

# An Overview of Fillet Weld Joints Subjected to Tensile and Compressive Loads

Sinjo Jose .V<sup>1</sup>, M. James Selvakumar<sup>2</sup>

<sup>1</sup>PG scholar, Department of Mechanical Engineering, Adhiyamaan College of Engineering (Autonomous), Hosur, India

<sup>2</sup>Professor, Department of Mechanical Engineering, Adhiyamaan College of Engineering (Autonomous), Hosur, India

**Abstract:** Mechanical assemblies and parts that are in service may be subject to high stresses and different types of loads such as fatigue loads, tension loads, compression loads. 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 metal constructions, machine assemblies, shipbuilding and other heavy industries, fillet joint is a widely used structural member. There are different types of loads acting on the fillet weld joints. There are various application of fillet weld joints. We can use fillet weld joints in steel bridge girder, building structures, machine assemblies etc. When vehicles are going above steel bridge girder, it will be subjected to various types of loads such as tensile loads, compressive loads, combination of tensile and compressive loads, fatigue loads etc. Stress concentrations usually occur at structural geometry discontinuities, e.g. weld toes, and crack-like defects. These stress concentration sites may serve for crack initiation and cracks that are propagating may lead to failure of weld joint. In the present work, I did the analysis and compared the effect of weld toe radius on compression strength, tensile strength of fillet weld joints under two cases and also experimental validation of result.

**Keywords:** Toe radius, Fillet weld, Tensile and Compressive strength

## 1. Introduction

A Reliable structural design of welded structures is the accurate assessment of the behavior of the welded connections. This explains the need for further research in this area. This project focuses on welded joint because of the complex behavior and their extensive application in engineering structures. 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. There are different types of loads acting on the fillet weld joints for example tensile loads, compressive loads. Fatigue loads etc.

There is various applications of fillet weld joints. we can use fillet weld joints in steel bridge girder, building structures, machine assemblies etc. when vehicles are going above steel bridge girder, it will be subjected to various types of loads such as tensile loads, compressive loads, combination of tensile and compressive loads, fatigue loads etc. similarly machine assemblies and building structures are also subjected to different types of loads. Stress concentrations usually occur at structural geometry discontinuities, e.g. weld toes, and crack-like defects. These stress concentration sites may serve for crack initiation and cracks that are propagating may lead to failure.

### 1.1 Tensile strength of structural steel

Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is the opposite of compressive strength and the values can be quite different.

Some materials will break sharply, without deforming, in what is called a brittle failure. Others, which are more ductile, including most metals, will stretch some - and for rods or bars, shrink or neck at the point of maximum stress as that area is stretched out. The UTS is usually found by performing a tensile test and recording the stress versus strain; the highest point of the stress-strain curve is the UTS.

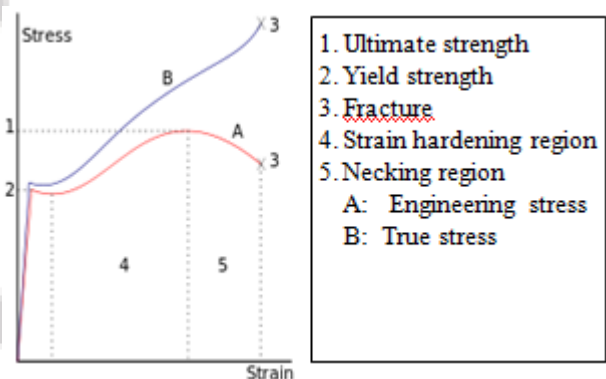


Figure 1: Stress vs. strain curve typical of structural steel

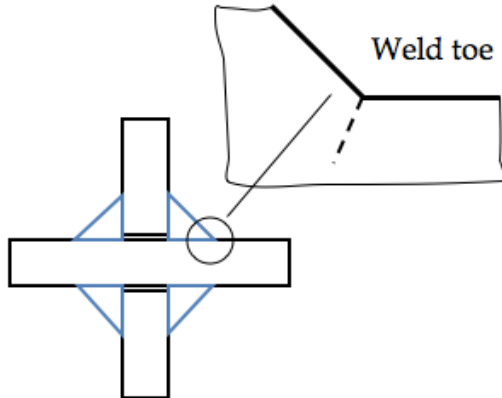
### 1.2 Compression strength of structural steel

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. It provides data (or a plot) of force vs. deformation for the conditions of the test method. When the limit of compressive strength is reached, brittle materials are crushed. Concrete can be made to have high compressive strength, e.g. many concrete structures have compressive strengths in excess of 50 MPa, whereas a material such as soft sandstone may have a compressive strength as low as 5 or 10 MPa. By contrast, a small plastic container might have a compressive strength of less than 250 MPa. By definition, the compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained

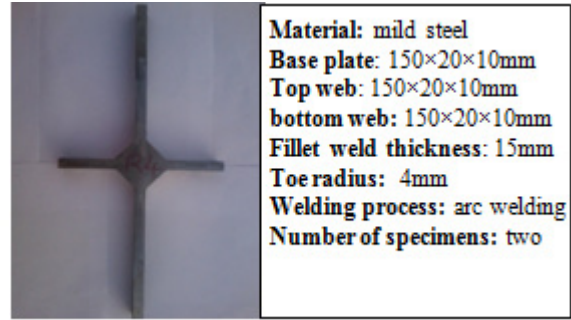
experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally.

**1.2 Weld toe radius**

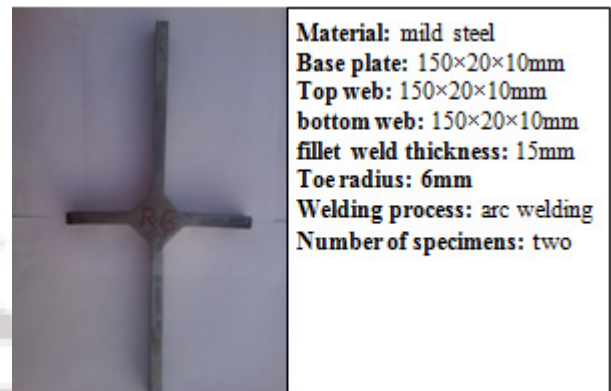
Weld toe radius is the radius which joining the fillet weld and base metal.



**Figure 2:** Weld toe of cruciform shape fillet weld joint



**Figure 3:** Specimen 1 and configuration



**Figure 4:** Specimen 2 and configuration

The objectives of this paper are as follows:

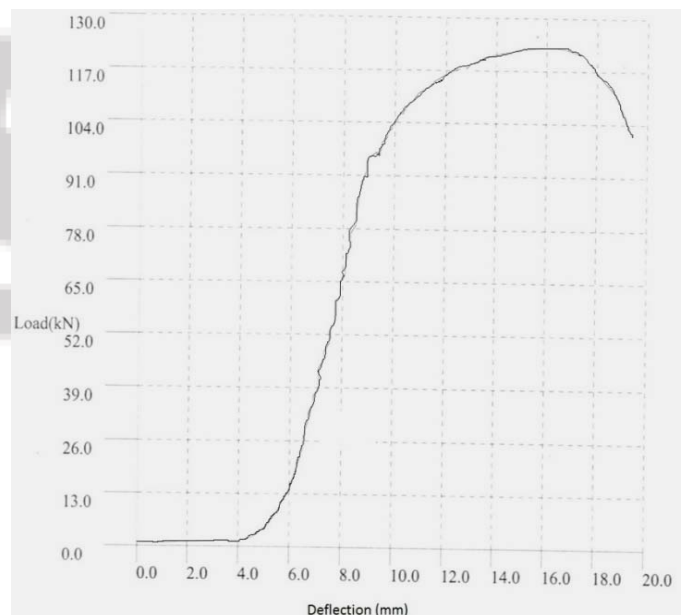
- Analysis and compare the effect of weld toe radius on tensile strength of fillet weld joints and validate the result by experimentally
- Analysis and compare the effect of weld toe radius on compressive strength of fillet weld joints and validate the result by experimentally

**2. Specimen details for tensile and compressive testing**

Figure 3 shows the specimen 1 for tensile and compressive testing. Figure 4 shows the specimen 2 for tensile and compressive testing. There are two number of specimens are prepared according to specimen 1 specification. Similarly there are two number of specimens are prepared according to specimen 2 specification. Specimen 1 configuration contains mainly three metal pieces. First one is the base metal. Which is of dimension 150x20x10 mm. Second one is the top web and third one is the bottom web. Top web and bottom web are of same dimension as that of base metal. After placing base metal, top web, bottom web in correct position, arc welding is carried out .Fillet thickness has given is 15mm.Specimen thickness, fillet thickness are given according to ASME quality welding fillet procedure. In specimen 1, 4mm toe radius is given by using end mill. Specimen 2 is of same configuration as that of Specimen1.But in specimen 2, 6mm toe radius is given by using end mill.

**3. Experimental tensile testing of specimen 1 and 2**

Tensile testing was carried out in UTM with digital controller. Machine model is TUE-400(c). Result for tensile test for specimen is given below. Tensile test is carried out till the specimen broke. When we are applying load from 0kN to top, yielding start at 95.76kN. Corresponding deflection is 9.1mm. Maximum load attained is 122.68kN. Deflection corresponding to maximum load is 15.9mm. Load at break point is 101.2kN. Ultimate tensile strength attained is 607.33N/mm<sup>2</sup>. Yield stress is 474.06N/mm<sup>2</sup>.



**Figure 5:** Load-deflection diagram for specimen 1 for tensile test

Maximum load = 122.68kN  
 Deflection at maximum load = 15.9mm  
 Load at yield point = 95.76kN  
 Deflection at yield point = 9.1mm  
 Load at breaking point = 101.20kN  
 Tensile strength =  $\sigma_t = F/A_o$   
 where F = Maximum load  
 $A_o$  =original cross sectional area  
 =  $(122.68 \times 10^3)/200$   
 = 607.33N/mm<sup>2</sup>  
 Yield stress =  $\sigma_y = F_1/A_o$   
 Where F<sub>1</sub>= Yield load  
 =  $(95.76 \times 10^3)/200$   
 =474.06N/mm<sup>2</sup>

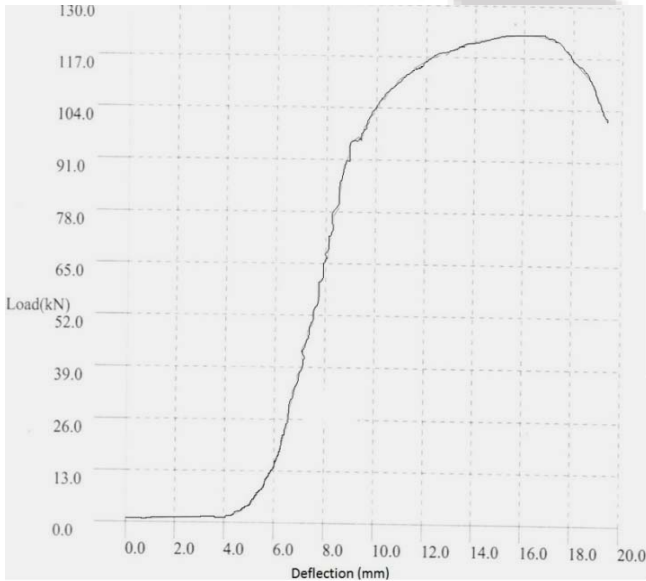


Figure 6: Load-deflection diagram for specimen 2 for tensile test

Maximum load = 119.32 kN  
 Deflection at maximum load= 11.4 mm  
 Load at yield point = 95.88kN  
 Deflection at yield point = 6.8 mm  
 load at breaking point = 106.84 kN  
 Deflection at breaking point= 14mm  
 Tensile strength=  $\sigma_t = F/A_o$   
 where F = Maximum load  
 $A_o$  =original cross sectional area  
 =  $(119.32 \times 10^3)/200$   
 = 585.48N/mm<sup>2</sup>  
 Yield stress =  $\sigma_y = F_1/A_o$   
 Where F<sub>1</sub>= Yield load  
 =  $(95.76 \times 10^3)/200$   
 = 470.46N/mm<sup>2</sup>

#### 4. Experimental compression testing of specimen 1 and 2

Compression testing was carried out in UTM with digital controller. Machine model is TUE-400(c). Result for compression test for specimen1 is given below. Compression test is carried out till the specimen start bending. When we are applying load from 0kN to top. Maximum load obtained is 53.64 kN. Corresponding deflection is 1.8mm. Compression strength obtained is 269.41N/mm<sup>2</sup>.

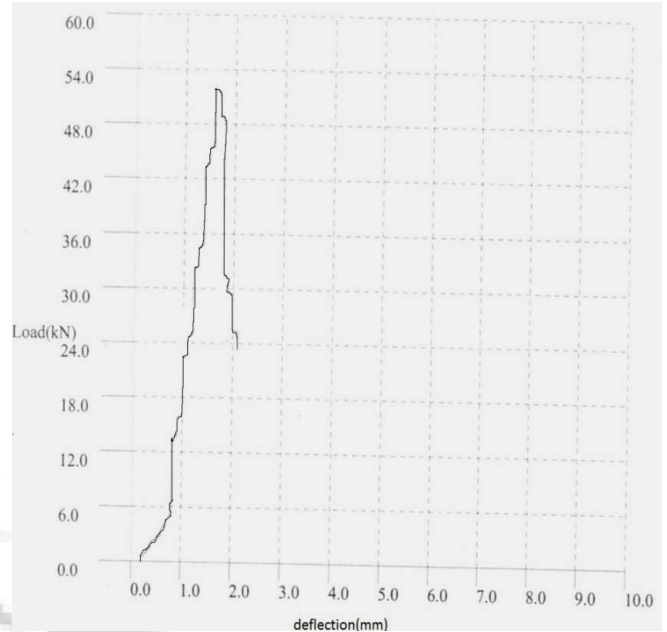


Figure 7: Load-deflection diagram for specimen 1 for compression test

Maximum load= 53.64kN  
 Deflection = 1.8mm  
 Compression strength =  $\sigma_c = F/ A_o$   
 Where F = Maximum load = 53.64kN  
 $A_o$  =original cross sectional area = 200mm<sup>2</sup>  
 =269.41N/mm<sup>2</sup>

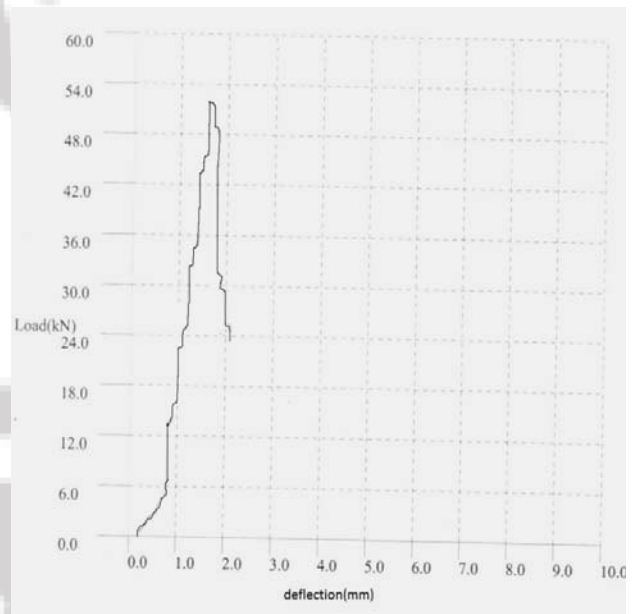


Figure 8: Load-deflection diagram for specimen 2 for compression test

Maximum load= 52.04 kN  
 Deflection = 1.6 mm  
 Compression strength =  $\sigma_c = F/A_o$   
 where F = Maximum load = 52.04kN  
 $A_o$  =original cross sectional area = 200mm<sup>2</sup>  
 =260.72N/mm<sup>2</sup>

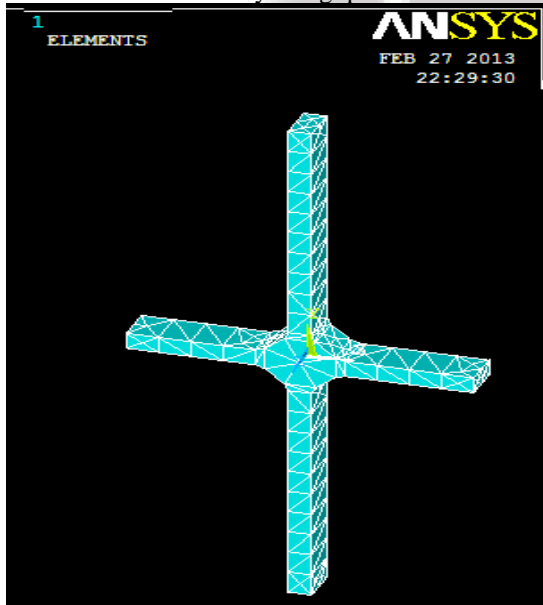
**5. Analysis of tensile and compression strength by ANSYS**

**Table 1: Analysis Criteria**

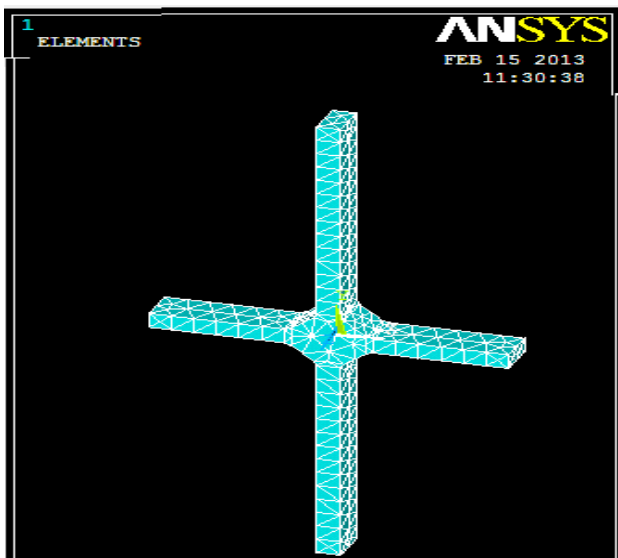
Element type	Solid tet 10 node 187 element
Type of mesh	Quadratic
Type of load applied	Pressure load
Load applied at	Top side of cruciform fillet weld joint
Boundary condition	Bottom end of cruciform fillet weld joint fixed
Type of stress applied	Von misses stress

Here specimen shape is cruciform shape fillet weld joint. Here element type used is solid 10 node 187 element. Type of mesh used is quadratic mesh. Type of load applied is pressure load. Here load applied at top side of cruciform fillet weld joint. Boundary condition is bottom end of cruciform shape fillet weld joint fixed. Type of stress applied is von misses stress.

Specimen 1 and 2 meshed by using quadratic element mesh

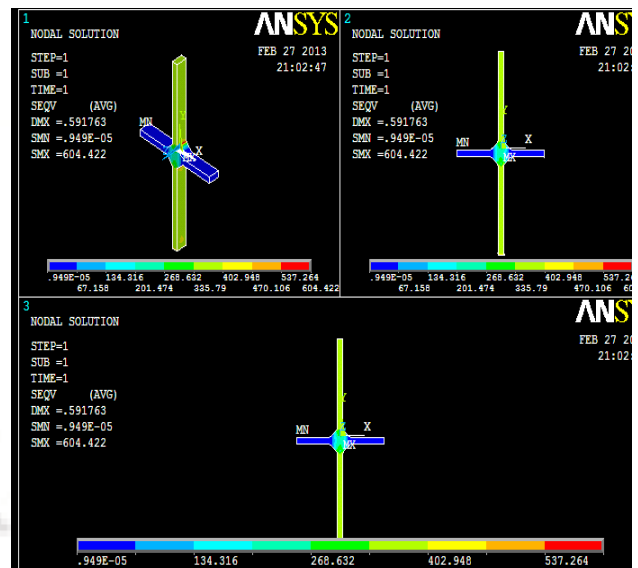


**Figure 9: Meshed view of specimen 1**



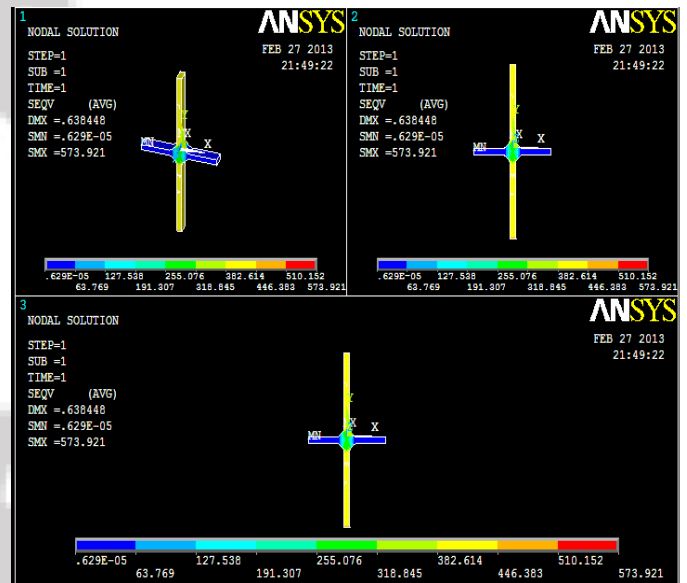
**Figure 10: Meshed view of specimen 2**

**6. Analysis of maximum stress under tensile load for specimen 1 and specimen 2**



**Figure 11: Analysis of maximum stress under tensile load for specimen 1**

In ANSYS tensile load is applied from 0 kN to more load .At 122 kN ,maximum stress is obtained .Which is equal to 604.422 N/mm<sup>2</sup>.This value is more closer to experimental value.So this result is experimentally validated.



**Figure 12: Analysis of maximum stress under tensile load for specimen 2**

In ANSYS tensile load is applied from 0 kN to more load .At 119 kN, maximum stress is obtained .Which is equal to 573.921 N/mm<sup>2</sup>.This value is more closer to experimental value. So this result is experimentally validated



### 7. Analysis of maximum stress under compressive load for specimen 1 and specimen 2

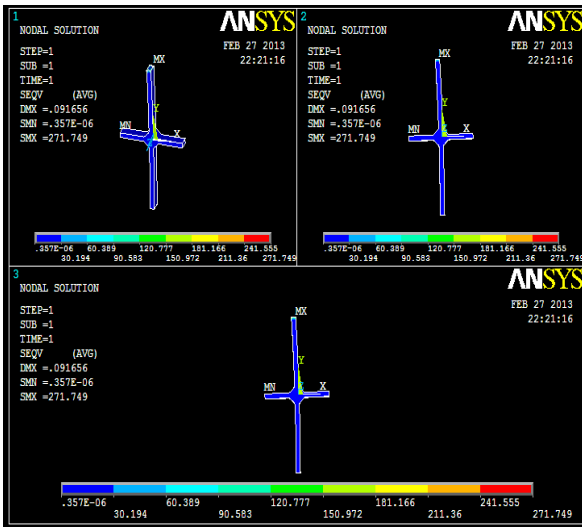


Figure 13: Analysis of maximum stress under compressive load for specimen 1.

In ANSYS compressive load is applied from 0 kN to more load .At 53.64 kN, maximum stress is obtained .Which is equal to 271.749 N/mm<sup>2</sup>.

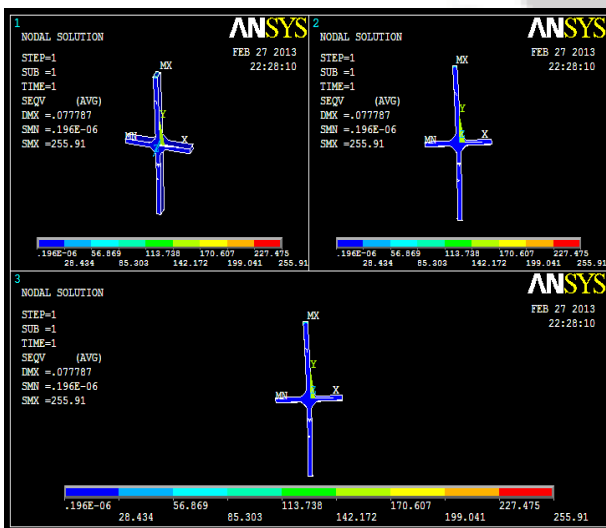


Figure 14: Analysis of maximum stress under compressive load for specimen 2.

In ANSYS compressive load is applied from 0 kN to more load .At 52 kN, maximum stress is obtained .Which is equal to 255.91 N/mm<sup>2</sup>.This value is more closer to experimental value. So this result is experimentally validated.

### 8. Results and Discussion

Table 2: Tensile test result comparison of specimens 1 and 2 by experiment

S. No.	specimens no.	Max load (kN)	Deflection (mm)	Maximum stress (compression strength) N/mm <sup>2</sup>
1	Toe radius 4mm	53.64	1.8	269.41
2	Toe radius 6mm	52.04	1.6	260.72

By using universal testing machine, tensile test is conducted for two cruciform shape fillet weld joints. Here first specimen can withstand more load compare to second specimen. Tensile strength and yield strength more in first specimen. So when toe radius increases, tensile strength increases in experimentally.

Table 3: Tensile test result comparison of specimens 1 and 2 by ANSYS

S. No	Specimen no.	Maximum applied load (kN)	Maximum stress(N/mm <sup>2</sup> )
1	Toe radius 4mm	53.64	271.749
2	Toe radius 6mm	52.04	255.91

By experimentally in tensile analysis, maximum stress for specimen1 (toe radius 4mm) was found out and which is equal to 607.33 N/mm<sup>2</sup>.Corresponding load is 122.68 kN .So in ANSYS, load applied from 0 to 122.68 kN. At 122.68kN, maximum stress obtained is 607.33 N/mm<sup>2</sup> .Similarly maximum stress for specimen2 (toe radius 6 mm) was found out and which is equal to 585.48 N/mm<sup>2</sup>.Corresponding load is 119.68 kN .So in ANSYS, load applied from 0 to 119.68 kN. At 119.68kN, maximum stress obtained is 573.921 N/mm<sup>2</sup>.

Table 4: Compression test result comparison of Specimens 1 and 2 by experimentally

S. No.	Specimens no.	Maximum load (kN)	Tensile strength (N/mm <sup>2</sup> )
1	Toe radius 4mm	122.68	607.33
2	Toe radius 6mm	119.68	585.48

By using universal testing machine, compression test was conducted for two cruciform shape fillet weld joints. Here first specimen can withstand more load compare to second specimen. The compression strength is more in first specimen. So when toe radius increases, compression strength decreases in experimentally.

Table 5: Compression test result comparison of Specimens 1 and 2 by ANSYS

S.No.	Specimen no.	Maximum applied load (kN)	Maximum stress (N/mm <sup>2</sup> )
1	Toe radius 4mm	122.68	604.422
2	Toe radius 6mm	119.32	573.921

By experimentally in compression analysis, maximum stress for specimen1 (toe radius 4mm) was found out and which is equal to 269.41 N/mm<sup>2</sup>.Corresponding load is 53.64 kN .So in ANSYS, load applied from 0 to 53.64 kN. At 53.64 kN, maximum stress obtained is 271.749N/mm<sup>2</sup> .Similarly maximum stress for specimen2 (toe radius 6 mm) was found out and which is equal to 260.72 N/mm<sup>2</sup>.Corresponding load is 52.04 kN .So in ANSYS, load applied from 0 to 52.04 kN. At 52.04 kN, maximum stress obtained is 255.91N/mm<sup>2</sup>.

### 9. Conclusion

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.

## References

- [1] Tolga Mert.(2009) 'Finite Element Analysis of Effect of Weld Toe Radius and Root Gap on Fatigue Life of T-Fillet Welded Joint', Conference of the International Journal of Arts and Sciences pp. 119 – 127
- [2] Caccese V. and Blomquistb P.A.(2006) 'Effect of weld geometric profile on fatigue life of cruciform welds made by laser/GMAW processes', Marine Structures Vol.19
- [3] Wenchun Jiang.(2010) 'A study of the effect of filler metal thickness on tensile strength for stainless steel plate-fin structure by experiment and finite element method', Materials and Design Vol.31, pp. 2387–2396
- [4] Kanvinde A.M.(2009) 'Strength and ductility of fillet welds with transverse root notch', Journal of Constructional Steel Research Vol.65, pp.948-958.
- [5] Biehn Baik and Kentaro Yamada.(2011) 'Fatigue crack propagation analysis for welded joint subjected to bending', International Journal of Fatigue Vol. 33, pp. 746–758
- [6] Khurshid M. and Mumtaz N.A.(2012) 'Ultimate strength and failure modes for fillet welds in high strength steels', Materials and Design Vol.40, pp. 36–42
- [7] Wenchun Jiang and Jianming Gong.(2010) 'A study of the effect of filler metal thickness on tensile strength for a stainless steel plate-fin structure by experiment and finite element method', Materials and Design Vol.31, pp.2387–2396
- [8] Lip H. Teh and Kim J.R. Rasmussen.(2007) 'Strength of arc-welded T-joints between equal width cold-formed RHS', Journal of Constructional Steel Research Vol.63, pp. 571–579
- [9] Rafael Pico and Jose Canas.(2009) 'On strength criteria of fillet welds', International Journal of Mechanical Sciences Vol.51, pp. 609–618
- [10] J Mashiri F.R., Zhao X.L., Grundy.P.(2001) 'Effects of weld profile and undercut on fatigue crack propagation life of thin-walled cruciform joint', Thin Walled Structures Vol.39, pp. 261–285
- [11] Partanen T.(2001), 'Finite element analysis of effect of weld geometry and load condition on fatigue strength of lap joint', International journal of pressure vessels and piping Vol.78, pp.591-597
- [12] Myung Hyun Kim , Sung Won Kang , Jeong Hwan Kim.(2010) 'An experimental study on the fatigue strength assessment of longi-web connections in ship structures using structural stress', International journal of fatigue Vol.32, pp.318-329.
- [13] Fourlaris G., Ellwood R., Jones T.B.(2007) 'The reliability of test results from simple test samples in predicting the fatigue performance of automotive components', Materials and design Vol.28, pp.1198-1210.
- [14] Lin S.H, Pan J., Wung P.(2006) 'A Fatigue crack growth model for spot welds under cyclic loading conditions', International journal of Fatigue Vol.28, pp.792-803

## Author Profile



**Sinjo Jose .V** received the Mechanical Engineering degree from Calicut University in 2010 and ME in Engineering Design from Anna University Chennai in 2013. He now is working as a assistant professor in Jawaharlal college of engineering and technology, Kerala under Calicut university.