

Fig. 10 Biaxiality Indication for applied boundary condition

The smaller principal stress is divided by the larger principal stress to determine biaxiality, with the principal stress closest to zero being omitted. Uniaxial stress is represented by a biaxiality of zero, pure shear is represented by a biaxiality of -1, and a pure biaxial condition is represented by a biaxiality of 1.

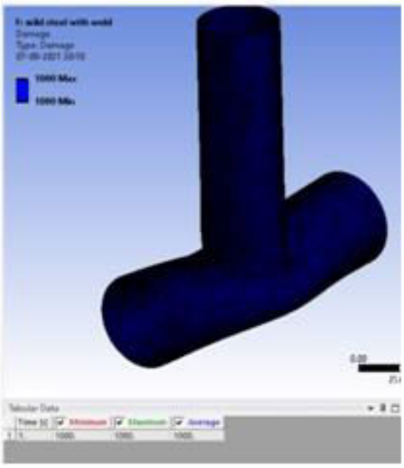

Fig. 11 Damage for applied boundary condition

In both constant amplitude and variable amplitude loading, fatigue damage rises with the number of loading cycles applied.

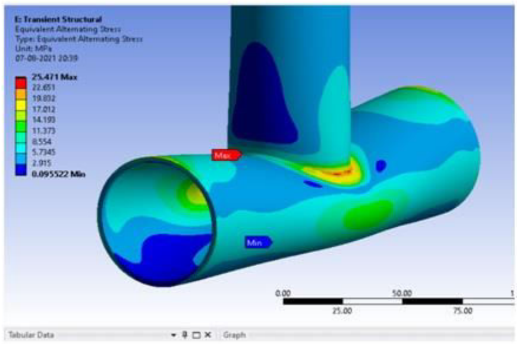

Fig. 12 Alternating Stress for applied boundary condition
In this evaluation the alternative stress is less than 86.2 Mpa which is 25.471 Mpa so the part will survive for 1e6 cycle
Here the safety is infinite number of cycles

In 2nd iteration cyclic loading 1000 to 10000 N for maxi failure for structural steel

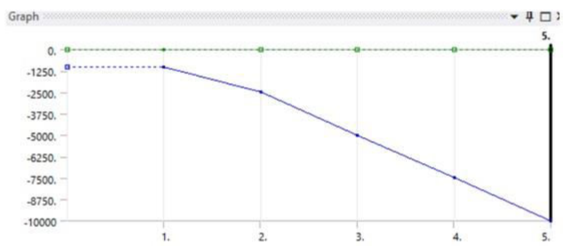

Fig. 13 Cyclic loading condition

Cyclic loading 1000 to 10000 N for maxi failure for structural steel at z direction downward

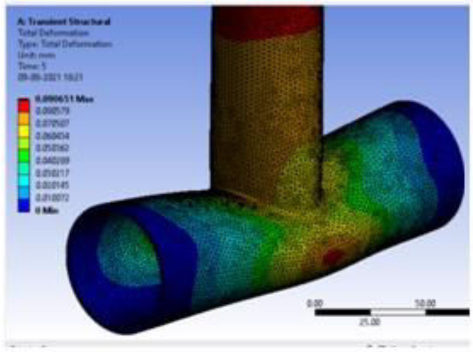

Fig. 14 Deformation for cyclic loading 1000N to 10000N

Total Deformation at applied boundary conditions is 0. 0.090651 mm

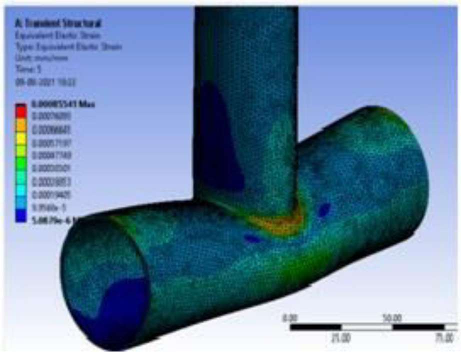

Fig. 15 Strain for cyclic loading 1000N to 10000N

The maximum equivalent elastic strain induced is at the joint of the product. The red colour indicates maximum strain which is 0.00085531

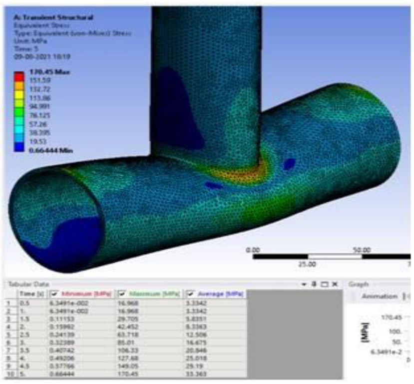

Fig. 16 Stress for cyclic loading 1000N to 10000N

The equivalent stress evaluated in this iteration is less as compared to the 1st boundary condition and it is 170.45Mpa.

Fatigue analysis

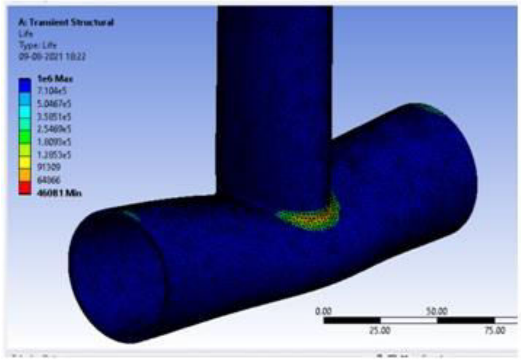

Fig. 17 Life for cyclic loading 1000N to 10000N

The available life for a certain fatigue analysis is referred to as fatigue life. The maximum life of product is 1e6 for the whole body and at the joint 46081 which is minimum.

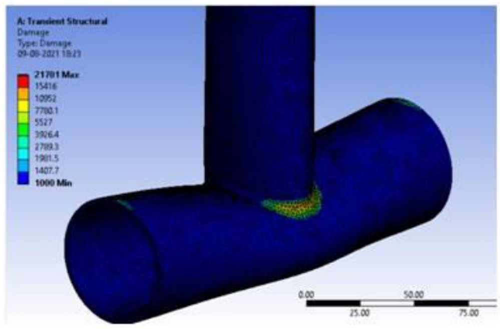

Fig. 18 Safety Factor for cyclic loading 1000N to 10000N

Safety Factor of whole product is 5 which is less as compared to the 1st boundary condition and at the joint is 0.52571 at is minimum.

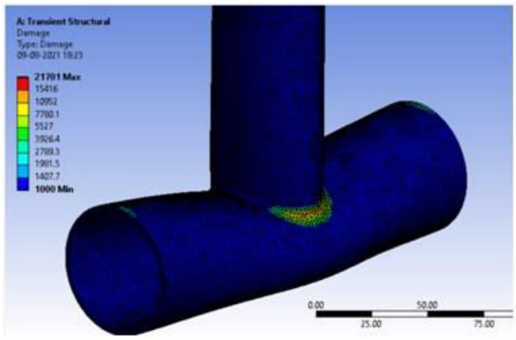

Fig. 19 Damage for cyclic loading 1000N to 10000N

Maximum Damage takes place at the joint where there is red colour and it is 21701 and whole body damage is 1000 minimum.

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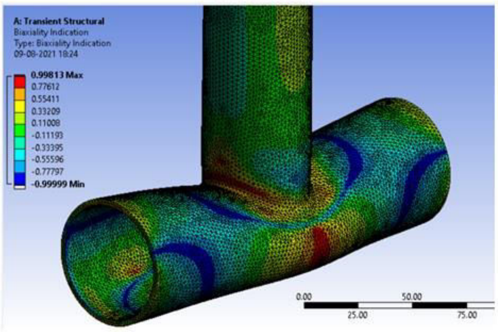

Fig. 20 Biaxiality Indication for cyclic loading 1000N to 10000N

The smaller principal stress is divided by the larger principal stress to determine biaxiality, with the principal stress closest to zero being omitted. At the joint part there is maximum reflection

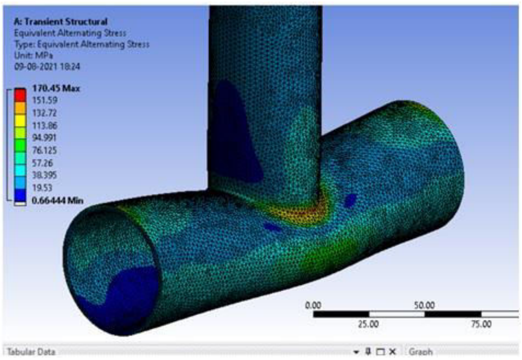

Fig. 21 Alternating Stress for cyclic loading 1000N to 10000N

The minimum alternating stress for the time interval of 5 seconds is 0.66444Mpa and maximum is 170.45Mpa.

Table 1. Result Table

Sr. No	**Process**	**Loading In 'N' z direction**	**Deformation in mm**	**Strain in mm/mm**	**Stress in Mpa**
1	Mild Steel	250 to 1500	0.013582	0.00012782	25.471
2	Mild Steel	1000 to10000	0.090651	0.00085531	170.45

8. CONCLUSION

This paper refers the physical properties & fatigue factors of welded joint of T-cross-section Thin wall tube which are having thickness less than 3mm (<3mm). 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 for iterations is as follows

1.1st iteration is solved, by applying varying non-linear loading condition starting from -250 to -1500 N in negative z direction for a time period of 5 seconds as we can see the load graph. And the results are increasing from 16.235 Mpa to 25.471 Mpa for an extra loading difference of 500N.

2. In 2nd iteration by means we have increased the loading condition for a cyclic load starting from -1000 to -10000N, by keeping the time constant for 5 seconds. And there was a variation in life and safety was too low.

Hence the FEM solution for the purposed thin wall tube is finished the obtained results are valid as per the material physical & chemical properties. & the results are in varying proportion

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