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Fracture Analysis of Welded Joints

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ABSTRACT

Understanding a failure occurrence and its propagation will lead to a better appreciation of welded joints from reliability point of view. Fracture mechanics is mechanics of solids containing planes of displacement discontinuities (cracks) with special attention to their growth. In this thesis, the fracture mechanics analysis in ANSYS for welded structure with cracks are investigated by determining the stress intensity factors, deformation and compared for different materials. Theoretical calculations are done to compare the stress intensity factors, and J - Integral. Structural and Fatigue analysis are also done. Two welded joints Edge joint and T – Joint using materials Steel, Copper and Aluminum alloy are considered.3D modeling is done in Creo 2.0 and Analysis is done in Ansys.

INTRODUCTION OF WELDED JOINTS

Welding isa materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material.

WELD JOİNT

There are 5 basic joint types in welding

- Butt joint
- Corner joint
- Lap joint
- Tee joint

FRACTURE MECHANICS

Fracture Mechanics is the field of mechanics concerned with the study of the propagation of cracks in materials. It uses methods of analytical solid mechanics to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture.

LITERATURE SURVEY

In the paper by Hiroshi shimanuki [1],A fatigue life prediction system for welded structures has been developed based on crack growth analysis. In the developed system, the fatigue life can be predicted taking into account the effects of the residual stress and the load sequences by the crack opening and closure simulation. Furthermore, the effect of fatigue strength improvement techniques, such as UIT, can be accurately predicted by the developed system. In the paper by D. K. Bhattacharya [2], for a failure at a welded joint, the important factors are:

(a) presence of defects in the form of physical discontinuities, (b) a bad microstructure, and (c) residual stresses. A few important examples of bad micro structures leading to failures in stainless steel and alloy steels are presented in the paper. Apart from the references cited in the text, a list of general references are included to help the reader to get a better perspective on the conditions under which the failure of a weld joint takes place. In the paper by Peter Bernasovský,[5] Failure Analysis Of Welded Components – Importance For Technical Practice The contribution deals with possibilities of metallographic identification of crack types in steel structures. The main features of cracks predominately in welded joints are illustrated on real cases of breakdowns.

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MODELING OF WELDED JOINTS PLATE IN CREO 2.0

For modeling of welded joints, the reference is taken from Fatigue Life Prediction of Welded Structures Based on Crack Growth Analysis by Hiroshi shimanuki. Large Plate length– 400mm, Large Plate width – 80mm, Large Plate thickness - 23 mm, Small Plate length - 100 mm, Small Plate width - 100 mm, Small Plate thickness -15mm

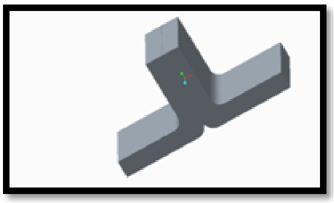

Fig: Final model of edge joint

Fig: Final model of T – Joint

CALCULATIONS FOR STRESS INTENSITY FACTORS

$K = F_0 \sigma_0 \sqrt{\pi a}$

$F_0 = [1+0.52\lambda +1.29\lambda^2 -0.074\lambda^3]^{1/2}$

$\lambda = \frac{a}{\sqrt{Rt}}$

Where σ_0 = Stress (considered from analysis results), a = Crack length major radius, R = crack length counter radius, t = thickness of the plate, a = 2 mm, R = 0.1 mm, t = 15 mm

CALCULATIONS FOR J – INTEGRAL

J – Integral = $K_{IC}^2 (1- \nu^2/E)$

Where K_{IC} = Fracture Toughness, ν = Poisson's ratio of the material, E = Young's modulus of the material

ANALYSIS OF WELDED JOINTS

The welded joints are analyzed for applied pressure is 15MPa.

STATIC STRUCTURAL ANALYSIS

MATERIAL – STEEL

EDGE JOINT

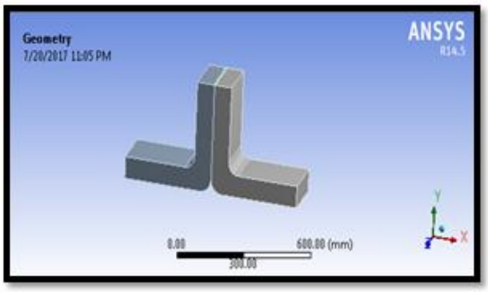

Fig: Imported Geometry of edge joint

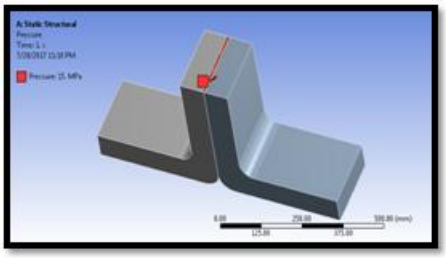

Fig: Pressure applied at the welded joint

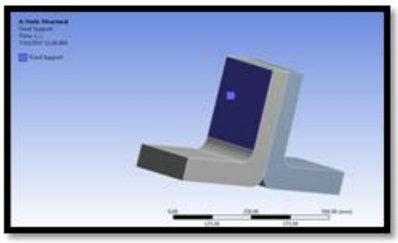

Fig: Fixed support applied on surfaces

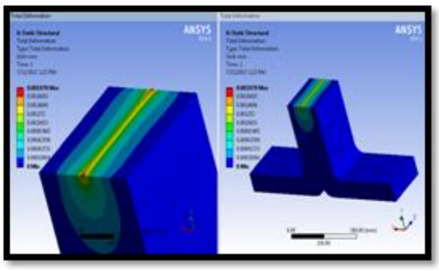

Fig: TotalDeformation on Edge Joint using Steel

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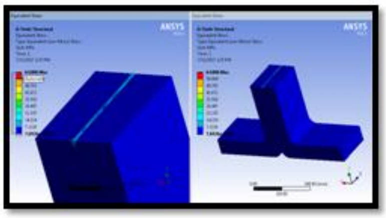

Fig: Stress on Edge Joint using Steel

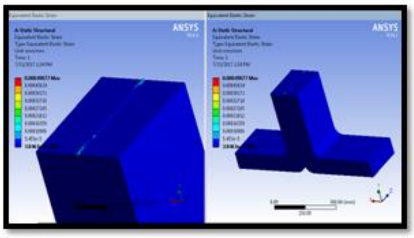

Fig: Strain on Edge Joint using Steel

T- JOINT

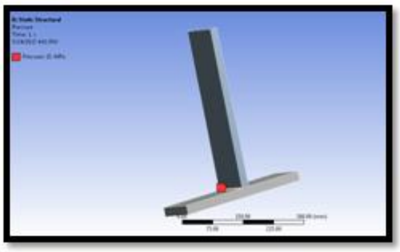

Fig: Pressure applied on the welded portion

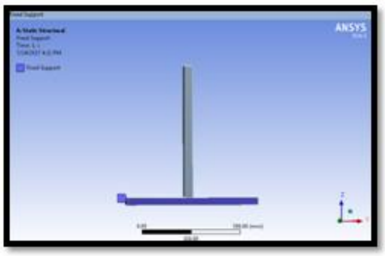

Fig: Fixed support applied on the base

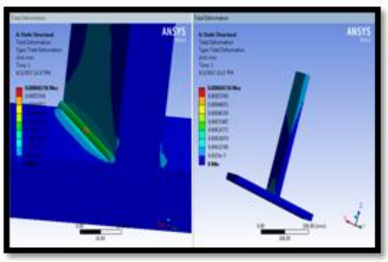

Fig: Total Deformationof T – Joint using Steel

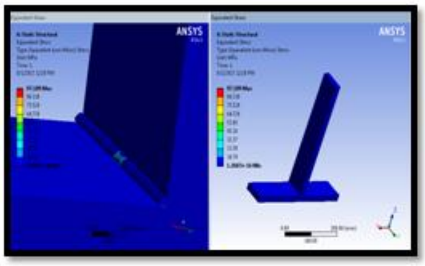

Fig: Stressof T – Joint using Steel

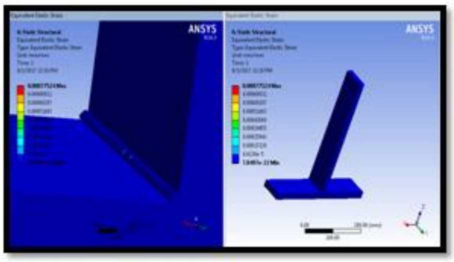

Fig: Strainof T – Joint using Steel

FRACTURE ANALYSIS OF WELDED JOINTS

EDGE JOINT

Select Crack Shape – Semi Elliptical, Enter major radius →1 mm, Enter minor radius→0.8 mm, Enter Fracture affected zone Height – 1.3007mm, Enter largest contour radius –0.5mm

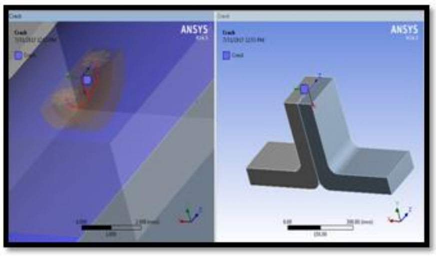

Fig: Crack on welded joints

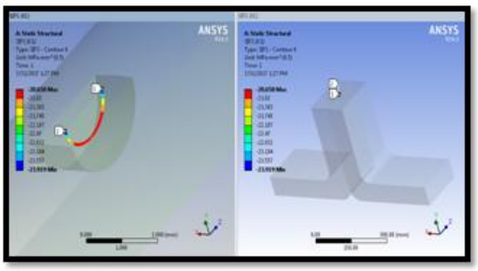

Fig: Stress Intensity Factor of edge joint using Steel

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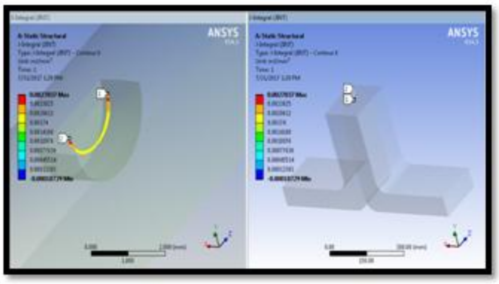

Fig: J-Integral of edge joint using Steel

T- JOINT

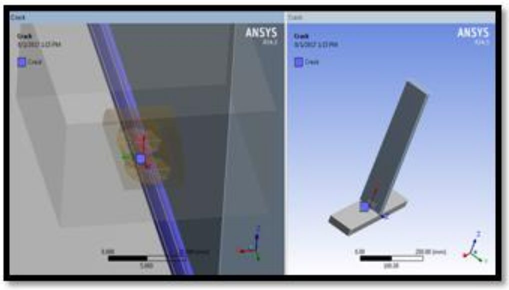

Fig: Crack on welded joints

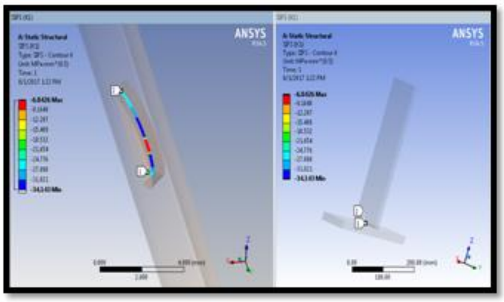

Fig: Stress Intensity Factor of T – Joint using Steel

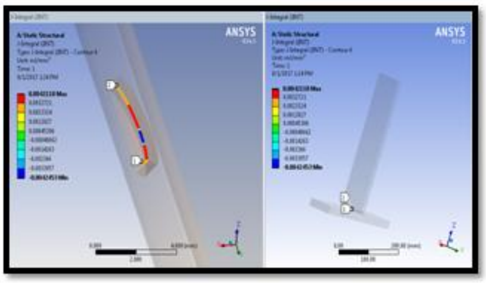

Fig: J-Integral of T – Joint using Steel

FATIGUE ANALYSIS OF WELDED JOINTS

EDGE JOINT

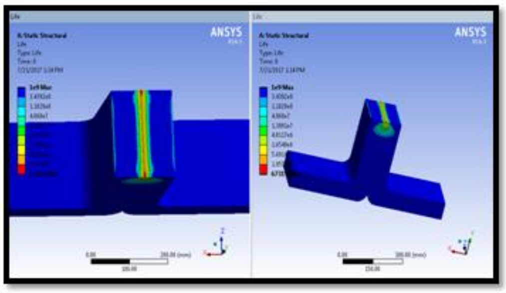

Fig: Life of Edge Joint using Steel

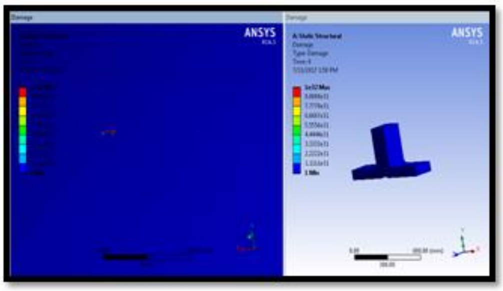

Fig: Damage of Edge Joint using Steel

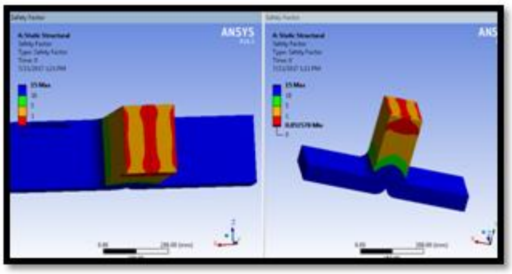

Fig: Safety factor of Edge Joint using Steel

RESULT & DISCUSSIONS

STATIC STRUCTURAL ANALYSIS

	Materials	Deformation (mm)	Stress (MPa)	Strain
Welded edge Joints	Steel	0.001878	64.006	0.00049077
	Copper	0.0029959	64.09	0.00072196
	Aluminum	0.0056749	64.085	0.0013965
Welded T-Joints	Steel	0.00060236	97.109	0.00077524
	Copper	0.00089069	98.103	0.0011217
	Aluminum	0.0017213	97.85	0.0027184

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FRACTURE ANALYSIS

	Materials	Stress intensity factor(Mpa.mm$^{0.5}$)	J-Integral (mJ/mm^2)
Welded edge Joints	Steel	-20.658	0.0027037
	Copper	-21.174	0.0041641
	Aluminum	-21.042	0.0079624
Welded T-Joints	Steel	-6.0426	0.0042118
	Copper	-6.1335	0.0064535
	Aluminum	-6.107	0.012358

FATIGUE ANALYSIS

	Materials	Life	Damage	Safety factor
Welded Edge Joints	Steel	2.67e5	1.111e31	0.013467
	Copper	1e5	7.77e31	0.017163
	Aluminum	1e5	1e32	0.00023407
Welded T-Joints	Steel	4e5	25007	0.0088766
	Copper	4.44e6	8.88e31	0.011213
	Aluminum	2.1e7	1e32	0.0001533

CONCLUSION

By observing the static analysis results, the stresses produced are more at the welded joint for both edge and T – Joints. The stresses are more for T – Joint than Edge Joint. The stresses are increasing by about 34% for T – Joint when compared with that of Edge Joint for all materials. The stress intensity factor is dependent on the geometry, the size and location of the crack, and distribution of loads on the material. The stress intensity factor is increasing by about 70% for Edge joint when compared with that of T – Joint for all materials. The calculation of J – integral values are dependent on the fracture toughness, Poisson's ratio and Elastic modulus of material.

The J – Integral value is inversely proportional to the Elastic Modulus of material. So Aluminum alloy has high J –Integral value. By observing the Fatigue analysis results, the life and damage are more for T – Joint. Since the damage value is more, to fail the T – Joint more loads multiplied by present applied load are needed when compared with that of Edge Joint. The life is also more for T – Joint. But the safety factor is less for T – Joint. Comparing between materials, the life and damage values are more when Aluminum alloy is used.

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