EXPERIMENTAL AND FINITE ELEMENT ANALYSIS OF ELECTRIC ARC WELDED JOINT FOR TENSILE STRENGTH

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***Abstract*: Welded joints are widely found in almost all applications like construction structures, automotive, industrial roofs and many more applications. In welding joint it is observed that the T joint Fails In Tensile, Bending, Fatigue loading so it is necessary to optimize T joint for above failure reason .For that identified the failure of T-joint and selected appropriate material for the T-joint. For modeling of T joint used CATIA V5 software with standard dimensions. Discretiztion (Meshing) and finite element analysis is carried out using ANSYS package. T joint is welded with holding fixture for carrying out experimental analysis. Experimental Stress analysis is carried out using strain gauge for measuring strain values and UTM for applying gradual loads. Load of similar values were applied on T Joint in tensile and bending manner. Results were validated by comparative analysis using FEA and strain gauge values. Experimental and FEA correlation was in linear relation. It was concluded that T joints are stronger in tensile as compared to that of bending loading conditions. Stresses observe in tensile loading as less as compare to bending. FEA and Experimental strains are in good correlation with each other which validates thesis work. Hence, T joint should be used tensile loading application other than bending.**

***Index Terms*: Material welding, T-Joint, Strain Gauges, CATIA, FEA, ANSYS.**

I. INTRODUCTION

Welding is a manufacturing process of creating a permanent joint obtained by the fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler material. The materials to be joined may be similar or dissimilar to each other. The heat required for the fusion of the material may be obtained by burning of gas or by an electric arc. The latter method is more extensively used because of greater welding speed. Welding is extensively used in fabrication as an alternative method for casting or forging and as a replacement for bolted and riveted joints. Welding is the most commonly used process for permanent joining of machine parts and structures. Welding is a fabrication process which joins materials (metals) or thermoplastics. In the joining process of welding application uses heat and/or pressure, with or without the addition of filler material. Various auxiliary materials, e.g. shielding gases, flux or pastes, may be used to make the process possible or to make it easier. The energy required for welding is supplied from outside sources Welding, a metal joining process can be traced back in history to the ancient times. In the Bronze Age, nearly 2000 years ago, circular boxes made of gold were welded in lap joint arrangement by applying pressure. However in the 20th century it lost its place to arc welding in most of the industrial applications. Advance welding techniques like Plasma Arc Welding, Laser Beam Welding, Electron Beam Welding, Electro-Magnetic Pulse Welding, Ultrasonic Welding, etc. are now being extensively used in electronic and high precision industrial applications .Weld joints may be subjected to variety of loads ranging from a simple tensile load to the complex combination of torsion, bending and shearing loads depending upon the service conditions. The capability of weld joints to take up a given load comes from metallic continuity across the members being joined. Mechanical properties of the weld metal and load resisting cross section area of the weld (besides heat affected zone characteristics) are two most important parameters which need to be established for designing a weld joint a poorly designed weld joint can lead to the failure of an engineering component in three ways namely:

a) Elastic deformation (like bending or torsion of shaft and other sophisticated engineering systems like precision measuring instruments and machine tools) of weld joint beyond acceptable limits,

b) Plastic deformation (change in dimensions beyond acceptable limits as-decided by application) of engineering component across the weld joint and

c) Fracture of weld joint into two or more pieces under external tensile, shear, compression, impact creep and fatigue loads.

Therefore, depending upon the application, failure of weld joints may occur indifferent ways and hence a different approaches are needed for designing the weld joints as per application and service requirements.

II. LITERATURE REVIEW

R. B. Sonawane et. al [1] studied experimental stress analysis & finite element analysis of T-Joint under tensile and bending loading. Tensile, bending, tortional and multi axial loads acts on various welded joints during operations' joints are used for various members coming together at same location joints behavior at tensile and bending loading needs to be investigated. T Joints are stronger in tensile loadings as compared to bending loadings.

Arunkumar. A et. al [2] studied The fillet welded joints commonly suffer from various welding deformation patterns, such as, angular distortion, longitudinal & transverse shrinkage in fabrication of structural members in shipbuilding, automobile and other industries that angular distortion defined through numerical calculation. The experimental analysis is carried out by using taguchi technique to evaluate the maximum breaking stress and results are compared with FE analysis and both are approximately acceptable. The finite element analysis is used in this work to evaluate the deformation breaking stress of weld T-joint to restrict the weldment failure (using low carbon steel as a base metal and copper filler material). Static stress analysis performed on the weldment under tensile load revealed the maximum Von-misses stress with respect to the gap between base plates using ANSYS work bench. The design and analysis of welded T-joint has been done successfully.

Pierluigi Mollicone et. al [3] studied experimental investigation and finite element analysis of welding induced residual stresses which gives welding distortions are sensitive to various aspects of configuration and process, such as lack of flatness, tacking procedures and variations in weld configuration. As distortion and stress fields are inter-related, it is to be expected that computational results based on an idealized geometry may not predict the measured residual stresses exactly. In this work, the finite element models can be said to have been successfully validated using hole drilling residual stress measurements. The technique also proved to be convenient and feasible for the configurations investigated. In this study, the hole drilling method was successful in measuring welding-induced residual stresses. Measured and predicted longitudinal stresses were well matched, especially for the region close to the weld where a tensile to compressive transition occurs.

Rabih Kassab et. al [4] presents the Finite Element (FE) modeling of a two-seam welding process for a T joint with a V chamfer preparation. In this study, the finite element modeling of welding a T-joint configuration with a V preparation was done. The simulated model was run with ANSYS software and the use of the "birth and death" property was programmed to simulate the filler metal deposition. The double ellipsoid model of Goldak was also used to simulate the heat source. During the both simulations, thermal and structural, the temperature dependent thermo-physical material properties were taken in consideration.

Ashutosh Jayasing Kate et. al [5] studied a theoretical and experimental analysis of fillet weld which gives the welded joints have the effect of residual stress on its strength. So there may be the variations in the theoretical stress values and the experimental stress values. Strain gauge rosette technique can be used for the stress analysis of welded joints and gives results in good agreement. In this work, as the load increases the stress and deflection values increases. This follows the good linear relationship. But the stress distribution pattern for the welded joints was similar in all loading cases.

Sinjo Jose. V et. al [6] studied an overview of fillet weld joints subjected to tensile and compressive loads, experimental investigation of failure in fillet welds has been extensive. Common method for connecting structural steel is welding process. Many fabrication shops prefer to weld rather than bolt. Welding in the field is avoided if possible due to welding condition requirements. There are several welding processes, types, and positions to be considered in building construction. In this study, finite element analysis software, ANSYS, is used for a parametric study to research the effect of weld toe radius in fillet welded joint on compression strength and tensile strength. In this project, the effect of weld toe radius on tensile strength and compressive strength of fillet weld joint has been analyzed. In experimental study, tensile test and compressive test were carried out by using Universal Testing Machine. The experiments have been validated by using ANSYS software. It has been found that when toe radius increases, tensile strength and compressive strength of fillet weld joint decreases.

Z. Tonkovic et. al [7] observed that during the welding process, due to localized heating and subsequent rapid cooling, residual stresses appear around welding zones and cause post-weld deformations of the structure.. This paper presents a numerical and experimental study of residual stresses and distortions induced by the T joint welding of two plates. Within the framework of numerical investigations a thermo-mechanical finite element analysis is performed by using a shell/three-dimensional modeling technique to improve both the computational efficiency and the accuracy. Efficiency and accuracy of shell/3D technique for welding simulation is investigated. The influence of the 3D zone size on the convergence of the results is defined. The minimal 3D submodel size is selected on the basis of the error analysis. The welding experiments are conducted and the measured temperatures and displacements are compared with results obtained by numerical analysis. It is shown that the numerical results agree well with the experimental results.

Akash Srivastava et. al [8] explained that welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence generated by with or without pressure and with or without temperature. This is frequently done by melting the work pieces and adding a filler material to form a loch of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. In present era it is necessary to build or create such type of joints which are heavy duty and durable for a long period of time so that prevent from any type of tragedy and to get maximum possible strength. Now in days it is very hard to choose a right one method for welding of metals. So we have done number of experiment for welding strength of mild steel to get the right one method for different type of joints.

Chetan S Baviskar et. al[9] explained the conclusion that deeper penetrating fillet welds experimentally developed could be made stronger, tougher, faster, and with less specific energy than welds without penetration. Weld penetration significantly increases the strength of fillet welds loaded in tension. Tension and peeling failure do occur in grounding of ships built with existing design standards. Fillet welds of stiffeners must have a T-joint strength equivalent to the web in order to prevent failure of welds in tension loading. In the peeling mode of failure the weld tearing work must be larger than the complementary work required to fold the hull plate in order to prevent weld failure. Testing on 6 mm leg length welds showed an increase of 63% in the tensile strength with penetrations increasing from 0 to 3.2 mm. The weld strength increased 50% from the 1.1 mm penetration with the parameters recommended by the manufacturer to the 3.2 mm penetration achieved by altering weld parameters. Fabco 802 electrode showed an increase in weld tensile strength of 37% with a 3.3 mm increase in penetration.

Bjork T. et. al[10] carried out experimental test for fillet welded joints weld made of ultra high strength S960 steel and the capacities were compared with results from nonlinear FEA. The following conclusions can be drawn out: - load carrying capacity of the studied joints seems to be evaluated using the current design rules deformation capacity was remarkable lower compared the capacities of conventional structural steel up to $f\text{y} \leq 460$ MPa. Failure mode was ductile rupture for all in room temperature tested joint. Using of under matched filler material can be improved the deformation capacity of filled welds. FEA predicted the ultimate capacity and failure path quite well but not the ultimate deformation capacity. Heat input is essential due to softening effect in HAZ and it should be considered (like in aluminum structures) if the critical heat input limits cannot be followed.

M. N. Buradkar et. al[11] have worked on "Experimental and photo elastic of arc welded Lap Joint" In this they explained The static stress analysis on arc lap weldment performed to take into account the positional error which may occur during manufacturing. For this purpose the gap between the parent plates is varied from 0.1mm to 1mm in the step of 0.1 mm and it is observed that the maximum shear stress in the weldment varies w.r.t. gap between the parent plates. It is seen that the maximum shear stress reduces as the gap between the plate increases.
From the above papers I have studied the While this option will result in a higher allowable strength, it comes at the cost of reduced ductility in the weld. From the above papers I have studied This may be due to shifting of shearing zone of the weldment which resulted into increase in the throat length. Further investigations are required to verify this fact under fatigue loading and also under other loading condition like bending load etc.

III. PROBLEM STATEMENT:

In welding joint observed that the T joint Fails In Tensile, Bending, Fatigue loading so that the problem optimize T joint for above failure reason. In previous studies observed that the T joint fails in tensile, bending, fatigue loading so that the problem optimize T joint for above failure reason. Welded joints are widely found in almost all applications like construction structures, automotive, industrial roofs and many more applications. Tensile, bending, tortional and multi axial loads acts on various welded joints during operations' joints are used for various members coming together at same location joints behaviour at tensile and bending loading needs to be investigated.

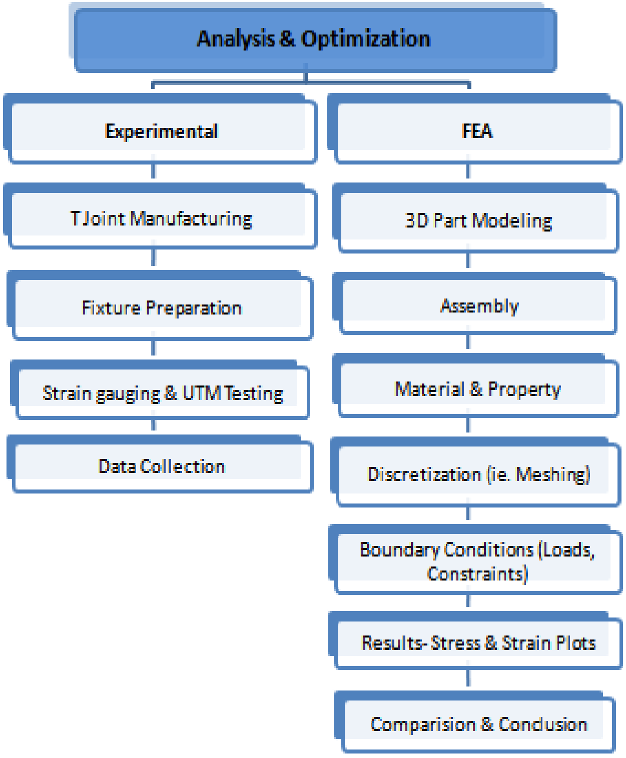
IV. OBJECTIVES:

- To study the various welding processes.
- To identify the failure of T joint.
- To carry out experimental analysis of T welded joint subjected to tensile and bending loading.
- To observe behavior of component at tensile and bending loading.
- To validate experimental and FEA results with respect to tensile strength.

V. SCOPE:

Finite Element method along with experimental techniques is used. Welded joint subjected to transverse static load is considered for the analysis. And the T-Joint fillet welding is the most common welding in engineering application, the overhead cranes ,automotive brackets and the used in Multi axial loading, Vibration test.

VI. METHODOLOGY:



VII. EXPERIMENTAL TESTING AND ANALYSIS

A. ANALYSIS: MILD STEEL:

Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young'...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa
12	Alternating Stress Mean Stress	Tabular	
16	Strain-Life Parameters		
24	Tensile Yield Strength	2.5E+08	Pa
25	Compressive Yield Strength	2.5E+08	Pa
26	Tensile Ultimate Strength	4.6E+08	Pa
27	Compressive Ultimate Strength	0	Pa

Fig. 1 Material properties

For Tensile Loading:

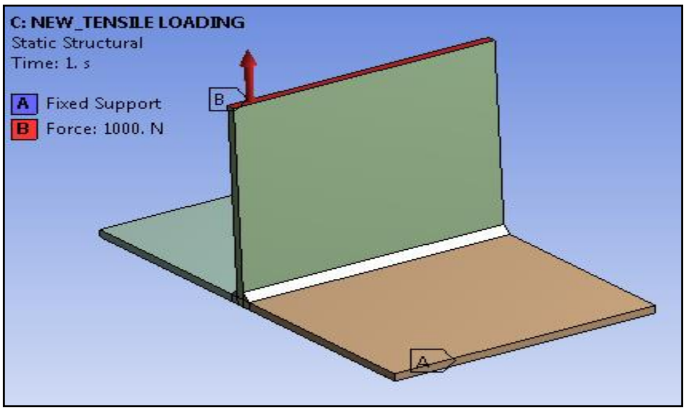


Fig. 2 Boundary condition

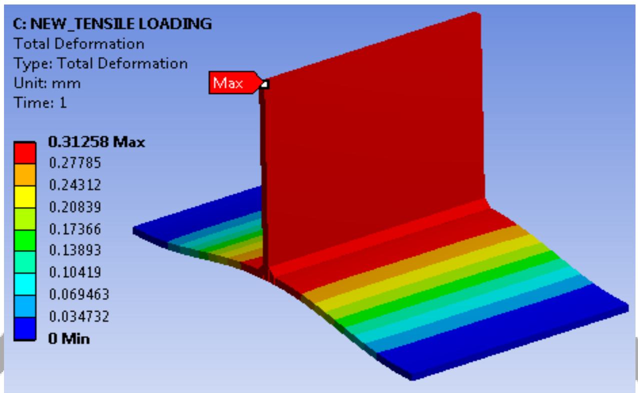


Fig. 3 Total deformation

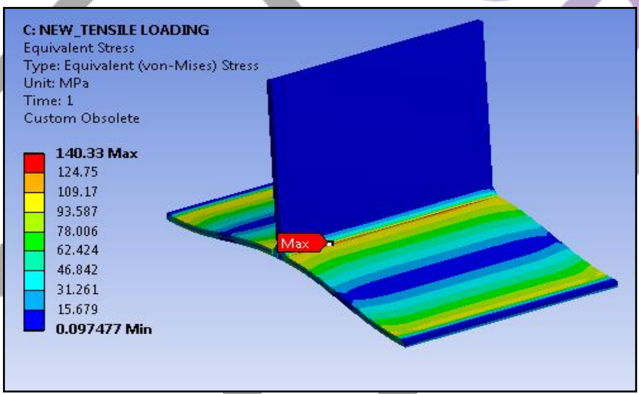


Fig. 4 Equivalent stress

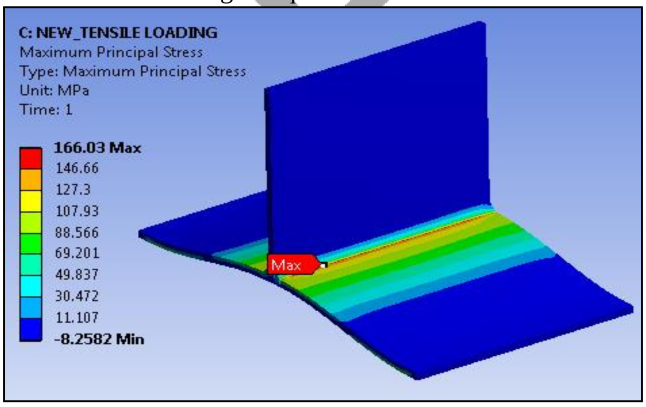


Fig. 5 Maximum Principle stress

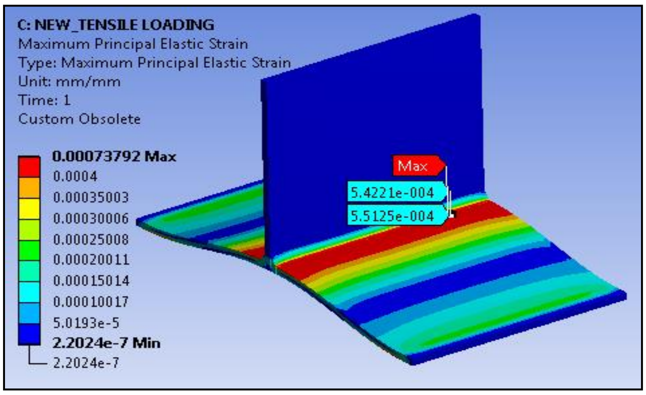


Fig. 6 Maximum principle strain

Strain gauge will be placed in nearby feasible location during fatigue life curve

Table of Properties Row 12: Alternating Stress Mean Stress

	A
1	Mean Stress (Pa)
2	0
*	

	B	C
1	Cycles	Alternating Stress (MPa)
2	10	3999
3	20	2827
4	50	1896
5	100	1413
6	200	1069
7	2000	441
8	10000	262
9	20000	214
10	1E+05	138
11	2E+05	114
12	1E+06	86.2

Fig.7. SN – curve for fatigue life calculation

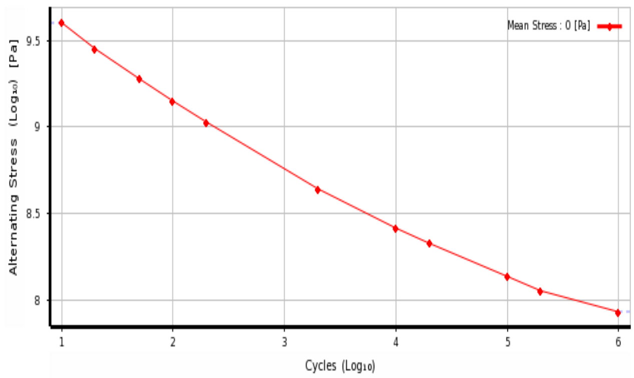


Fig.8 Fatigue life curve

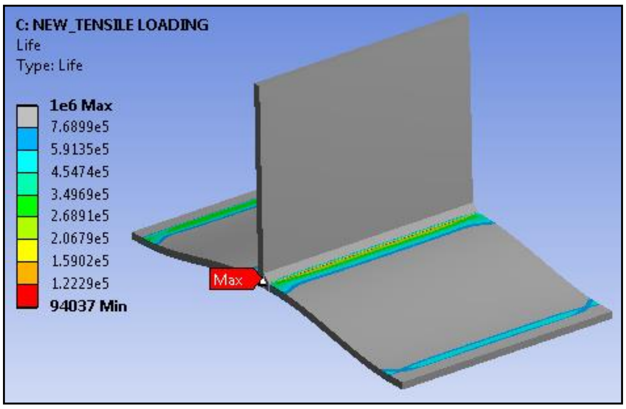


Fig.9 Fatigue life

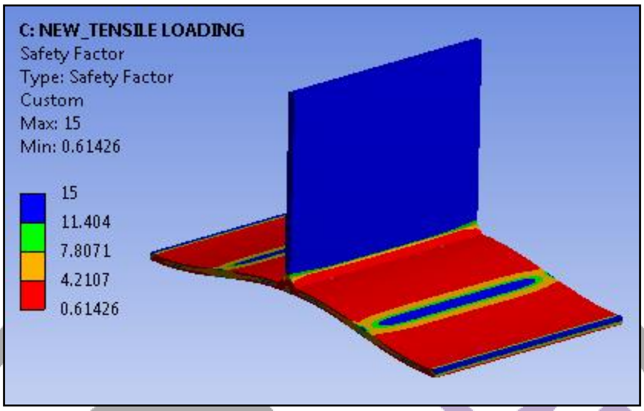


Fig.10 Factor of safety

For Bending loading

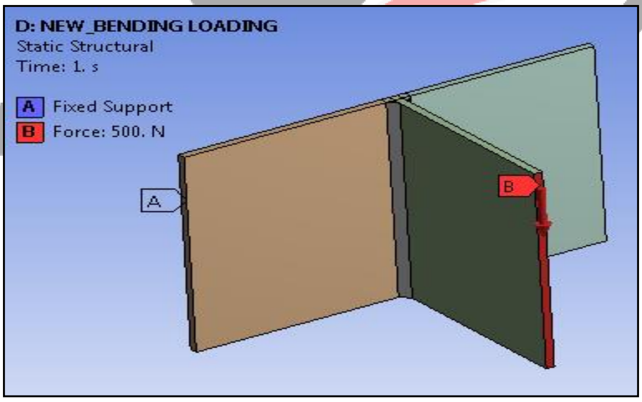


Fig.11 Boundary condition

In the above figure A fixed support B is 500 N

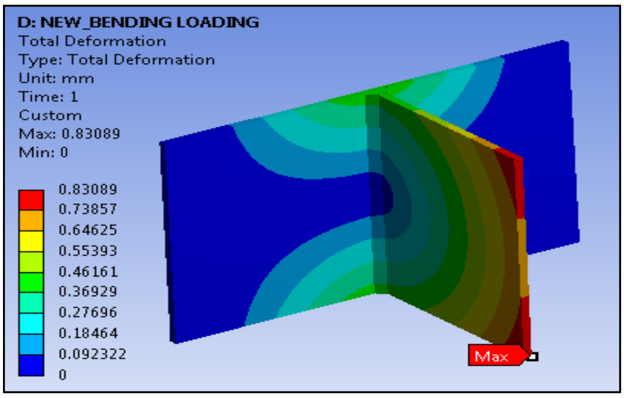


Fig.12 Deformation

In the above figure total Deformation is maximum 0.83089

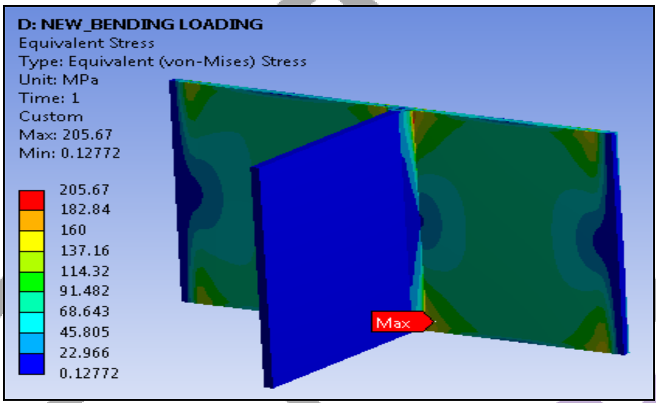


Fig.13 EQVI – Von Misses Stress

In the above figure Max.Von Misses stress is 205.67 and Min Von Misses Stress is 0.12772

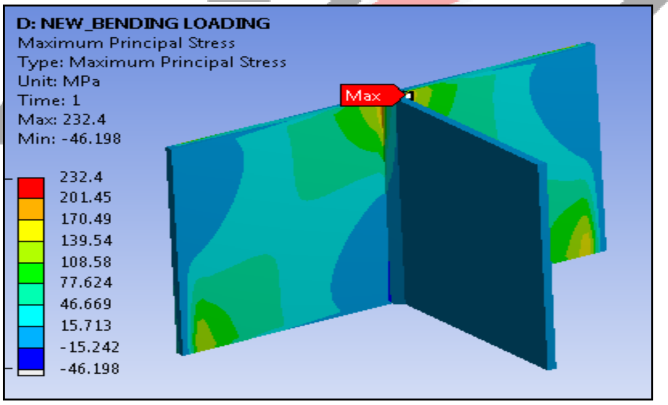


Fig.14 Maximum Shear Stress

In the above figure Maximum Principal Stress is 232.4 and Minimum Principal stress is -46.198

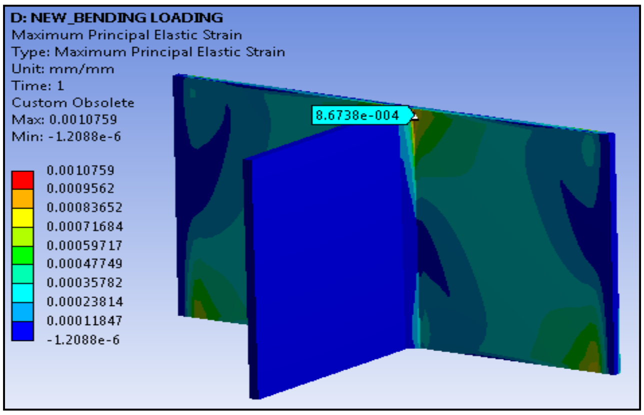


Fig.15 Max principal strain

In the above figure the Max principal strain is 0.0010759 and Minimum principal stress is -1.2088e-6

Table of Properties Row 12: Alternating Stress Mean Stress

	A
1	Mean Stress (Pa)
2	0
*	

	B	C
1	Cycles	Alternating Stress (MPa)
2	10	3999
3	20	2827
4	50	1896
5	100	1413
6	200	1069
7	2000	441
8	10000	262
9	20000	214
10	1E+05	138
11	2E+05	114
12	1E+06	86.2

Fig. 16 SN – curve for fatigue life calculation

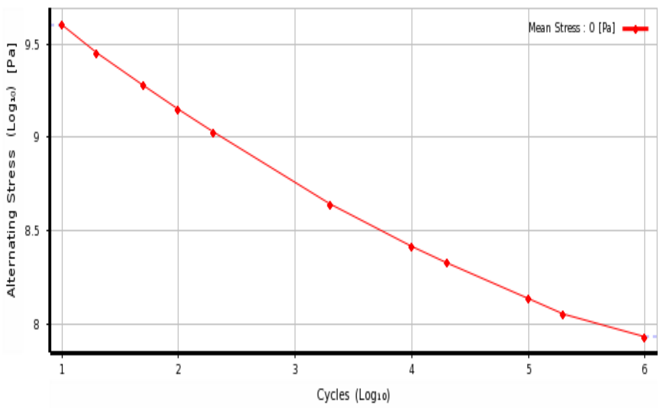


Fig.17 Fatigue life curve

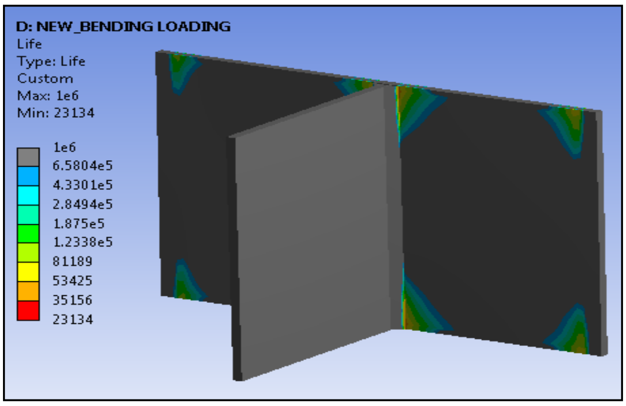


Fig.18 Fatigue life

In the above figure Maximum Fatigue life is 1e6 Max and Minimum fatigue life is 23134

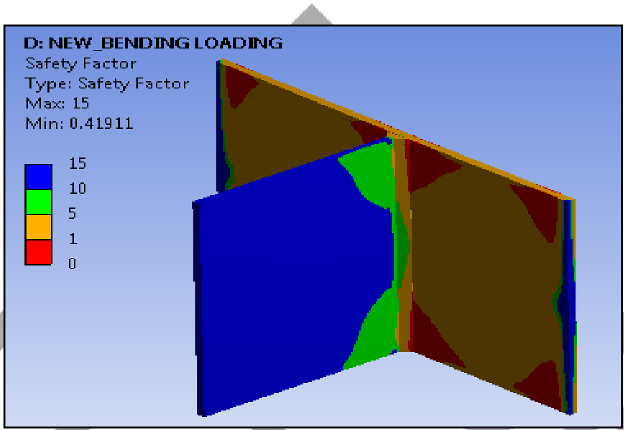


Fig.19 Factor of safety

In the above figure Maximum Factor of safety is 15

B. EXPERIMENTAL TESTING:

There are various types of experimental methods to analyse strains and stresses at a point. Strain gauge methods use either electrical or mechanical means to measure strains. In these types of strain gauges, electrical resistance strain gauges are the most accurate and widely used ones. This experiment consists of three parts, all utilizing electric resistance strain gauges.
Historically, the development of strain gauges has followed many paths and various methods have been developed based on mechanical, optical, electrical, acoustic and pneumatic principles. In spite of the very wide variations in the strain gauge designs, they all have four basic common characteristics. These are gauge length, gauge sensitivity, measuring range, and, accuracy and reproducibility. Gauge Length: Strains cannot be measured at a point with any type of gauge, and as a consequence non-linear strain fields and local high strains are measured with some degree of error being introduced.

Strain Gauge:
A strain gauge is a device used to measure strain on an object. The most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate. As the object is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor.
There are different types of commercial strain gauges; these are:
1. Unbonded wire gauges
2. Bonded wire gauges
3. Bonded foil gauges
4. Piezo-resistive gauges
5. Semi-conductive gauges

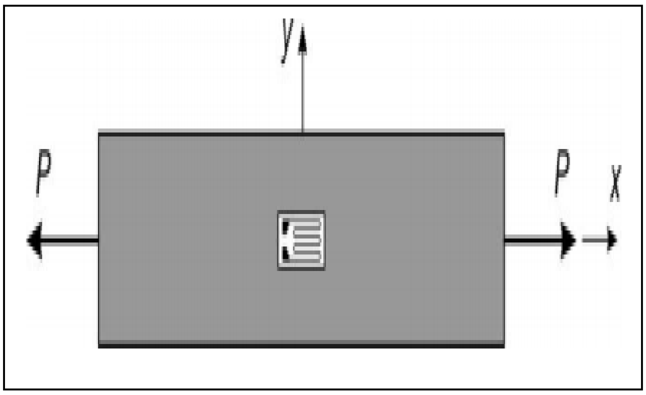


Fig.20. Bonded Foil strain gauges

About **UTM**: A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile)

For Bending Loading:


Fig. 21 Bending Loading on T-Joint

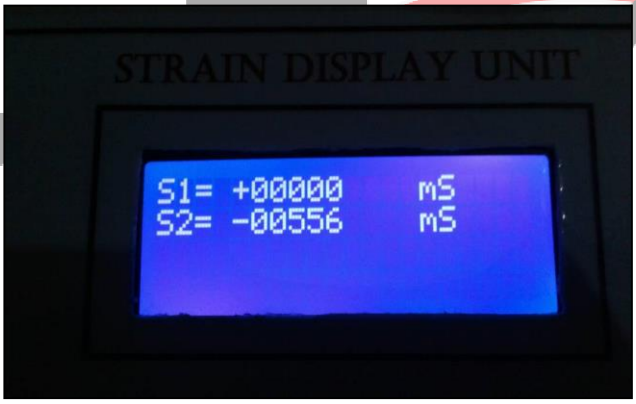


Fig. 22 Strain gage output 556 micro strains

For Tensile Loading:

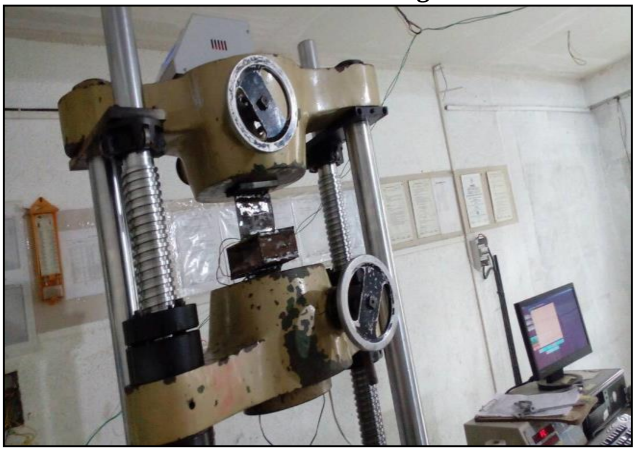


Fig. 23 Tensile Loading on T-Joint

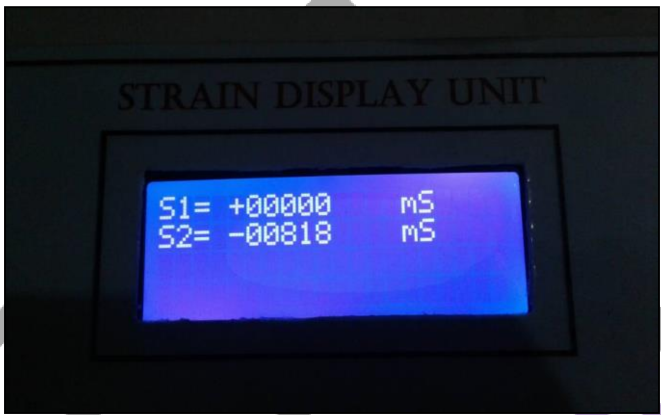


Fig. 24 Strain gauge output 818 micro strains.

VIII. RESULT AND DISCUSSION

1. FEA analysis

Characteristics	Tensile	Bending
Total deformation (mm)	0.3125	0.8308
Equivalent stress (MPa)	140.33	205.67
Maximum principle stress (MPa)	166.03	232.4
Maximum principle strain	0.000738	0.00107
Fatigue life	10^6	10^6
Safety factor	15	15

2. Experimental analysis

Characteristics	Tensile	Bending
Stress (MPa)	111.2	163.6
Strain	0.000556	0.000818

IX. CONCLUSION:

The following conclusions are drawn from the present work.

1. T Joints are stronger in tensile loadings as compared to bending loadings.
2. Stresses observe in tensile loading as less as compare to bending.
3. Hence, T joint should be used tensile loading application other than bending.
4. FEA and Experimental strains are in good correlation with each other which validates thesis work.

X. FUTURE SCOPE:

1. The natural frequency and harmonic analysis also perform for the better result.
2. We can also perform the same analysis for different welded joints.(Lap joint, T joint etc.

XI. ACKNOWLEDGMENTS

I take this opportunity to express a deep sense of gratitude towards my guide Prof. Sanjay A. Pawar, for providing excellent guidance, encouragement and inspiration throughout the project work. Without his invaluable guidance, this work would never have been a successful one. I would also like to thank all my classmates for their valuable suggestions and helpful discussions.

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