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Mechanical Behavior of Double Fillet Weld using Finite Element Modeling

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Abstract*: Welding is one of the most important phenomena required in day to day activities like construction, machining, etc. Therefore, it becomes important to choose optimal parameters for its process since non-efficient selection of its parameter can result in failure of activities it is associated with. Studies show that stress concentration zones, are those where maximum stress is generated. In case of welding, these zones are weld root and weld toes. In order, to get accurate results fine meshing becomes necessary. In the current study, a 3-D structure i.e., two perpendicular plates are connected to a reclining plate by welding, precisely fillet weld. Finite element analysis has been conducted on the above-mentioned structure. Mechanical behavior has been studied for various values of fillet radius and load values. Fillet radius and load (on right as well as left hand side) has been varied from 3mm-9mm, with a difference of 2mm and 100N-10000N, in the multiple of 10N respectively. Continued increase in load, in turn, accelerates the stress, in the weld root and toes. The relation between stress, strain and total deformation with fillet radius is inversely proportional.

***Keywords*: double fillet weld; finite element, stress; strain.**

I. INTRODUCTION

Welding is the principal method used for joining two metals; they can either be structure's, machine's, equipment's or bridge's. Weld root and toes are the essential parts of any welding assembly, since these are the points where utmost amount of failure and stress occurs. In welding two parts of metal are joined together by the employment of fusion or localized heat. This process can be achieved either with or without the application of filler material or pressure. Finite element analysis is an elite method which helps engineers to develop a weld joint that can withstand the poorest of conditions. Welding has numerous applications like, regenerating or fusing two broken or ripped parts to make material homogenous through the section.

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Joints and welds are of different types. They are classified on the basis of mating parts geometry. Joints are of five types; namely, butt, corner, t, lap or edge. Weld on the other hand can be divided into two types i.e., butt and fillet. Fillet weld again can be divided into two types: longitudinal and transverse. Geometry of the weld is shown in Fig 1, it consists of face, root, toes and throat.

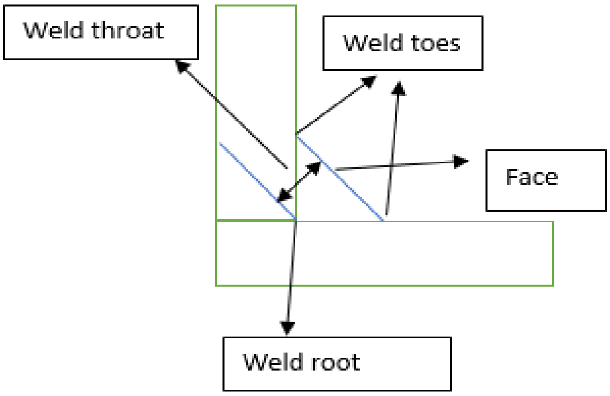


Fig. 1. Geometry of fillet weld

II. LITEREATURE REVIEW

da Silva et al [1], conducted a study to determine the influence of fillet end geometry on fatigue behavior of welded joints. They considered four arrangements of welded joints and implemented on them numerical examination by using FEM and XFEM. Khoshroyan et al [2], studied the circulation of temperature and afterward the appropriation of residual stress and contortion in the solidified aluminum alloy AI 6061-T6 plates under the metal inert gas [MIG] welding process were examined by 3-D thermo-mechanical coupled FEM utilizing ANSYS programming. The outcomes demonstrated that speed up diminished the vertical avoidance in the plate, transverse shrinkage and precise twisting of plate and the horizontal redirection of stiffener yet extended the most extraordinary longitudinal tensile stress in the plate and stiffener.
Krejsa. et al [3], study deals with the numerical modelling of steel fillet welded joints. The principle points of the study were structuring and characterizing of tried examples for numerical modelling dependent on FEM examination and utilizing the program ANSYS. Introduced approach speaks to proficient calculation of strain investigation of steel supporting components utilizing trial acquired information.
Meneghetti et al [4], presented a research on utilizations of the PSM pertinent to steel welded joints under uniaxial just as multi-axial fatigue loadings.

On account of generally coarse FE investigations required and straight forwardness of post-preparing the determined pinnacle stresses, PSM may be helpful in the regular design practice.

Ramos et al [5], examined joint welded setups, considering arc & laser beam welding.

Hence, the programming ESI SYSWELD were incorporated, since it is one of the most developed instruments. These models depend on limited components, along these lines, a mesh affectability investigation was acted so as to assess the base component size required for exact outcomes.

Sun et al [6], researched the mechanical conduct of transverse filet welded joints of HSS utilizing computerized picture connection procedures. Tousignant et al [7], performed FE displaying to widen the results of a starting late completed exploratory test program to evaluate thee static quality of filet welds in X-relationship between round empty areas (CHS). Nonlinear FE models with weld crack were affirmed by connection of spot strains, load mis-hapening reaction and weariness load with 12 tests. Yang. L et al [8], look into concentrated on the standard uniaxial tests drove on the round bar tests made of tempered steel and the contrasting weld metal. Th stress-strain bend of both the base metal and the relating weld metal were procured.

III. MODELING

The geometric modelling of fillet weld has been done and explained in this study. The model along with meshing which includes nodes and elements that are used represent the physical system is also discussed. Final analysis has been conducted after the generation of the model and application of the specific boundary conditions.

In this paper the modelling is done on ANSYS WORKBENCH 15.0. the designing procedure is as follows:

- Open ANSYS WORKBENCH 15.0. Double click on 'Static Structural' present in the toolbox, left-hand side of the appeared window.
- Now double click on geometry. A: Static Structural-Design Modeler window will appear.
- From the bar given on the left-hand side select 'Sketching' and draw the required geometry. The structure considered in this studied is shown in figure 2 with its dimensions. All four-fillet weld applied are of 5mm each.

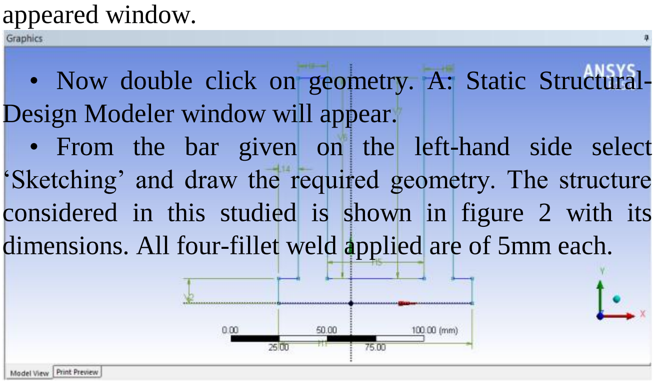
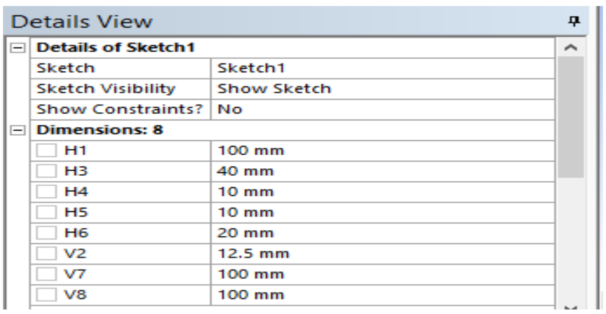


Fig. 2. Modeling done using ANSYS 15.0



Details View

Details of Sketch1	
Sketch	Sketch1
Sketch Visibility	Show Sketch
Show Constraints?	No
Dimensions: 8	
H1	100 mm
H3	40 mm
H4	10 mm
H5	10 mm
H6	20 mm
V2	12.5 mm
V7	100 mm
V8	100 mm

Fig. 3. Geometry and Dimensions

IV. MATERIAL PROPERTIES

The mechanical properties of steel are mentioned in Table 1 and physical properties are as follows:

- Steel possess eminent strength
- The material has subsided weight.
- The endurance of the material is high.
- Being an alloy, steel can be easily into wires or can be hammered into sheets without been broken.
- Unlike its base metal iron, steel can withstand the inflictions which are caused by oxidization.
- Similar to iron, steel too is an efficient transmitter of electricity.

Table 1: Mechanical Properties of Steel

Properties	Steel
Young's Modulus	$2x10^{11}$ Pa
Poisson Ratio	0.3
Tensile Strength	$4.6x10^{8}$ Pa
Density	7850 kg/m^3

The mechanical properties of epoxy are mentioned in Table 2 and the physical properties are as follows:

- Epoxy possess elevated toughness.
- Epoxy has a lower probability of depletion which can occur in adhesive systems due to heat.
- It retains excellent adhesiveness to different substrates.
- The electrical segregation of epoxy is efficient.
- Epoxy is resistant to various chemicals and solvents.
- It is non-lethal and comparatively inexpensive.

Table 2: Mechanical Properties of Epoxy

Properties		Epoxy
Young's Modulus	Longitudinal	$7x10^{10}$ Pa
	Transverse	$7x10^{10}$ Pa
Poisson Ratio		0.23
Tensile Strength	Longitudinal	$6x10^{8}$ Pa
	Transverse	$6x10^{8}$ Pa
Density		1600 kg/m^3

V. BOUNDARY CONDITIONS

Following are the boundary conditions considered in the current study.

- Tension force is applied on both sides of the horizontal plate.
- Both vertical plates are kept fixed.
- In the present paper, to monitor the effects of different material on generation of stress, strain and total deformation, Steel and Epoxy have been considered.

VI. RESULT AND DISCUSSIONS

A. *Outcomes of Loading Condition*

In order to examine the outcomes of the loading conditions 5mm radius of fillet is taken into consideration. The estimates of the load have been differed. It can be deferred from the tables 3 and 4 that with rise in the load estimates, the measure of strain, stress and total deformation caused in the weld area too rises.

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Table 3: Stress, Strain and Total Deformation for Steel at different loading conditions

Tensile Load N		Stress MPa	Strain mm/mm	Total Deformation
Left	Right	Max	Max	Max
100	100	0.160	$8.248\text{x}10^{-7}$	$3.534\text{x}10^{-5}$
100	1000	1.636	$8.433\text{x}10^{-6}$	$3.647\text{x}10^{-4}$
1000	100	1.636	$8.433\text{x}10^{-6}$	$3.647\text{x}10^{-4}$
1000	1000	1.600	$8.258\text{x}10^{-6}$	$3.534\text{x}10^{-4}$
10000	10000	17.39	$8.768\text{x}10^{-5}$	$3.786\text{x}10^{-3}$

Table 4: Stress, Strain and Total Deformation for Epoxy for different loading conditions

Tensile Load N		Stress MPa	Strain mm/mm	Total Deformation
Left	Right	Max	Max	Max
100	100	0.1566	$1.866\text{x}10^{-9}$	$8.127\text{x}10^{-8}$
100	1000	1.6732	$1.991\text{x}10^{-8}$	$8.374\text{x}10^{-7}$
1000	100	1.6732	$1.991\text{x}10^{-8}$	$8.374\text{x}10^{-7}$
1000	1000	1.566	$1.866\text{x}10^{-8}$	$8.127\text{x}10^{-7}$
10000	10000	18.058	$2.147\text{x}10^{-7}$	$8.677\text{x}10^{-6}$

B. *Effect of Fillet Radius*

Set 4 is chosen to see the effect of change in fillet radius. The estimates considered are 3mm, 5mm, 7mm and 9mm. Table 5 shows the assessment of the stress, strain and total deformation devised for steel.

Table 5: Stress, Strain & Total Deformation for steel (1000N & 1000N)

Load (Tensile)	Stress (MPa))	Strain (mm/mm)	Total Deformation
Value	Max	Max	Max
3mm	1.9603	$9.8607\text{x}10^{-6}$	$3.5548\text{x}10^{-4}$
5mm	1.6	$8.2581\text{x}10^{-6}$	$3.5344\text{x}10^{-4}$
7mm	1.5411	$7.9778\text{x}10^{-6}$	$3.5213\text{x}10^{-4}$
9mm	1.4563	$7.4658\text{x}10^{-6}$	$3.5057\text{x}10^{-4}$

Figure 4-15 shows stress, strain & total deformation results for all fillet radius measured in the present study. The material for the aforementioned figures is steel. Figure 16-18 gives a better perspective to study the effect of fillet radius on stress, strain total deformation caused by similar loading condition. It is quite easy to infer that with rise in the fillet radius, the measure of mechanical behaviour caused on the fillet weld decreases.

To study outcome of fillet radius 1000 N and 1000 N has been taken into account and estimates of fillet radius has been differed from 3mm and 9mm. Table 6 depicts the estimates of the stress, strain, total deformation generated for epoxy.

Figures 19-21 are the graphical representation of quantity of stress, strain, total deformation developed in the fillet weld made of epoxy. Figure 19 depicts an analogy of the stress developed in the fillet weld made of steel and epoxy. It has been concluded that with gain in the fillet radius quantity of stress generated in the fillet weld (epoxy) declines by great amount when compared to the fillet weld (steel).

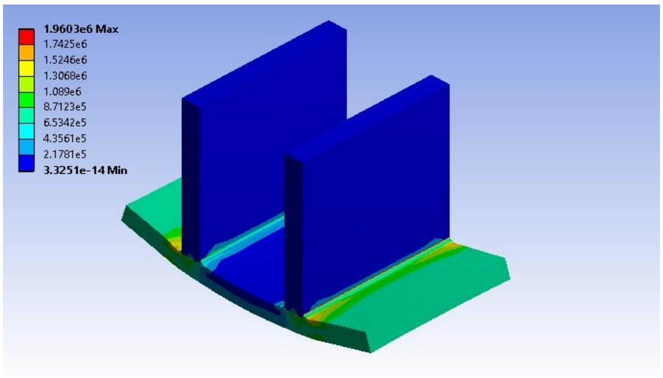

Fig. 4: Von-mises stress on 3mm fillet radius under load of 1000N & 1000N.

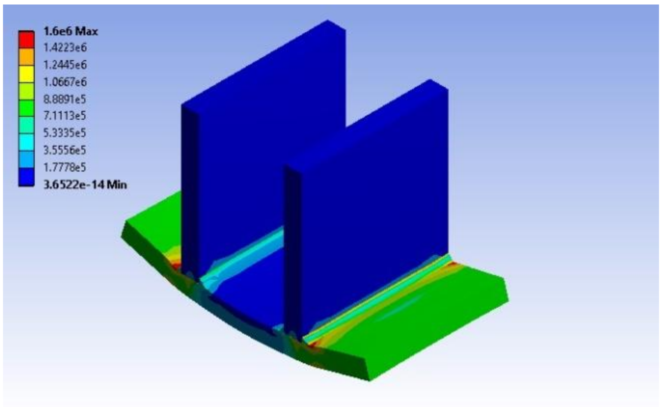

Fig. 5: Von-mises stress on 5mm fillet radius under load of 1000N & 1000N.

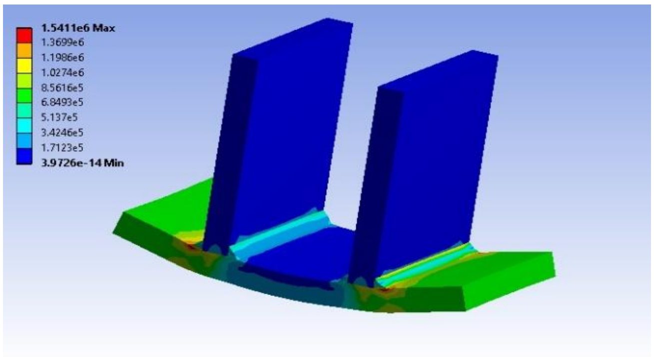

Fig. 6: Von-Mises stress on 7mm fillet radius under load of 1000N & 1000N.

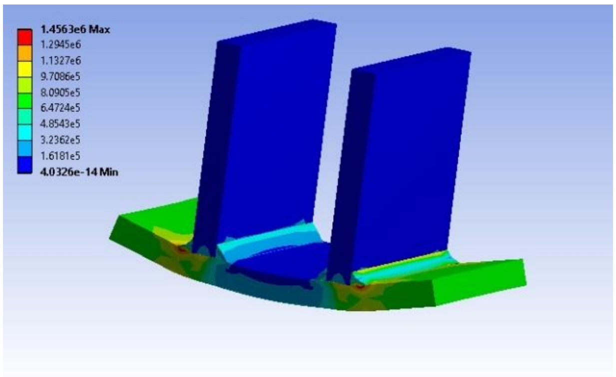

Fig. 7: Von-mises stress on 9mm fillet radius under load of 1000N & 1000N.

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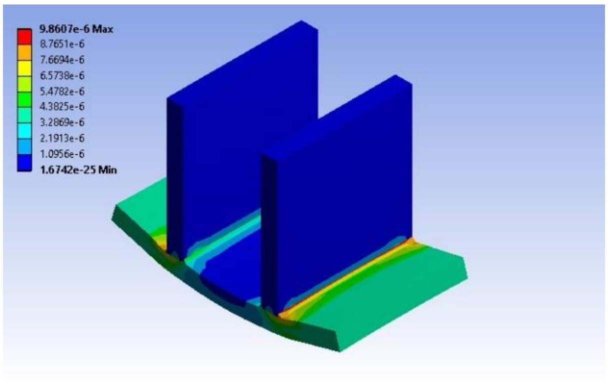

Fig. 8: Von-mises strain on 3mm fillet radius under load of 1000N & 1000N.

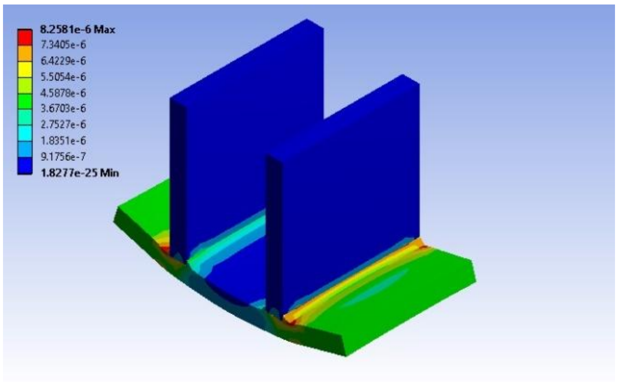

Fig. 9: Von-mises strain on 5mm fillet radius under load of 1000N & 1000N.

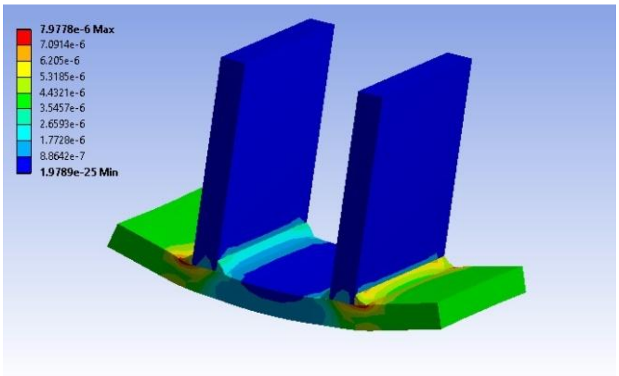

Fig. 10: Von-mises strain on 7mm fillet radius under load of 1000N & 1000N.

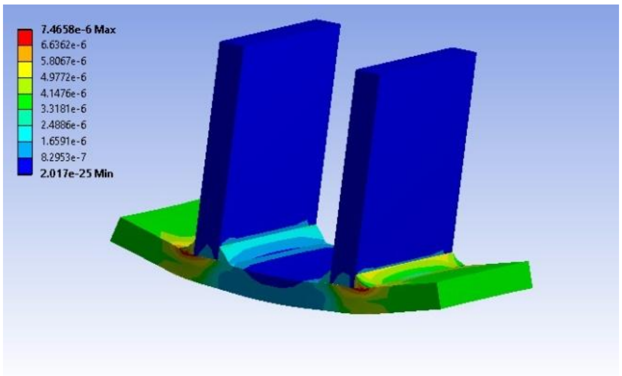

Fig. 11: Von-mises strain on 9mm fillet radius under load of 1000N & 1000N.

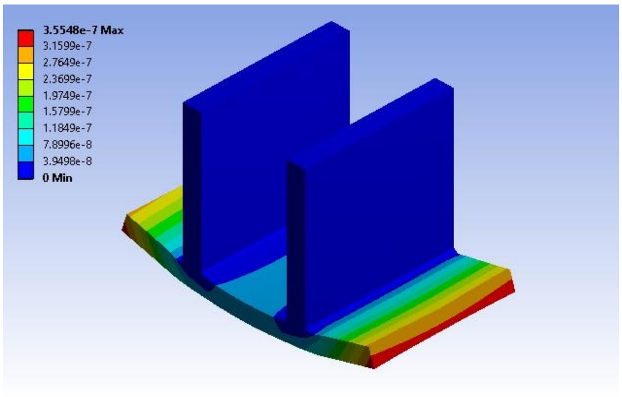

Fig. 12: Total deformation on 3mm fillet radius under load of 1000N & 1000N.

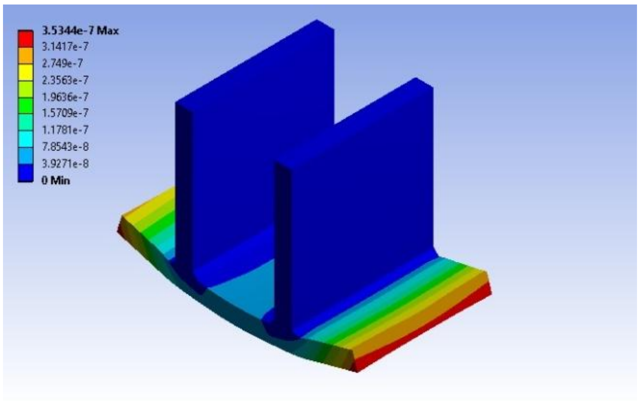

Fig. 13: Total deformation on 5mm fillet radius under load of 1000N & 1000N.

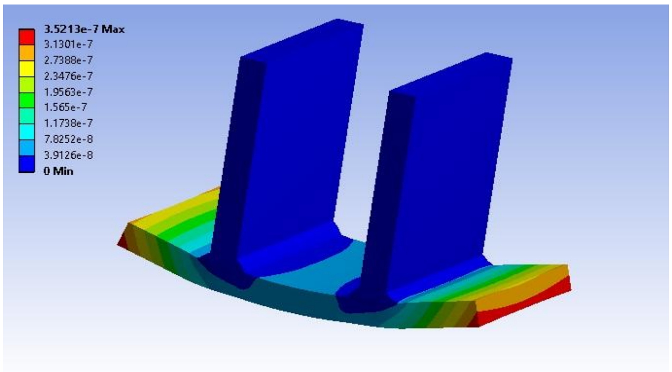

Fig. 14: Total deformation on 7mm fillet radius under load of 1000N & 1000N.

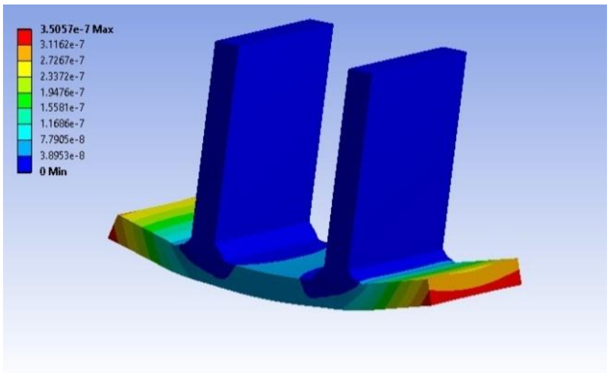

Fig. 15: Total deformation on 9mm fillet radius under load of 1000N & 1000N.

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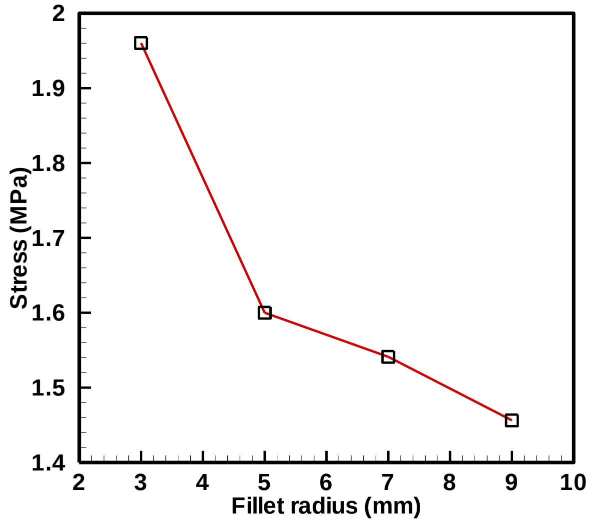

Fig.16: Stress vs Fillet Radius

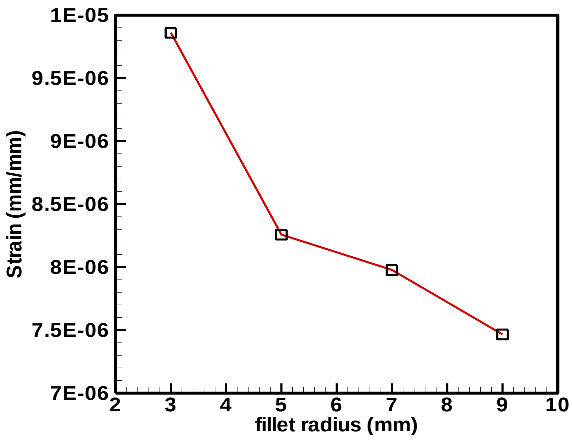

Fig. 17: Strain vs Fillet Radius

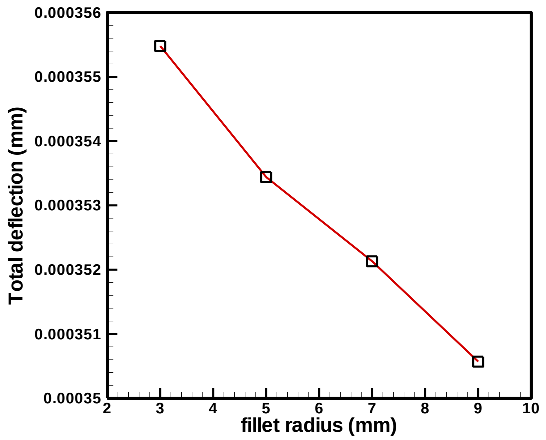

Fig. 18: Total deformation vs Fillet radius

Table 6: Stress, Strain, Total deformation for Epoxy (1000N & 1000N)

Load	Stress (MPa)	Strain (mm/mm)	Total Deformation
Value	Max	Max	Max
3mm	2.0326	2.4082×10^{-8}	8.1773×10^{-7}
5mm	1.5657	1.8661×10^{-8}	8.127×10^{-7}
7mm	1.484	1.8058×10^{-8}	8.0995×10^{-7}
9mm	1.4031	1.6945×10^{-8}	8.0696×10^{-7}

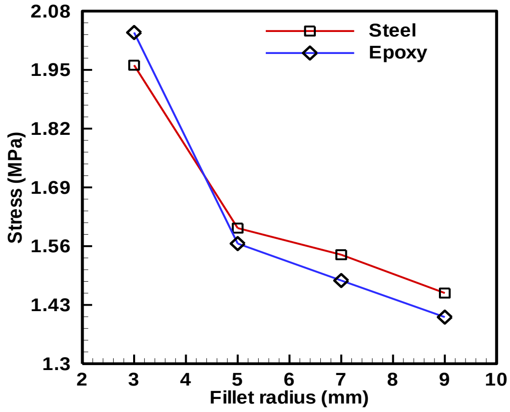

Fig. 19: Evaluation of Stress for steel & epoxy with fillet radius

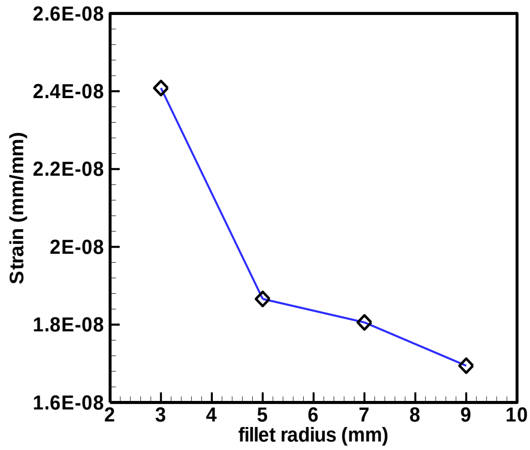

Fig. 20: Strain vs fillet radius for Epoxy material

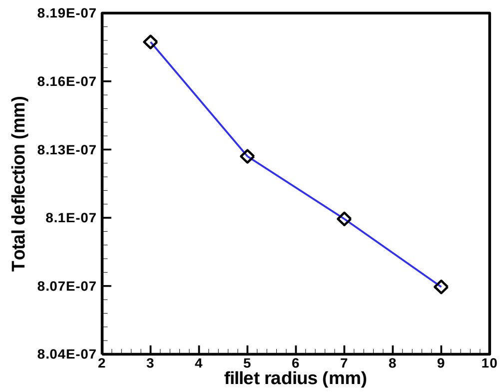

Fig. 21: Total deformation vs Fillet radius for Epoxy

VII. CONCLUSION

The following points can be concluded from various results, and observations:

Stress, strain and deformation generated on weld toes and root areas has been analysed and discussed. Materials considered are steel and epoxy. Out of the two it can be concluded that epoxy is the better one because of its less weight and good load bearing quality.

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Fillet weld radii varying from 3mm to 9mm by a difference of 2mm has been considered. As well as changing of load applied on both sides of horizontal plates has been done. From tables 5 and 6 it can be concluded that stress, strain and deformation reduce continuously with increase in fillet radius. From tables 3 and 4 it can be concluded that stress, strain and deformation all increase continuously with increment in load. The above two conclusions hold true for both steel and epoxy.

VIII. FUTURE SCOPE OF WORK

The following future scope of work can be performed. Experiments can be conducted for the cases considered in the present work to get actual physical results. Inclusion of other materials to see their effects can also be done in future. Fatigue testing along with increasing the mesh element size can also be done to obtain better results.

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