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"Fractural Mechanics Crack Propagation Study of Welded Joint of Different Material and Different Crack Location in ANSYS"

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Abstract - *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. For the simulations and calculations done in this thesis, the FE program ANSYS 19.1 is used. Six different variations of material and crack tip of the welded joint are analyzed, one where the v-notch near the weld and second one where the v-notch is near the or in the hole where bolt assembly is there. For the one joint, the crack assumes to start near the weld and for the other joint the crack can originate either from hole where the stress intensity of joint is increased.From this it is concluded that if we need more life and less stress resistance then one can use aluminum alloy. On the other hand if we need more stress resistance and less no of cycles or life of part then go for either structural steel or stainless steel. Hardness of material plays an important role in resisting crack propagation. The modules of elasticity or constant use in Paris law such as material constant (which came from experimental investigation) influence strength and life of material.*

Keywords — *Fracture Mechanics, Crack tip , Welded Joint, Strength & Life of Material, Ansys.*

I. INTRODUCTION

There are spectacular failures of structures, product of ductile material. They fail in a very brittle fashion. So, earlier, folks weren't victimization constructions productof m etals, there was associate explosive use of metals. So, afteryou have associate explosiveuse of those metals, you would like to know, what their structural behavior. one in every of the earliest developments in fashionable Science was, they'd developed locomotives and locomotives had boilers and boilers ar primarily pressure vessels. And, you stumble upon pressure vessels, in several of our day to day life. You have got the Indane gas cylinder; it's a pressure vessel is extremely vital facet that must be understood well. But, you had ruinous accidents of boilers. So, which means what? The information at that point wasn't ample to stop these accidents. So, researchers attempt to scrutinize, what to do. And, they were able to trace out that a number of these accidents were because of poor style, which was later improved by more sensible choice of materials and improvedproduction ways.They realize explanationfor those ruinous accidents. Once they known that, they were because of poor design; they were able to improve it. Once they realize that, strength of the fabric should be improved; they went sure alloying the materials and new materials is developed and that they additionally improved the assembly ways. Fracture Mechanics, there square measure two broad classes that you just will think about. One is Linear Elastic Fracture Mechanics. Another one is Elasto-plastic Fracture Mechanics. The entire of Fracture Mechanics focuses on structures fabricated from ductile, high strength alloys. This is often vital. We have a tendency to can't apply Fracture Mechanics to soft-cast steel. Just for high strength alloys, Fracture Mechanics is applied. The high strength alloys fail in an exceedingly brittle fashion has prompted the birth of Fracture Mechanics. The ideas generated by D. W. Griffith, for a brittle solid were extended to ductile, high strength materials by Irwin in 1948. Irwin shifted the main target from the crack to the crack-tip. Then, the entire of Fracture Mechanics became terribly straightforward. Moving the analysis to the crack-tip, he devised feasible parameters like stress intensity issue and energy unleash rate. So, that was the vital contribution by Irwin. He was shifted the main target to the crack-tip, we have a tendency to were able to get convenient parameters; comparatively as a result of if we glance at the strain intensity issue. Compare to what D. W. Griffith was making an attempt to mention, what Irwin aforesaid was easier for individuals to know and, we've already stressed that the instant you've got a crack, you'll have terribly high level of stresses. So, positively there'll be a plastic zone developed. And, if you consider L.E.F.M., these accounts just for little scale

yielding (S.S.Y.) close to the crack-tip. And, this abbreviation S.S.Y. is additionally a awfully necessary abbreviation in Fracture Mechanics. So, once you encounter S.S.Y. the employment of L.E.F.M. is found in part structures as a result of you utilize basically skinny structures and by enlarge; it's a lot of Thumb Rule.
Theplasticzone isextremely little and extremely localized.
The plastic zone within the case of a plane strain is way smaller than within the case of a plane stress. The plastic zone is extremely localized and in reality, if the plastic zone is slightly unfold as in an exceedingly plane stresscondition, it's helpful fromFractureMechanics purpose of read. The structure as a full can still stays as brittle solely. Once the load is applied, it'll have elastic response; it'll not have a plastic response. But, close to the crack you'll have a plastic zone. And, that plastic zone indicates however the crack goes to behave. And, in reality in Fracture Mechanics, if you've got some physical property close to the crack-tip, it's helpful. It prevents the crack to grow easier. So, it's smart from the purpose of read of safety. Necessary fact is that modes of loading close to the crack-tip. This is often once more, the contribution by Irwin. And, he discovered that there square measure three freelance ways in which, within which the two crack surfaces will move with reference to one another

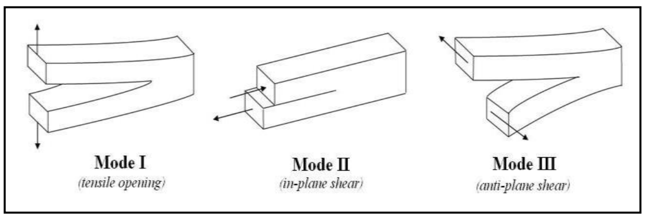


Figure1.1: Failure Modes

The corresponding modes square measure labelled as Mode I, Mode II and Mode III. There may well be 3 freelance ways that during which the 2 crack surfaces will move. And, what's the wonder of this idea is that the 3 modes describe all the doable modes of crack behavior within the most general elastic state.
Mode I this is often additionally known as as gap Mode. In the main as a result of you have got the crack and therefore the crack unveil like this. Owing to the load, the crack unveil like this, this is often one in all the foremost common and dangerous modes of loading for crack growth. Individuals have developed theories and showed that crack can eventually take a path such; the loading is perpendicular to it. So, Mode I loading is that the most dangerous. And even, once we need to search out out the strain field equations, we'd develop the strain field equations formodeI.ModeII isadditionally called a slippery Mode. Ther e's a slippery within the plane. And, this known as as In-plane Shear Mode or slippery Mode. The displacement of crack surfaces is within the plane of the crack and perpendicular to the forefront of the crack. The third mode is it's tearing like this. It's out of plane shear. However the faces move, reckoning on that as Mode I, Mode II or Mode III. Really if you opt for bi-material issues, apparently external gap mode may also cause a slippery of the crack faces. So, it depends on the matter. this is often the Tearing Mode additionally known as as Mode III. It's known as as Out of plane shear mode. And, this is often additionally known as as Tearing Mode. For every of those modes, just like the strain concentration issue that is often called a stress intensity issue, that dictates the strength of the strain field within the close to neighbourhood. And, this is often labelled as KI.

II. GENERAL DESCRIPTION OF MODEL:

This is weld joint consider for analysis having hole at center and having v-notch (to start crack propagation need to model those notch as initiation of crack; analysis with crack tip became more easy) at various location. The material property, nomenclature, actual geometry of model and loading condition is given as follows;

Table1: Nomenclature of various models

Model	Nomenclature
V notch near welding	
(a) Structural steel	(V1-SS)
(b) Aluminum alloy	(V1-AA)
(c) Stainless steel	(V1-StS)
V notch near hole	
(d) Structural steel	(V2-SS)
(e) Aluminum alloy	(V2-AA)
(f) Stainless steel	(V2-StS)

Table 2: Material Properties

Material	Stainless Steel	Structural Steel	Aluminum Alloy
Density (Kg/m3)	7.75E+03	7.85E+03	2.77E+03
Young's Modulus (Mpa)	1.93E+05	2.00E+05	71000
Poisson's Ratio	0.31	0.3	0.33
Bulk Modulus (Mpa)	1.69E+05	1.67E+05	69608

Shear Modulus (Mpa)	73664	76923	26692
Tensile Yield Strength (Mpa)	207	250	280

Loading on Geometry

Loading on geometry is place such a way that loading should be perpendicular to crack. For crack propagation should start the 0.01 mm pull/displacement is applied to geometry is as shown in figure2 (b). Also to maintain equilibrium a fixed support is added to the base.

GEOMETRICAL DETAIL

The geometrical detail of the model is as shown in figure 2. Crack tip model is shown in figure 2(a) and loading and support condition is shown in figure 2(b). All this condition forms six models which are further analyzed for different material and different crack location for pull/displacement loading and crack propagation study.

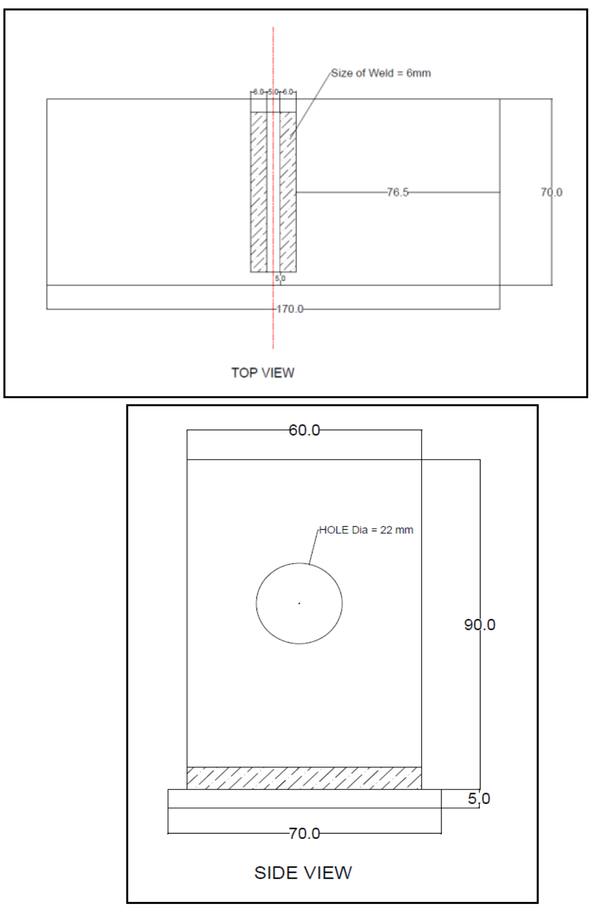
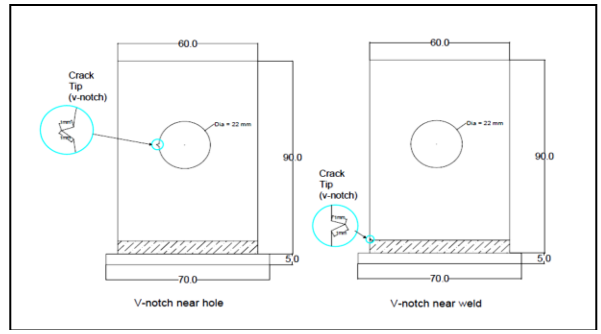
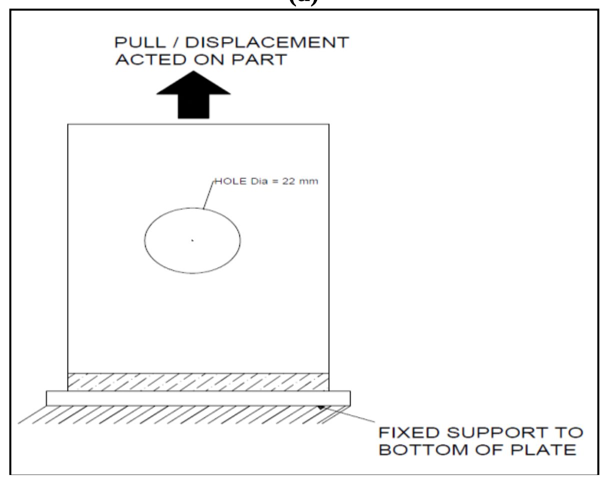


Figure 2: Top View and Side View of Geometry.



(a)



(b)

Figure 3: (a)V-notch near hole and weld and (b) loading and support condition of part/ geometry

III. RESULT & DISCUSSIONS

A. Stress Intensity Factors

The stress intensity factor was developed in 1957 by George R Irwin, the man usually considered to be the father of fracture mechanics. The stress intensity factor is abbreviated SIF and represented by the variable, K. It is one of the most fundamental and useful parameters in all of fracture mechanics. The stress intensity factor describes the stress state at a crack tip, is related to the rate of crack growth, and is used to establish failure criteria due to fracture.

Table 3.: Average value of SIFS (K1)

Average value of SIFS (K1) [MPa·mm^(0.5)] (Crack tip near hole)								
Aluminum Alloy (V2-AA)			**Stainless Steel** (V2-StS)			**Structural Steel** (V2-SS)		
Contour 1	Contour 2	Contour 3	Contour 1	Contour 2	Contour 3	Contour 1	Contour 2	Contour 3
48.75	54.81	55.19	129.75	148.16	148.16	134.24	150.92	152.34

Table 4: Average value of SIFS (K1)

Average value of SIFS (K1) [MPa·mm^(0.5)] (Crack tip near weld)								
Aluminum Alloy (V1-AA)			**Stainless Steel** (V1-StS)			**Structural Steel** (V1-SS)		
Contour 1	Contour 2	Contour 3	Contour 1	Contour 2	Contour 3	Contour 1	Contour 2	Contour 3
27.49	30.74	31.03	73.43	81.85	83.20	78.57	87.90	88.56

1. From above figure, it is seen that stress intensity factor of structural steel is greater than stainless steel and aluminum alloy.
2. It is seen from that as modulus of elasticity of material is more stress intensity factor also comes more.

B. Equivalent average stress (von-misses principle)

Table 5 : Equivalent Stress Average (MPa) (Crack tip near weld)

Equivalent Stress Average (MPa) (Crack tip near weld)			
Time [s]	Aluminium Alloy (V1-AA)	Stainless Steel (V1-StS)	Structural Steel (V1-SS)
0.1	5.2293	14.16	14.646
0.2	4.9078	13.376	13.684
0.3	4.5689	12.301	12.655
0.4	3.9922	10.891	11.274
0.5	3.7067	9.9063	9.8673
0.6	3.8795	11.115	12.43
0.7	4.3321	10.851	11.596
0.8	4.0893	10.257	10.101
0.9	3.8844	9.7084	11.937
1	3.4272	8.6691	10.831

The maximum distortion criterion (also von Mises yield criteria) considers that yielding of a ductile material begins when the

Table 6: Equivalent Stress Average (MPa) (Crack tip near hole)

Equivalent Stress Average (MPa) (Crack tip near hole)			
Time [s]	Aluminium Alloy (V2-AA)	Stainless Steel (V2-StS)	Structural Steel (V2-SS)
0.1	9.9807	27.042	27.98
0.2	9.5171	25.541	26.428
0.3	8.439	22.295	23.452
0.4	6.8576	19.448	19.504
0.5	7.1085	22.018	21.894
0.6	6.2105	20.474	20.229
0.7	6.2033	18.113	17.474
0.8	5.5717	16.503	15.732
0.9	5.2873	14.019	17.571
1	6.2051	16.739	16.197

From above figure it is seen that stress resistance of structural steel material is greater than stainless steel and aluminum alloy in starting and most of the time when crack propagates. It is seen from that as modulus of elasticity of material is more that's why stress intensity factor also comes more.

III. Total deformation

Table 7: Total Deformation (mm) (Crack tip near weld)

Total Deformation (mm) **(**Crack tip near weld)			
Time [s]	Aluminum Alloy (V1-AA)	Stainless Steel (V1-StS)	Structural Steel (V1-SS)
0.1	9.88E-04	9.82E-04	9.79E-04
0.2	9.99E-04	9.92E-04	9.92E-04
0.3	1.02E-03	1.02E-03	1.01E-03
0.4	1.05E-03	1.04E-03	1.04E-03
0.5	1.07E-03	1.08E-03	1.07E-03
0.6	1.05E-03	9.79E-04	9.96E-04
0.7	1.05E-03	1.00E-03	1.04E-03
0.8	1.11E-03	1.05E-03	1.09E-03
0.9	1.14E-03	1.08E-03	1.14E-03
1	1.20E-03	1.12E-03	1.20E-03

Table 8: Total Deformation (mm) (Crack tip near hole)

Total Deformation (mm) **(**Crack tip near hole)			
Time [s]	Aluminum Alloy (V1-AA)	Stainless Steel (V1-StS)	Structural Steel (V1-SS)
0.1	4.17E-03	4.17E-03	4.16E-03
0.2	4.22E-03	4.19E-03	4.20E-03

0.3	4.24E-03	4.23E-03	4.25E-03
0.4	4.28E-03	4.36E-03	4.33E-03
0.5	4.59E-03	4.78E-03	4.70E-03
0.6	4.67E-03	4.81E-03	4.74E-03
0.7	4.86E-03	4.84E-03	4.75E-03
0.8	4.95E-03	4.92E-03	4.89E-03
0.9	5.06E-03	4.96E-03	5.18E-03
1	5.16E-03	5.24E-03	5.21E-03

From above figure, it is observed that deformation of aluminum alloy material is slightly greater than stainless steel and structural steel at some time of cycle when crack propagates. Most of the time deformation is nearly same as in all material and all crack tip variation of model.

IV. Crack length v/s No. of life cycle.

Table 9: Crack length (mm) v/s No. of life cycle (Crack tip near hole)

Aluminium Alloy (V2-AA)		Stainless Steel (V2-StS)		Structural Steel (V2-SS)	
Crack Extension Probe [mm]	Total Number of Cycles Probe	Crack Extension Probe [mm]	Total Number of Cycles Probe	Crack Extension Probe [mm]	Total Number of Cycles Probe
0.66053	10120	0.70789	2646	0.71623	2407
1.4686	10254	1.5589	2719	1.5536	2473
2.2273	10356	2.3771	2777	2.3778	2526
2.9718	10449	2.9964	2815	3.0525	2564
3.8139	10536	3.6389	2854	3.7373	2601
4.5938	10623	4.2889	2896	4.5007	2641
5.4398	10707	5.0811	2939	5.5207	2695
6.233	10788	5.9411	2987	6.1352	2727
6.8431	10851	6.5872	3024	6.846	2762
7.4908	10915	7.3137	3062	7.57	2800

cycles of part is less as compare to aluminum alloy that means resistance to vibration is more in case of aluminum alloy than structural steel and stainless steel.

V. CONCLUSIONS

For the simulations and calculations done in this thesis, the FE program ANSYS 19.1 is used. Six different variations of material and crack tip of the welded joint are analyzed,

one where the v-notch near the weld and second one where the v-notch is near the hole. For the one joint, the crack assumes to start near the weld and for the other joint the crack can originate either from hole where the stress intensity of joint is increased and the following conclusions are made.

1. It is observed from all the result for same crack length the no cycles of Aluminum Alloy is more than Stainless Steel and Structural steel.

Table 10: Crack length (mm) v/s No. of life cycle (Crack tip near weld)

Aluminium Alloy (V1-AA)		Stainless Steel (V1-StS)		Structural Steel (V1-SS)	
Crack Extension Probe [mm]	Total Number of Cycles Probe	Crack Extension Probe [mm]	Total Number of Cycles Probe	Crack Extension Probe [mm]	Total Number of Cycles Probe
0.61336	60439	0.63558	11408	0.64098	10350
1.0809	62185	1.1312	11974	1.1508	10888
1.6728	63554	1.7336	12443	1.7965	11330
2.3417	64724	2.4061	12854	2.4415	11683
2.9791	65661	3.0045	13166	3.0847	11971
3.6708	66481	3.6765	13465	3.7263	12234
4.3383	67183	4.3222	13726	4.3872	12473
4.9842	67746	4.8782	13916	5.0631	12688
5.6353	68283	5.4776	14115	5.7511	12881
6.1265	68667	6.1129	14316	6.2648	13012

From above, it is observed that life cycle of aluminum alloy is more than structural steel and stainless steel.For fatigue crack propagation it is find from observation that material hardness influences the life cycle even modulus of elasticity is low in case aluminum alloy rules in resisting crack propagation.In terms of structural steel and stainless steel have more resistance to load but the life of part/No. of

2. On the other hand structural steel has more stress resistance to similar crack length.

3. From this it is concluded that if we need more life and less stress resistance then one can use aluminum alloy.

4. On the other hand if we need more stress resistance and less no of cycles or life of part then go for either structural steel or stainless steel.

5. Hardness of material plays an important role in resisting crack propagation.

6. The modules of elasticity influences strength and life of material.

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