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Effect of Fillet Radius on Stress Generated in Double Fillet Weld Root and Toe

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Abstract: FEA (Finite element analysis) of the stress generated in the double fillet weld joint has been conducted for different fillet radius values. Fillet weld considered in the present study is three dimensional and have two-vertical plates which are attached to a horizontal plate by welding. Analysis of stress in the weld toes and weld root has been studied and shown. Five different sets of load values varying from 100N to 10000N have been considered on the left-hand side and right-hand side of the horizontal plate. Fillet radius has been varied from 3mm, 5mm, 7mm to 9mm to study its effect. Meshing is very important stages which affect the finite element results by a large amount. As meshing plays a good role in the FEA analysis, fine meshing near the weld toes and weld root has been adopted for accurate results. Study reveals that weld roots and toes are the zone where maximum amount stress developed which can also called as stress concentration zone. With increment in load stress generated in the weld toes and weld roots areas increases continuously. Total deformation increases with load. Increasing the fillet radius reduces the amount of stress and strain developed on the weld.

I. INTRODUCTION

Two parts joined together by application of localised heat or fusion is called a weld they joined together either with or without the pressure or filler material application. Amount of heat necessary for fusion is attained by burning of gas or an electric arc. Weld means joining of two metals by heat while joint means a point where two parts connects together they can be anything. Most vital components of a welding assembly are weld toe and weld roots where maximum amount of stress and failure occurs. It is practically impossible to have weld which have 100% efficiency.

Welding is a complex procedure which varies the weld joint physical, mechanical and chemical properties. They have numerous applications. For example like repairing or uniting the two broken or torn parts to make material homogeneous throughout the section. Goldak et al¹ in 1984 conducted their study on FEM of welding heat sources.

Goldak's new method has shown to be more accurate than previous methods such as the Pavelic² disc method, as well as the previously mentioned Rosenthal theory for heat distribution in welding. Michaleris et al³ in 1999 investigated the use of the thermal tensioning technique to reduce residual stress and distortion in welding. Barsoum and Lundback⁴ in 2009 conducted 2D and 3D FE simulation of fillet weld to study the residual stresses formation. Picon and Canas⁵ in 2009 studied about two strength criteria utilized for fillet welds ISO and Eurocode-3.

Aarbogh et al⁶ in 2010 conducted validation of FEM codes of welding deformation. Jose-V and Selvakumar⁷ in 2012 studied about the effect of fillet radius on tensile and compressive load for fillet weld joint. Tonkovic et al⁸ in 2012 conducted experimental and numerical modelling of T-type fillet weld joint process to study the residual stresses and distortion. Xiao et al⁹ in 2012 studied fatigue strength of transverse fillet weld under bending loads.

Tahami and Asl¹⁰ in 2013 conducted AISI 304 stainless steel T-shape fillet weld numerical and experimental investigation. Wang et al¹¹ in 2013 conducted temperature simulation and analysis of sleeve fillet weld used in multi-pass welding. Cerit et al¹² in 2014 conducted fillet weld fracture mechanism design and reliability assessment under tension and torsion loading condition of cylindrical fillet weld. Dutta and Narendranth¹³ studied the thermal cycle effect on the GTA high carbon steel weld joint with temperature dependent process parameter.

Krscanski and Turkalj¹⁴ developed stress concentration factor utilizing FEM for fillet weld of (Circular Hollow Section) CHS-plate T-joint. Lu et al¹⁵ in 2015 studied the fillet welds strength under transverse and longitudinal shear loading condition. Fu et al¹⁶ in 2016 studied the effect of welding sequence on the distortion and residual stress of fillet weld.

II. MODELLING

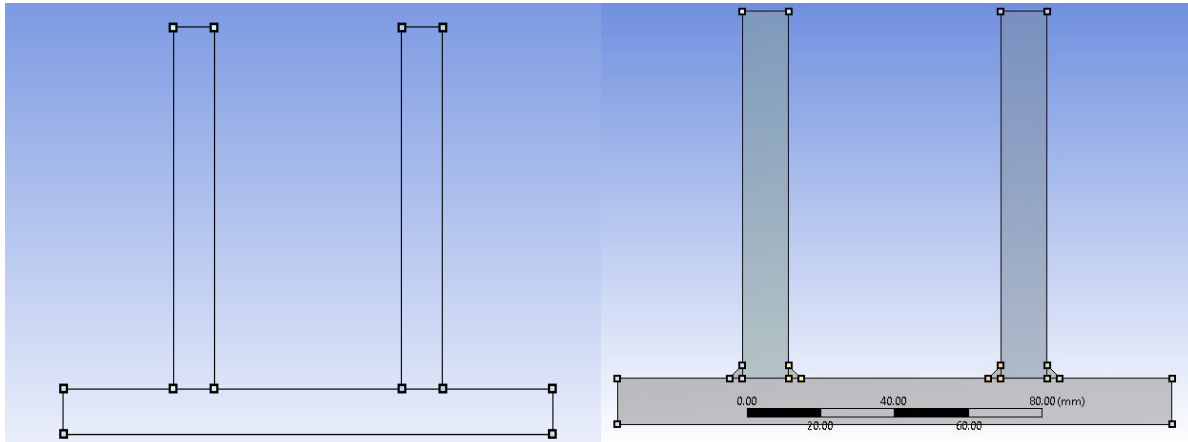


Figure 1 Weld with and without weld joints

III. MATERIAL PROPERTIES

Two different material steel and Epoxy has also been considered in the present study to see the effect of the material on the stress generation, strain generation and total deformation. Weight study has also been conducted in the present problem. Table 1 shows the mechanical properties of steel and Epoxy considered.

Table 1: Mechanical properties of steel

Properties	Steel	Epoxy
Young's modulus (E)	$2E^{11}$ Pa	$85E^{12}$ Pa
Poisson ratio	0.3	0.23
Tensile Ultimate strength	$4.6E^8$ Pa	$9 E^8$ Pa
Tensile yield strength	$2.5E^8$ Pa	1470 Pa
Density	7850 Kg/m^3	2160 Kg/m^3

IV. RESULT AND DISCUSSION

In this work effect of different loading conditions and fillet radius on the total deformation, equivalent von-mises stress and equivalent von-mises strain have been studied in detailed. Figure 2 shows the boundary condition applied on the fillet weld. On the right and left side of the horizontal plate tension force has been applied while vertical plates have been kept fixed.

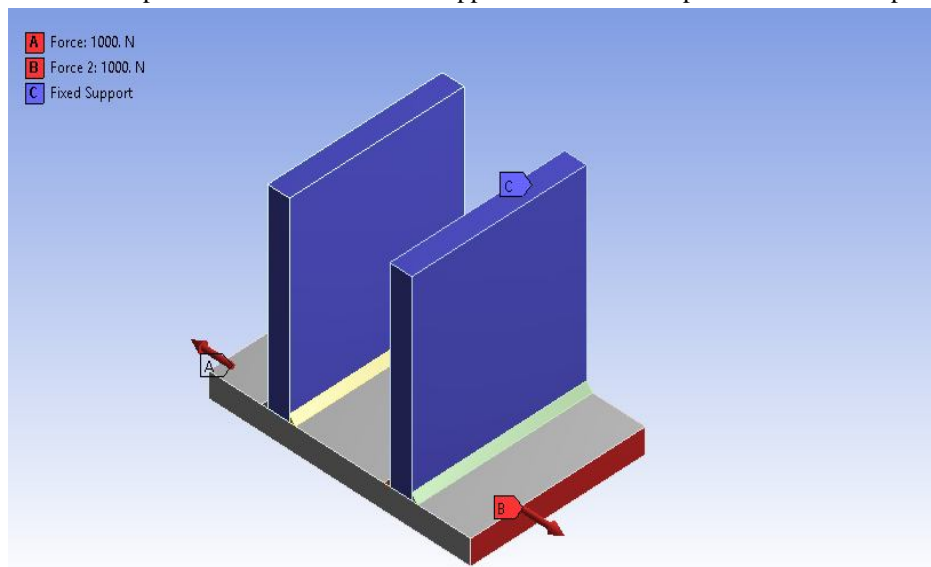


Figure 2: Boundary condition on fillet weld

Five different sets of load values varying from (100N to 10000N) have been considered on the left-hand side and right-hand side of the horizontal plate. Table 2 shows the five different set of loading values considered. Fillet weld radius has been varied from (3mm, 5mm, 7mm and 9mm) to see its effect on the stress generation, strain generation and total deformation.

Table 2: Loading values considered on the fillet weld

Set No.		1	2	3	4	5
Load (Tensile)	Left	100N	100N	1000N	1000N	10000N
	Right	100N	1000N	100N	1000N	10000N

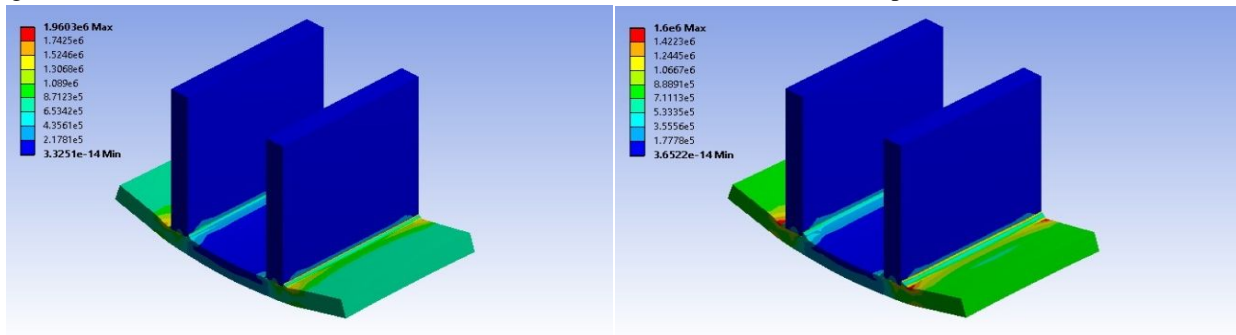
A. Effect of the fillet radius

To study the effect of the fillet radius set-4 (1000N and 1000N) has been considered and values of fillet radius has been varied from 3mm, 5mm, 7mm to 9mm. Table 3 shows the values of the stress, strain and total deformation developed for the steel material.

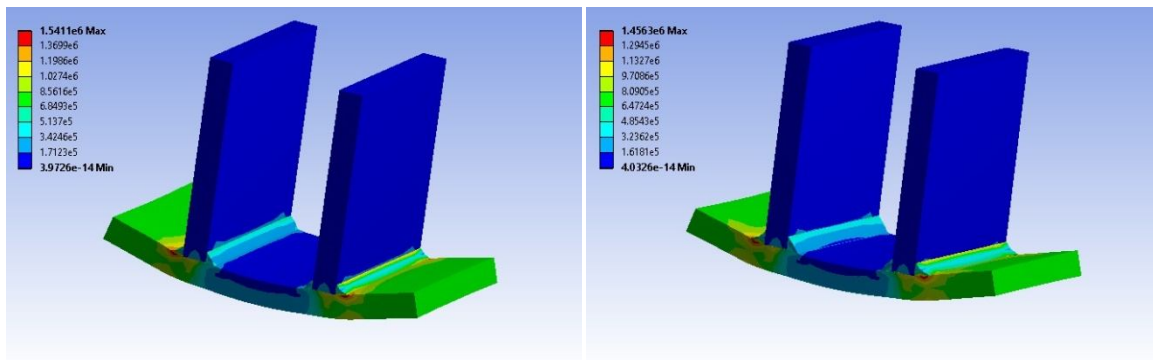
Table 3: Stress, strain and total deformation for steel under (1000N and 1000N) load

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

Figure 3, 4 and 5 shows the stress, strain and total deformation generated for all fillet radiuses considered in the present study. Steel as a material has been considered for these figures. Figure 6 to 8 represents a better view of studying the effect of fillet radius on the stress, strain and total deformation generated under the same loading condition. From the figures 6-8 it can be noticed that maximum munt of stress generated is near the weld are. It can be easily observed that with increment in the fillet radius or increasing the size of fillet reduces the amount of stress, strain and total deformation developed on the fillet weld.

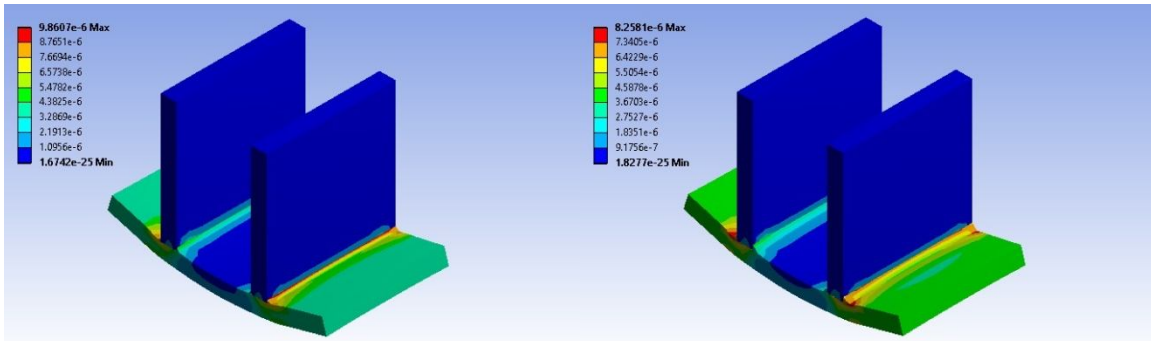


(a) 3mm fillet radius (b) 5mm fillet radius

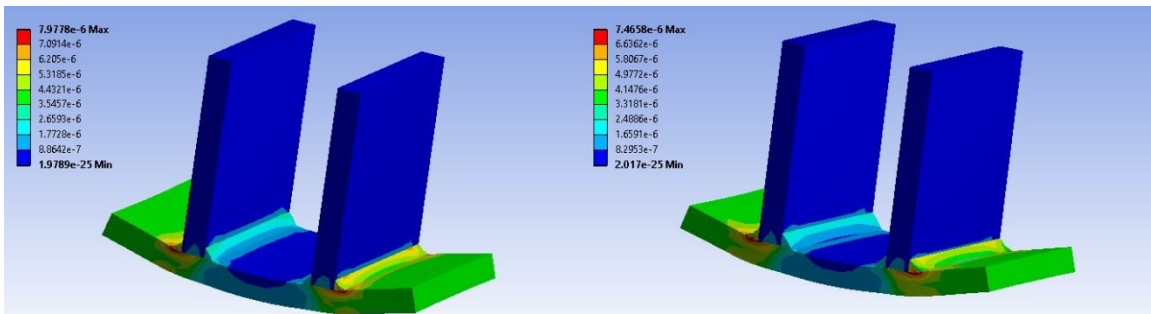


(c) 7mm fillet radius (b) 9mm fillet radius

Figure 3: Von-mises stress under the load of 1000N and 1000N

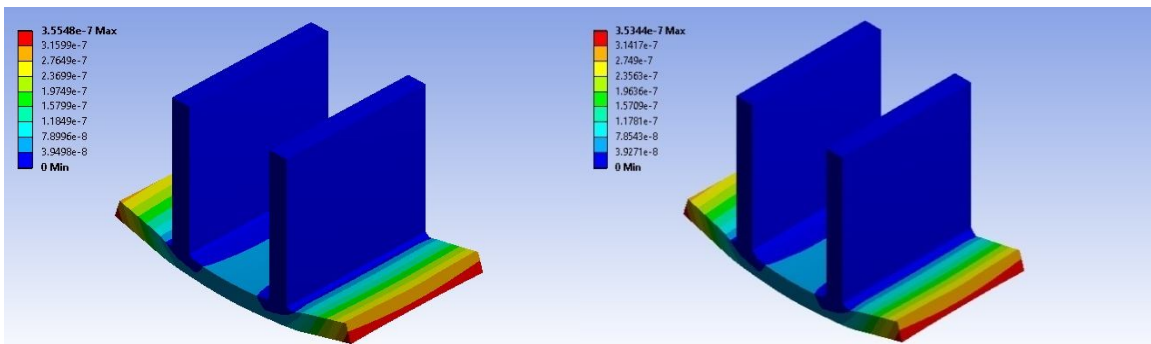


(a) 3mm fillet radius (b) 5mm fillet radius

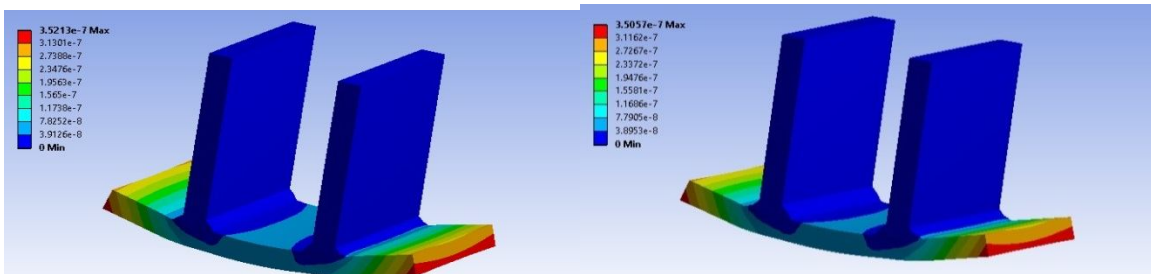


(c) 7mm fillet radius (b) 9mm fillet radius

Figure 4: Von-mises strain under the load of 1000N and 1000N



(a) 3mm fillet radius (b) 5mm fillet radius



(c) 7mm fillet radius (b) 9mm fillet radius

Figure 5: Total deformation under the load of 1000N and 1000N

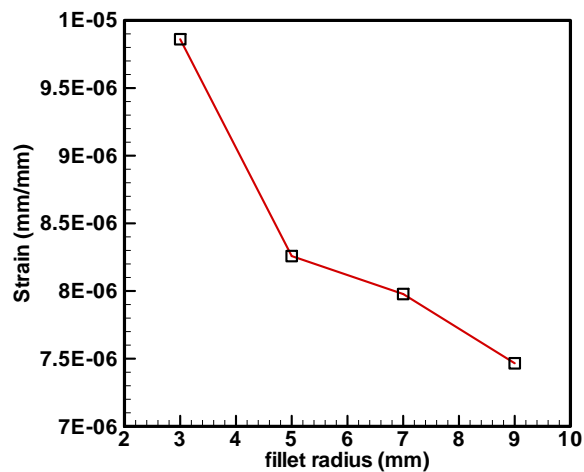
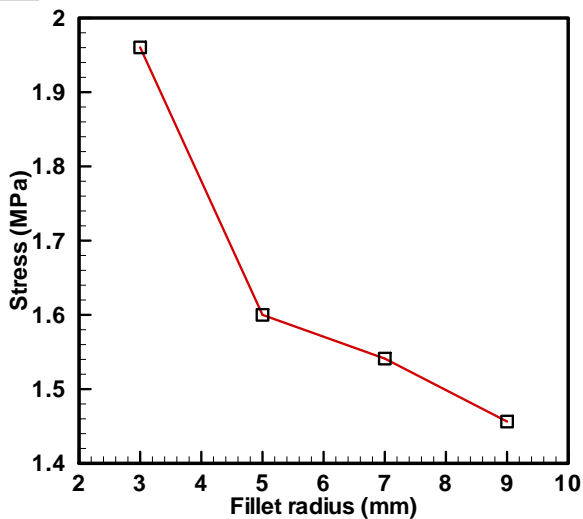


Figure 6: Stress vs. fillet radius Figure 7: Strain vs. fillet radius

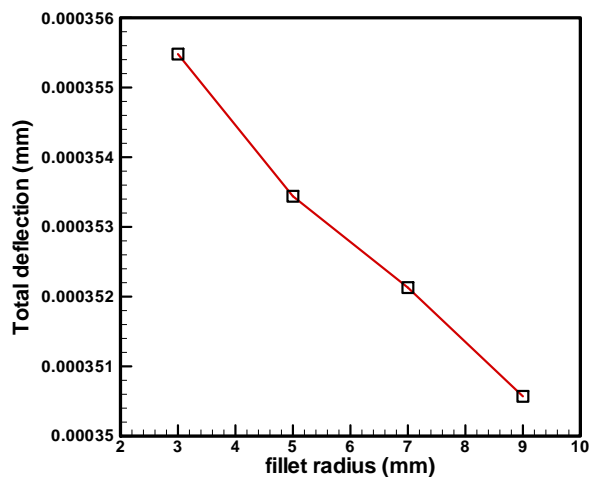


Figure 8: Total deformation vs. fillet radius

To study the effect of the fillet radius set-4 (1000N and 1000N) has been considered and values of fillet radius has been varied 3mm, 5mm, 7mm and 9mm. Table 4 shows the values of the stress, strain and total deformation developed for Epoxy material.

Table 4: Stress, strain and total deformation for Epoxy under (1000N and 1000N) load

Load (Epoxy)	Stress (MPa)	Strain (mm/mm)	Total Deformation (mm)
Value	Max	Max	Max
3mm	2.0326	2.4082e ⁻⁸	8.1773e ⁻⁷
5mm	1.5657	1.8661e ⁻⁸	8.127e ⁻⁷
7mm	1.484	1.8058e ⁻⁸	8.0995e ⁻⁷
9mm	1.4031	1.6945e ⁻⁸	8.0696e ⁻⁷

Figure 9 to 11 shows the amount of stress, strain and total deformation generated in the fillet weld made of Epoxy material. Figure 9 shows the comparison of the stress generated in the fillet weld made of steel and Epoxy material. It can be observed that with increment in the fillet radius amount of stress developed in the fillet weld made of Epoxy material is decreases by greater amount when compared with fillet weld made of steel.

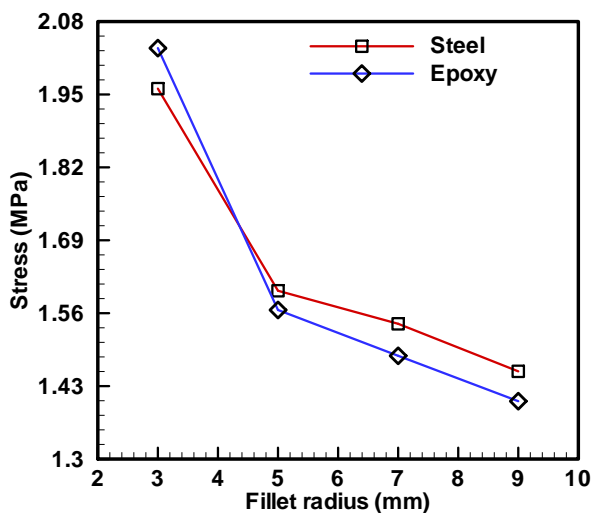


Figure 9: Comparison of Stress for steel and Epoxy with fillet radius

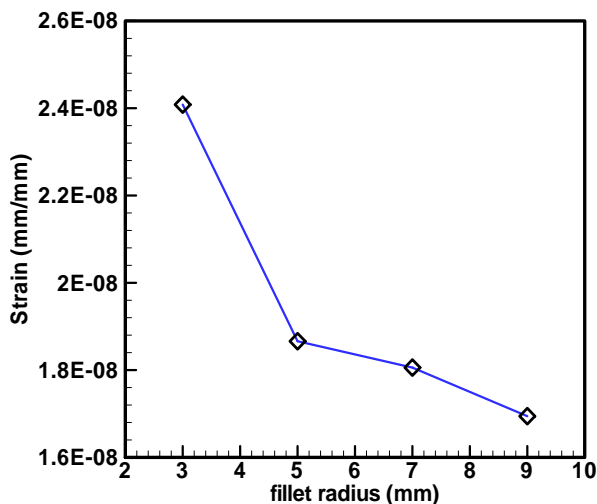


Figure 10: Strain with fillet radius for Epoxy material

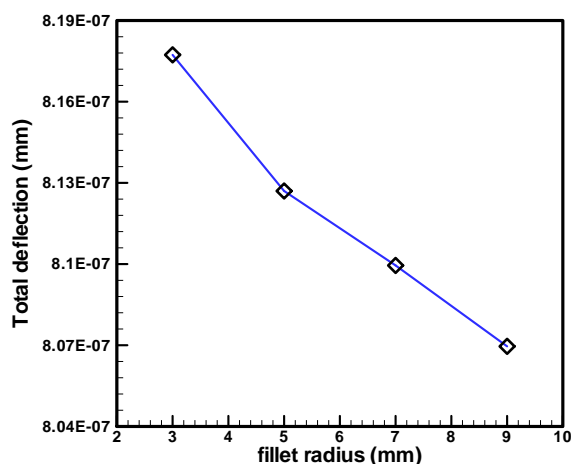


Figure 11: Total deformation with fillet radius for Epoxy material

B. Effect of the Loading Condition

To study the effect of the load one fillet radius (5mm) has been considered and values of load has been varied. It can be observed from the table that with increment in the load values amount of stress, strain and total deformation generated in the weld area increases.

Table 5: Stress, strain and total deformation for steel for different load values

Set No. (Material-Steel)	Load (Tensile)		Stress (MPa)	Strain (mm/mm)	Total Deformation (mm)
	Left	Right	Max	Max	Max
1	100N	100N	0.160	8.258e ⁻⁷	3.534e ⁻⁵
2	100N	1000N	1.636	8.433e ⁻⁶	3.647e ⁻⁴
3	1000N	100N	1.636	8.433e ⁻⁶	3.647e ⁻⁴
4	1000N	1000N	1.600	8.258e ⁻⁶	3.534e ⁻⁴
5	10000N	10000N	17.39	8.768e ⁻⁵	3.786e ⁻³

Table 6: Stress, strain and total deformation for Epoxy for different load values

Set No. (Material- Epoxy)	Load (Tensile)		Stress (MPa)	Strain (mm/mm)	Total Deformation (mm)
	<i>Left</i>	<i>Right</i>	<i>Max</i>	<i>Max</i>	<i>Max</i>
1	100N	100N	0.1566	1.866e ⁻⁹	8.127e ⁻⁸
2	100N	1000N	1.6732	1.991e ⁻⁸	8.374e ⁻⁷
3	1000N	100N	1.6732	1.991e ⁻⁸	8.374e ⁻⁷
4	1000N	1000N	1.566	1.866e ⁻⁸	8.127e ⁻⁷
5	10000N	10000N	18.058	2.147e ⁻⁷	8.677e ⁻⁶

V. CONCLUSION

- A. Three-dimensional double fillet weld finite element analysis has studied on weld toes and root areas.
- B. With increment in load stress generated increases continuously.
- C. Total deformation increases with increment in load.
- D. Increasing the fillet radius reduces the amount of stress and strain developed on the weld.
- E. With increment in the fillet radius, amount of deformation generated is reduced.

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