TWO DIMENSIONAL CRACK ANALYSIS OF AL7075-7651 UNDER VARIOUS TENSILE LOAD

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ABSTARCT: *The recent Development in Materials had made the scope for research widen. This Project deals with analysis of Stress intensity factor of Al7075-T651which is often called as Aircraft Aluminum. The project deals with Analysis of Through crack model of plate with hole. The analysis is carried out under constant load by varying the crack length. The Stress intensity factor, Beta function is studied various the load applied and behavior of material is compared. The change in the beta function for each load case is analyzed. The stress intensity factor of the crack varies with the number, location of holes and the size of the crack in the model. The stress intensity factor value for through straight crack varies with the crack length and the tensile loading. The Stress Intensity factor varies with the crack location and the number of holes.*

KEYWORDS: **Research widen, Beta function, Stress intensity, Crack model, Tensile load**

1. INTRODUCTION:

The technological advancement in the creation of new materials has enabled a wide scope for the material selection for different application, but the problem of fracture and susceptibility of the material towards crack propagation poses a serious threat in the usage of material in the long run. The material used for engineering application is considered as homogenous and flawless, but the material formed by manufacturing does have some flaws and defects. These materials when used fail before the estimated life cycle. Small defects such as scratch, blow holes and micro cracks have a major impact under a particular environment and loading condition. These defects under repeated loading and environmental change develop into cracks that pose serious problems while in service. The fracture mechanics deals with the crack analysis, the behavior of the crack and the propagation of the crack in a particular environmental condition. Understanding of fracture mechanics is essential in dealing with the problems. This work deals with the study of the stress intensity factor along the crack. The stress intensity factor defines the stress field around the crack.

The aerospace industries faced a serious threat in the early years of aviation history as the sudden failures of the structures were unexplained. The aircraft structures are made of material with high strength to weight ratio and the design safety factor close to unity. The sudden failure of the components or structure risks the life of many people travelling in the aircraft and billions of dollars poured to make the aircraft. The model described in the study is the plate made of Al7075-T651 with two holes at the centre and the crack formed around the hole. These plates are specifically used for aircraft structures with riveted holes. The environment in which the plates are going to use is susceptible to temperature change and the loading effect. The environment can transform the micro cracks into major cracks and cause sudden failure of the material. The impact of temperature and moisture is not discussed in this work. The study of stress intensity factor helps define the stress field around the crack tip. The stress intensity factor provides the necessary details for failure of the material under tensile loading. When the stress intensity factor values increase beyond the critical value, the crack starts to open up, propagate and leads to failure of the plate.

2. MODELLING OF THE PLATE:

MATERIAL PROPERTIES: The material being used for the analysis is Al7075-T651 Aluminum Alloy[15]. Aluminum alloy has a high strength to weight ratio and finds its major application in the field of aerospace and missile engineering. This is a tempered Aluminum Alloy and corresponds to the series of 7075 Al alloys.

CHEMICAL COMPOSITION:

COMPOUNDS	WEIGHT PERCENTAGE
ALUMINIUM	87 – 91.4
ZINC	5.1 – 6.1
MAGNESIUM	2.1 – 2.9
COPPER	1.2 – 2.0
IRON	0.5 Max
SILICON	0.4 Max
MANGANESE	0.3 Max

CHROMIUM	0.18 – 0.28
TITANIUM	0.2 Max

CHEMICAL COMPOSITION OF AL7075-T651

PROPERTIES:

PROPERTIES	UNITS	VALUE
DENSITY	g/cc	2.81
MODULUS OF ELASTICITY	G Pa	71.7
POISONS RATIO		0.33
ULTIMATE TENSILE STRENGTH	M Pa	572
YIELD STRENGTH	M Pa	503
FATIGUE STRENGTH	M Pa	159
BRINELL HARDNESS	BHN	150
SHEAR MODULUS	G Pa	26.9

PROPERTIES OF AL7075-T651

PLATE MODEL: The plate model as shown in Figure 2and3 is modelled using ANSYS with two holes at the centre of the place. The plate is found to have symmetry along the centre of the hole and the crack is modelled in the horizontal plane at the ends of the hole. The symmetry condition means that only one half of the plate is modelled to introduce the crack and find the stress intensity factor for the whole model. The visibility of the crack at the centre of the model is more in the symmetric modelling of the plate. The plate shown in Figure 2 has two clamped portions on either ends of the model, these portions will not be modelled in ANSYS as it is used to clamp the plate while experimental analysis are carried out.The dimensions of the plate are determined by the following relationship.

$r/t = 0.075, 0.1, 0.2, 0.333, 0.5, 1.0, 2.0, 3.0, 6.0$

$L = 1D, 2D, 3D, 4D$

$D_1/D_2 = 0.5, 1.0, 2.0$

$B = 1D, 2D, 3D, 4D$

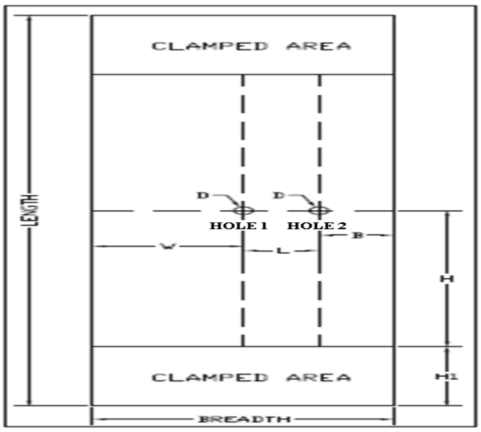


PLATE MODEL (FRONT VIEW)

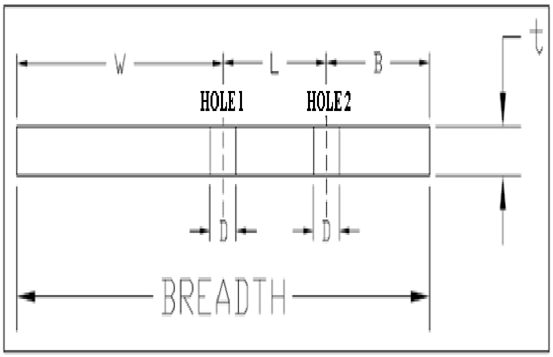


PLATE MODEL (SECTION ALONG CENTER)

DIMENSIONS OF THE PLATE:

t		6.350 mm
r	0.5t	3.175 mm
D_1	1 D_2	6.350 mm
L	4D	25.40 mm
B	4D	25.40 mm

DIMENSION OF THE PLATE

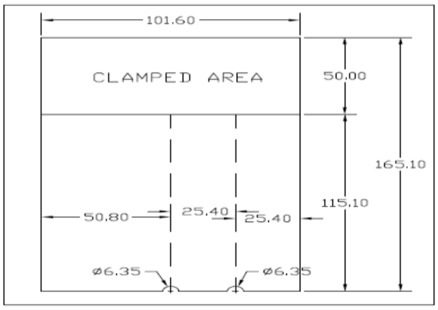


PLATE DIMENSION (FRONT VIEW)

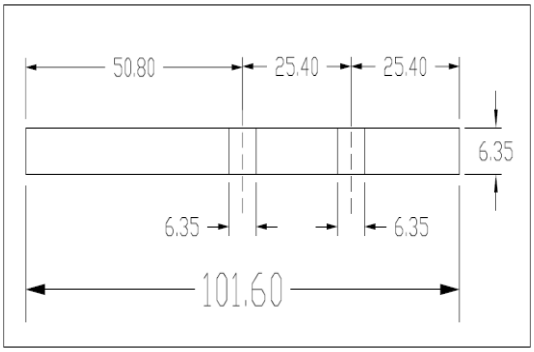
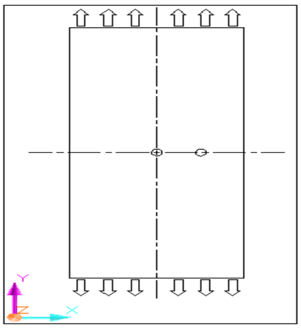


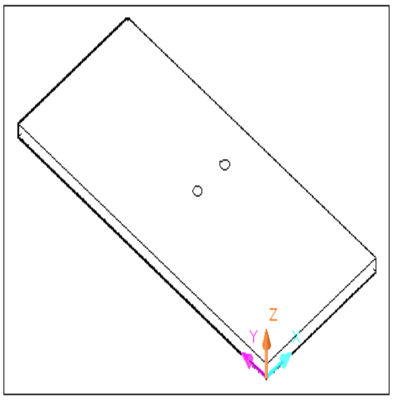
PLATE DIMENSION (SECTION ALONG CENTER)

CRACK MODEL: The major requirement in the crack analysis of the plate lies in defining the crack tip and the crack front of the model. The model is considered to be symmetric in nature along the crack face. In order to find the Stress intensity factor (SIF) for the crack model, the crack tip should be a singularity element. Singularity elements are defined as the quadratic elements with the mid-side nodes placed at the quarter point of the crack tip.

MODELING: The through crack model is modelled with respect to the dimensions given in Figure 4and5. The key points in the global co-ordinate system is defined and this forms the edges of the model. The key point corresponding to the Crack tip is defined along with other key points. The lines are generated and area is formed using the lines. The holes are drilled using the Boolean Operation- Subtract in ANSYS command. The locations of the holes are based on the global co-ordinate system. The crack is perpendicular to the XY plane and parallel to Z direction.

STRESS INTENSITY FACTOR ANALYSIS: PLANE STRESS CONDITION: The plane stress and plane strain conditions are differentiated mainly on the thickness of the model. The thin plate model is considered under plane stress condition. The model should have dimension in Z axis lesser than the dimension in the X and Y direction. The mid-plane direction forms the plane XY direction. The plane normal to the mid plane is Z direction. The forces and the constraints are being applied in the mid-plane direction. The plate material should be made using a same material. The plate should preferably have uniform thickness throughout the length of the plate.





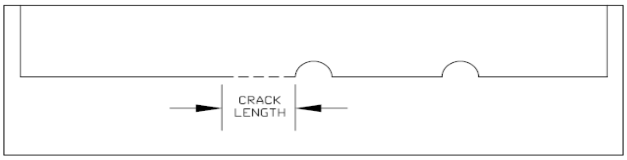
THREE DIMENSIONAL PLATE MODEL AND LOADING CONDITION

CONSTANT LOAD METHOD:

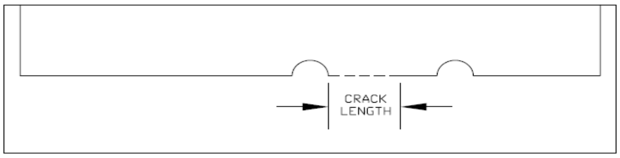
CASE WITH SINGLE CRACK EMANATING FROM A HOLE: The model is generated with the crack formed on the sides of the hole as shown in Figures. The singularity points are generated around the crack tip and the Stress intensity factor is calculated. The tensile load acting on the plate is 50MPa. Individual cases are divided into numerous sub cases as shown in Table 4

CASE	CRACK LENGTH (mm)
1.1	1
1.2	2
1.3	3
1.4	4
1.5	7
1.6	10
1.7	13
1.8	16

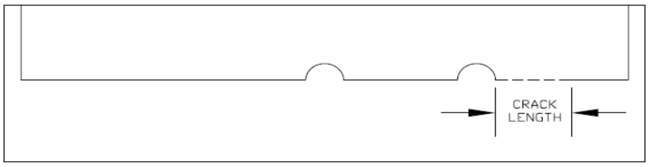
SUBCASES FOR DIFFERENT CRACK LENGTH



CRACK LOCATION FOR CASE I



CRACK LOCATION FOR CASE II



CRACK LOCATION FOR CASE III

RESULTS AND DISCUSSION:

CRACK LENGTH	STRESS INTENSITY FACTOR		
	CASE I	CASE II	CASE III
1	128.75	128.21	118.48
2	142.15	143.56	135.34
3	147.83	148.07	141.21
4	158.91	157.66	150.55

7	183.33	185.71	187.53
10	210.01	218.7	217.77
13	238.24	260.21	289.29
16	270.44	327.89	375.28

STRESS INTENSITY FACTOR FOR A SINGLE CRACK FROM A HOLE

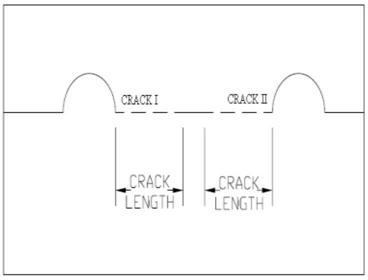
CRACK LENGTH	BETA FUNCTION		
	CASE I	CASE II	CASE III
1	1.4528	1.4467	1.3369
2	1.1342	1.1454	1.0798
3	0.963	0.9646	0.9199
4	0.8965	0.8895	0.8494
7	0.7819	0.792	0.7998
10	0.7493	0.7804	0.777
13	0.7456	0.8143	0.9053
16	0.7629	0.9249	1.0586

BETA FUNCTION FOR A SINGLE CRACK FROM A HOLE

The analysis shows the non linear change in the stress intensity factor value with the change in the crack length. The Beta value obtained from the stress intensity factor results have inverse square root curve. The change in the crack length shows a gradual decrease in the value of the Beta. The stress intensity factor is obtained for the plane stress criteria. The stress intensity factor is linear for case I and the SIF value deviates from case I with the increase in the crack length from case II and case III. The increase in the value is due to the closeness of the crack to hole 2 in case II. The SIF value for Case III is more than the Case 2 due to the closeness of the crack to the end of the plate. The closeness of the crack to the end of the plate has a larger impact compared to the closeness to the hole of the plate. The same can be found from the change in the Beta function for different crack length.

CRACKS FROM ADJACENT HOLE TOWARDS ONE ANOTHER:

The model is generated with the crack emerging from both the hole as shown in Figure 29. The crack from one hole is kept constant and the crack length of the other crack is varied. The singularity points are generated around the crack tip and the Stress intensity factor is calculated. The tensile load acting on the plate is 50MPa.



CRACK LOCATION FOR CASE IV

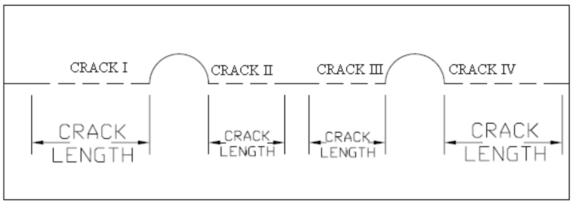
3. RESULTS AND DISCUSSION:

CASE	CRACK LENGTH (mm)	STRESS INTENSITY FACTOR K	BETA	STRESS INTENSITY FACTOR K	BETA
		CRACK I		CRACK II	
4.1	1	149.85	1.6908	175.72	1.9827
4.2	2	163.12	1.3015	178.06	1.4207
4.3	3	175.53	1.1435	181.35	1.1814
4.4	5	201.05	1.0145	191.59	0.9668
4.5	7	233.46	0.9957	209.59	0.8939
4.6	9	276.31	1.0392	243.7	0.9166

STRESS INTENSITY FACTOR VALUES FOR CASE IV

The analysis is made by keeping the crack length at one hole constant (Crack I) and the increasing the crack length of the other hole (Crack II) until it reaches close to the other crack. The increase in the crack length (Crack II) shows an increase in the stress intensity factor of the crack. The increase in the stress intensity factor causes the decrease in the Beta value. The crack having constant length (Crack I) also has an impact due to the change in the crack length of the crack from the other hole (Crack II). The stress intensity factor of Crack I start increasing even without any change in the crack length. The change in the stress intensity factor of Crack I is similar to that of change in the stress intensity factor of the Crack II.

CRACK EMANATING FROM BOTH SIDES OF THE HOLE: The model is generated with the crack emerging from both sides of hole as shown below. The singularity points are generated around the crack tip and the Stress intensity factor is calculated. The tensile load acting on the plate is 50MPa.



CRACK LOCATION FOR CASE V

CASE	CRACK LENGTH (mm)
5.1	6
5.2	7

SUBCASES FOR DIFFERENT CRACK LENGTH

RESULTS AND DISCUSSION:

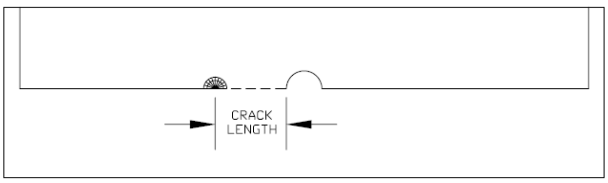
CASE	CRACK LENGTH (mm)	STRESS INTENSITY FACTOR K	STRESS INTENSITY FACTOR K	STRESS INTENSITY FACTOR K	STRESS INTENSITY FACTOR K
		CRACK I	CRACK II	CRACK III	CRACK IV
5.1	6	246.84	279.37	297.1	258.3
5.2	7	289.63	359.43	368.88	311.91

STRESS INTENSITY FACTOR VALUES FOR CASE V

The stress intensity factor of cracks (II and III) between the two holes is more than the stress intensity factor of the crack (I and IV) outside the hole. The stress intensity factor of crack IV is more than the stress intensity factor of Crack I due to the proximity of Crack IV to the edge of the plate.

COMPARISON OF STRESS INTENSITY FACTOR FOR SINGLE HOLED AND DOUBLE HOLED MODEL:

Case VI LOCATION OF CRACK ON LEFT SIDE OF HOLE 1: The model consists of single hole with the outer dimensions of the plate similar to that of the dimension of the model discussed in Case I. The crack starts at the left side of the hole. The crack length under each case starts increasing with the constant tensile load of 50MPa applied at the ends of the plate. The results are compared with the results of the Case I (Plate with double hole).



CRACK LOCATION FOR CASE VI

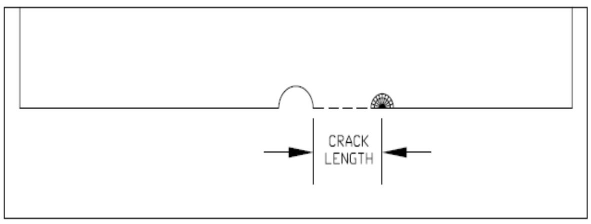
RESULTS AND DISCUSSION:

CASE	CRACK LENGTH (mm)	STRESS INTENSITY FACTOR K	BETA	STRESS INTENSITY FACTOR K	BETA
		SINGLE HOLE		DOUBLE HOLE	
6.1	1	127.39	1.4374	128.75	1.4528
6.2	2	137.12	1.0940	142.15	1.1342
6.3	3	144.36	0.9404	147.83	0.9630
6.4	4	151.61	0.8553	158.91	0.8965
6.5	7	177.65	0.7576	183.33	0.7819
6.6	10	204.02	0.7280	210.01	0.7493
6.7	13	233.85	0.7318	238.24	0.7456
6.8	16	266.1	0.7506	270.44	0.7629

STRESS INTENSITY FACTOR VALUES FOR CASE VI & CASE I

The comparison of the stress intensity factor of the single and the double crack is similar. The deviation in the stress intensity factor is found to be less than 2%. The impact of the hole on the left side crack of Hole 1 is found to be less. The plot of stress intensity factor and the Beta value is almost same as shown in Figure 34 and 35.

Case VII LOCATION OF CRACK ON THE RIGHT SIDE OF HOLE: The model consists of single hole with the outer dimensions of the plate similar to that of the dimension of the model discussed in Case II. The crack starts at the right side of the hole. The crack length under each case starts increasing with the constant tensile load of 50MPa applied at the ends of the plate. The results are compared with the results of the Case II (Plate with double hole).



CRACK LOCATION FOR CASE VII

4. CONCLUSION:

The analysis shows the non linear change in the stress intensity factor value with the change in the crack length. The Beta value obtained from the stress intensity factor results have inverse square root curve. The change in the crack length shows a gradual decrease in the value of the Beta. The stress intensity factor is obtained for the plane stress criteria. The stress intensity factor is linear for case I and the SIF value deviates from case I with the increase in the crack length from case II and case III. The increase in the value is due to the closeness of the crack to hole 2 in case II. The SIF value for Case III is more than the Case 2 due to the closeness of the crack to the end of the plate. The closeness of the crack to the end of the plate has a larger impact compared to the closeness to the hole of the plate. The same can be found from the change in the Beta function for different crack length.The comparison of the stress intensity factor of the similar crack in the single holed plate and double holed plate is made. The stress intensity factor for the crack close to the hole 1 is same in both the case. The stress intensity factor of the double holed plate varies as the crack from the hole 1 moves closer to the hole 2. The change in the stress intensity factor occurs only when the crack moves close to the hole 2. The deviation is more than 25% as it moves closer to the hole 2. The beta value is also found to provide the similar results.

5. REFERENCES:

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