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Finite Element Analysis of Crack

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Abstract:
The study of cracks comes under separate branch called as fracture mechanics. Fracture mechanics is an arrangement of theories depicting the behavior of solids or structures with geometrical discontinuity at the size of the structure. The cracks highlights might be line discontinuities in two dimensional media and surface discontinuities in three dimensional media. A crack that usually occurs in a structural member is a line which is of varying curvature. Therefore the stress in the region of crack varies from each point to other point. A part of the crack can be divided majorly into three main modes. Mode 1, Mode 2, & Mode 3. In this thesis the work has been carried out on mode 1 type of opening i.e. sliding mode. Here the design procedure has been automated in Visual Basic software to determine the stress intensities of a cracked plate at different points. And the analysis has also been done in STAAD.Pro and the comparison of results has been done.

Keywords: Fracture Mechanics, Geometrical discontinuity, Surface discontinuities, Visual Basic, Stress intensities,

I. INTRODUCTION

All engineering components and structures contain geometrical discontinuities threaded connections, windows in aircraft fuselages, keyways in shafts, teeth of gear wheels etc. the size and shape of these features are important because the determine the strength of the artefact. Conventionally, the strength of components or structures containing defects is assessed by evaluating the stress concentration caused by the discontinuity features. However such a conventional approach would give erroneous answers if the geometrical discontinuity features have very sharp radii. To illustrate this point, consider the following four cases:

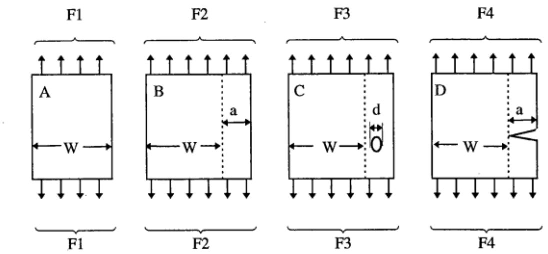

Figure.1.1 Strength of uncracked and cracked plates

The thickness of each plate is the same. The forces required to break the four samples can be arranged in the following order:
F4<F3<F1<F2
Fracture mechanics is a set of theories describing the behavior of solids or structures with geometrical discontinuity at the scale of the structure. The discontinuity feature may be in the form of line discontinuities in two dimensional media and surface discontinuities in three dimensional media. Fracture mechanics has now evolved into a mature discipline of science and engineering and has dramatically changed our understanding of the behavior of engineering materials. The common difference between a cracked body and an uncracked body is that the extra area interlinked with a crack. It is mandatorily known that creating a new (crack) area takes energies, because areas carry more energy than the body. Then it goes back on a thing that whether or not a stressed cracked body can be solid or not in solid position which is further dependent on the thing that the has sufficient energy to give rise to an extra area when it subjected under equilibrium.

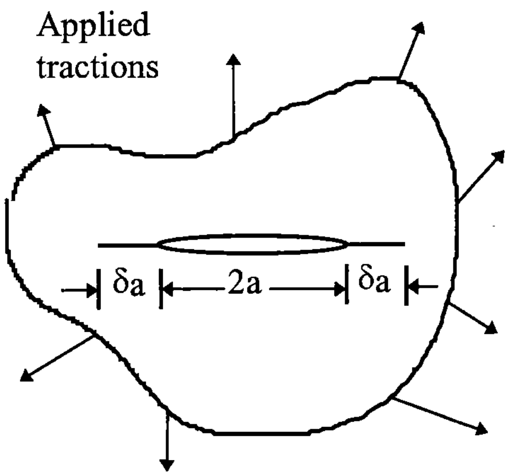

Figure.1.2 Equilibrium and vitality of cracked body

II. METHODOLOGY

2.1 DESIGN PROCEDURE

This chapter gives us the method adopted to perform the task and writing code for the analysis and obtaining the results according to a hypothesis. This task is carried out in two different steps. Firstly using a programme oriented software called as visual basic, a code is written for the cracked material with certain assumption made. Secondly a corresponding model is created in a structural software called STAAD and then the required properties are assigned and then analysed to get the results. Then the main aim was to check the stress intensity obtained in both the soft wares and to find the shape of the stress formed around the cracked tip and its comparison.

2.2 ANALYSIS USING VISUAL BASIC

Initially before writing the code for a required task it is important to do the preliminary studies on that content. There were three modes of cracks that occur which are classified as mode1, mode2, mode3, my concentration of study was only on the mode1. Since there is no much other difference in other two modes the only difference is that the plane of failure.

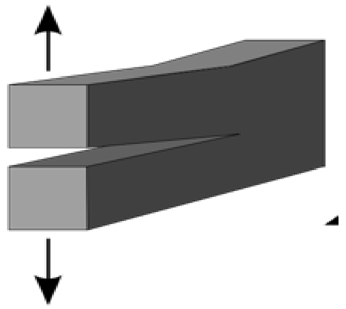

Figure.2.1 Mode 1 type of failure

There are many approaches have been done to find the intensities at a cracked material. But I have used a westergaard's approach and used the formulas given in this to determine the stress intensity, developed a programme for these formulas with required assumptions and properties.

$$\sigma_{11} = \frac{K}{(2*\pi*r)^\wedge 0.5} * \cos\frac{\theta}{2}\left(1 - \sin\frac{\theta}{2} * \sin\frac{3\theta}{2}\right)$$

$$\sigma_{12} = \frac{K}{(2*\pi*r)^\wedge 0.5} * \sin\frac{\theta}{2} * \cos\frac{\theta}{2} * \cos\frac{3\theta}{2})$$

$$\sigma_{22} = \frac{K}{(2*\pi*r)^\wedge 0.5} * \cos\frac{\theta}{2}\left(1 + \sin\frac{\theta}{2} * \sin\frac{3\theta}{2}\right)$$

In this the stress intensity are measured in terms of N/mm2.

Where, K= Stress intensity factor = $(\sigma * \pi * a)^\wedge 0.5$

Ɵ = Angle between the crack tip and point of interest.

R= Distance between the crack tip and reference point.

For these equations we develop a programme in visual basic and get the stress intensities and plot the graph for the corresponding.

2.3 ANALYSIS USING STAAD PRO

In this software the modelling has been done according to the required dimensions. The dimensions of the plate are 400*800 mm. The width of the crack given is 100 mm.

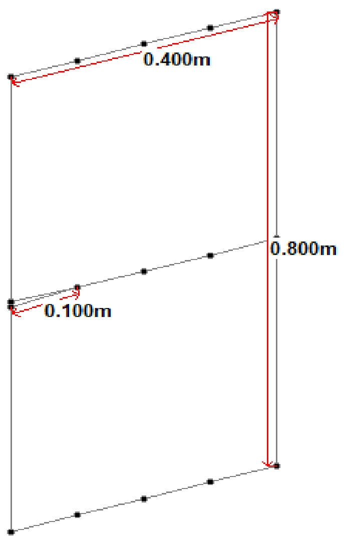

Figure.2.2 Modelling in STAAD

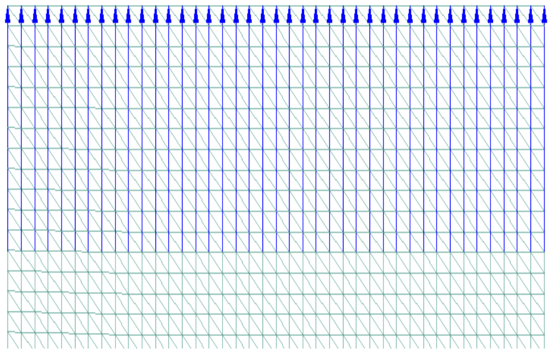

Figure.2.3 Loading of the model

Once the structural model is ready, it is then analyzed and the results are obtained. Since it is a plate material we will get different types of stress acting on the plate. According to different types of theories and the principle stress we obtain stresses in Major X and Y direction. So these stresses are mainly called as plate stresses.

III. RESULT AND DICUSSION

The following are the results obtained from the finite element analysis of cracks which is automated in visual basic and STAAD Pro. Results are drawn in tables and graphs, and based on the results following conclusion are obtained.

Table 3.1 Stress intensities in a plate for X=0 and varying depth (y coordinate).

x	y	σ_{11}	σ_{12}	σ_{22}
0	0	0.059	-0.059	0.178
0	10	0.06	-0.06	0.18
0	20	0.061	-0.061	0.182
0	30	0.062	-0.062	0.185
0	40	0.063	-0.063	0.188
0	50	0.063	-0.063	0.19
0	60	0.064	-0.064	0.193
0	70	0.065	-0.065	0.196
0	80	0.066	-0.066	0.199
0	90	0.067	-0.067	0.202
0	100	0.068	-0.068	0.205
0	110	0.07	-0.07	0.209
0	120	0.071	-0.071	0.213
0	130	0.072	-0.072	0.217
0	140	0.074	-0.074	0.221
0	150	0.075	-0.075	0.225
0	160	0.077	-0.077	0.23
0	170	0.078	-0.078	0.235
0	180	0.08	-0.08	0.24
0	190	0.082	-0.082	0.245
0	200	0.084	-0.084	0.252
0	210	0.086	-0.086	0.258
0	220	0.088	-0.088	0.265
0	230	0.091	-0.091	0.273
0	240	0.094	-0.094	0.281
0	250	0.097	-0.097	0.29

0	260	0.1	-0.1	0.301
0	270	0.104	-0.104	0.312
0	280	0.108	-0.108	0.325
0	290	0.113	-0.113	0.339
0	300	0.119	-0.119	0.356
0	310	0.125	-0.125	0.375
0	320	0.133	-0.133	0.398
0	330	0.142	-0.142	0.425
0	340	0.153	-0.153	0.459
0	350	0.168	-0.168	0.503
0	360	0.188	-0.188	0.563
0	370	0.217	-0.217	0.65
0	380	0.265	-0.265	0.795
0	390	0.375	-0.375	1.125
0	400	0.375	-0.375	1.125
0	410	0.375	-0.375	1.125
0	420	0.265	-0.265	0.795
0	430	0.217	-0.217	0.65
0	440	0.188	-0.188	0.563
0	450	0.168	-0.168	0.503
0	460	0.153	-0.153	0.459
0	470	0.142	-0.142	0.425
0	480	0.133	-0.133	0.398
0	490	0.125	-0.125	0.375
0	500	0.119	-0.119	0.356
0	510	0.113	-0.113	0.339
0	520	0.108	-0.108	0.325
0	530	0.104	-0.104	0.312
0	540	0.1	-0.1	0.301
0	550	0.097	-0.097	0.29
0	560	0.094	-0.094	0.281
0	570	0.091	-0.091	0.273
0	580	0.088	-0.088	0.265
0	590	0.086	-0.086	0.258
0	600	0.084	-0.084	0.252
0	610	0.082	-0.082	0.245
0	620	0.08	-0.08	0.24
0	630	0.078	-0.078	0.235
0	640	0.077	-0.077	0.23
0	650	0.075	-0.075	0.225
0	660	0.074	-0.074	0.221
0	670	0.072	-0.072	0.217
0	680	0.071	-0.071	0.213
0	690	0.07	-0.07	0.209
0	700	0.068	-0.068	0.205
0	710	0.067	-0.067	0.202
0	720	0.066	-0.066	0.199
0	730	0.065	-0.065	0.196
0	740	0.064	-0.064	0.193
0	750	0.063	-0.063	0.19
0	760	0.063	-0.063	0.188
0	770	0.062	-0.062	0.185
0	780	0.061	-0.061	0.182
0	790	0.06	-0.06	0.18
0	800	0.059	-0.059	0.178

This is table gives the value of stress intensities corresponding to different points on the plate, where x and y represent the position of the point where stress to be required.

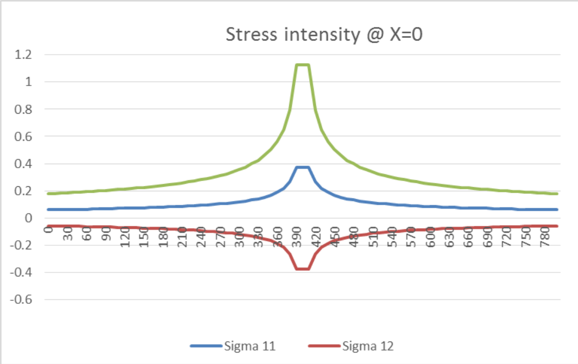

Figure.3.1 Graph of stress intensities v/s depth of plate. (y-coordinate) at X=0

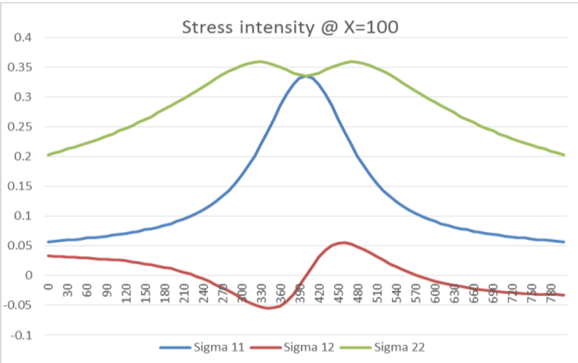

Figure.3.2 Graph of stress intensities v/s depth of plate (y-coordinate) at X= 100mm.

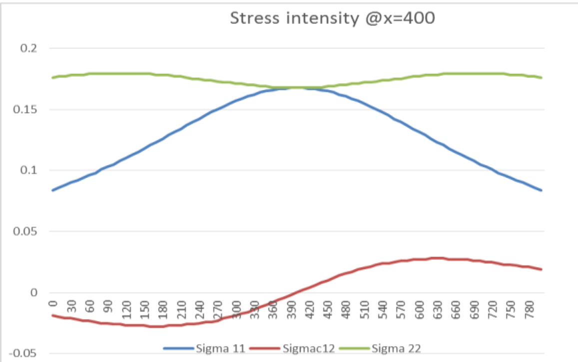

Figure.3.3 Graph of stress intensities v/s depth of plate (y-coordinate) at X= 400mm.

From graph we can observe that for a constant value of X=0 we get the stress intensities varying and it is noted that as the depth reaches near the crack tip the stress intensities reach their maximum value i.e. 1.125N/mm2 T a depth of Y = 400 mm, and again it goes decreasing linearly and maintains the constant stress intensity when it moves away from the crack. The red colour line in the graph indicates the shear acting on it and it reaches the maximum negative value near the crack phase. These above graphs are the result of stress intensities of varying x-direction i.e. at x= 100,400 mm. And we can conclude that maximum intensities obtained is at a point where the coordinates are (100,330). And it is equal to 0.359N/mm2. The above graphs showed the variation along depth with constant width. Now let us consider the results obtained for the constant values along the depth and varying width. In the same manner we obtain the similar results from the STAAD.Pro software where both the results obtained arein good agreement.

IV. ACKNOWLEDGEMENT

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V. CONCLUSIONS

- A summed up, friendly, stream outline and source code have been produced in Visual Basic for the finite element analysis of cracks.
- The main intention was to verify the stress contour formation around the crack tip in both the software which represents contour formation i.e. the stresses get aligned in the form of a butterfly.
- Since the maximum stress obtained in both analysis are different but the stress around the crack tip in both results are same.
- Both the results show maximum stress acting at the tip of the crack.
- In the same way the stress concentration will be more at crack tips in other two modes of failure in fracture mechanics. But the difference will be the shape of stress contour.
- These results are useful for a designer in many practical applications.
- The westergaard's approach used is not the general way of solving, but the problems of infinite plate are easier to solve since stress fields far from the crack are simple to solve.

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