CRACKED ENGINEERING MATERIALS UNDER IMPACT AND HIGH FREQUENCY LOADING

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ABSTRACT

This work explains about free vibration analysis of plates containing a single crack as the crack parameters (i.e. length , orientation and location) is varied. The influences of these parameters on the natural frequencies and the corresponding mode shapes are examined for several squared simply supported plates including internal crack or edge crack or corner crack. Vibration analysis for these plates is carried out using finite element method through ANSYS package version 18. It is found from present study that the length of the crack as well as its orientation and location are shown to have significant effects on the natural frequency and mode shape of the plates. Some new cases are also discussed in detail. The study is particularly useful in the understanding and offering a better insight into the free vibration of the plates with various crack configurations.

Keywords: crack, frequency, simply supported, clamped condition.

INTRODUCTION

Engineering structures are designed to withstand the loads they are expected to be subject while in service. Among them Rectangular plate and beams are a standout amongst the most usually utilized structural components within various structural elements in numerous engineering applications and experience a wide mixed bag of static and element loads. Rectangular plate and beams are widely used as structural components in engineering applications and also provide a fundamental model for many engineering applications. Aircraft wings, helicopter rotor blades, spacecraft antennae, and robot arms are all examples of structures that may be modelled with beam-like elements. Beam sort structures are being generally utilized in steel shaped structure and manufacturing of machines.

LITERATURE REVIEW

Structures experiences a wide variety of static and dynamic loads usually suffers from damages, its dynamic properties can change, especially crack damage can cause a reduction in stiffness, with an inherent reduction in natural frequencies, and a change of mode shapes. For vibrational analysis of cracked rectangular plate and beams and shafts, the fracture mechanics procedure is generally preferred.

Irwin (1957) **[1]** has explained the relation between the applied load and the strain energy concentration around the tip of crack. A crack on elastic structural member introduces considerable local flexibility due to strain energy concentration in the vicinity of crack tip under load. A local compliance has been used to quantify, in microscopic way, the relation between applied load and strain energy concentration around the tip of crack.

Qian et al. (1990) **[2]** developed a finite element model of an edge cracked beam. They have used finite element model to analyze the effect of crack closure in transverse vibration on beam. The stiffness matrix of the system has been deduced from stress intensity factors, and it gives two values, one for the closed crack (uncracked beam) and for the open crack. The sign of stress on crack has been used to determine the crack is open or close at each step of time.

Douka et al. (2005) **[3]** have investigated dynamic behavior of single breathing crack on cantilever beam both theoretically and experimentally. Empirical mode decomposition and Hilbert transform were used and instantaneous frequency was obtained. It was seen that instantaneous frequency oscillation revealed the breathing crack behavior. The crack size was detectable with the variation trend of frequency.

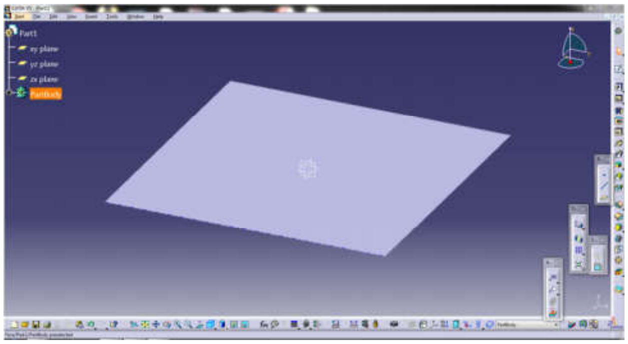
Chondros et al. (2001) [4] studied a continuous cracked beam vibration theory is used for the prediction of changes in transverse vibration of a simply supported beam with a breathing crack. The Eigen frequency changes due to a breathing edge-crack are shown to depend on the bi-linear character of the system. The changes in vibration frequencies for a fatigue-breathing crack are smaller than the ones caused by open cracks.

MODELLING

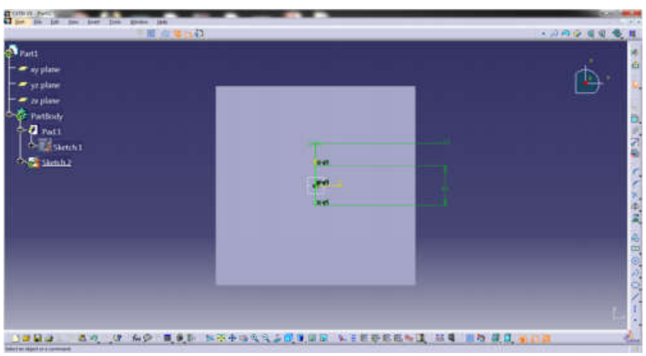
To create geometrical body, many softwares are available in the market like CREO, CATIA, UNIGRAPHICS, SOLID WORKS and IDEAS. We can create any complicated shapes which we consider using the above software commands.I

Initially sketch module is selected in CATIA software. which is user friendly module. in this we can draw the any shape of object and can give the required dimension after then we can modify it also. here rectangular command is used to create the plate. with is placed using origin of worksheet for future reference.

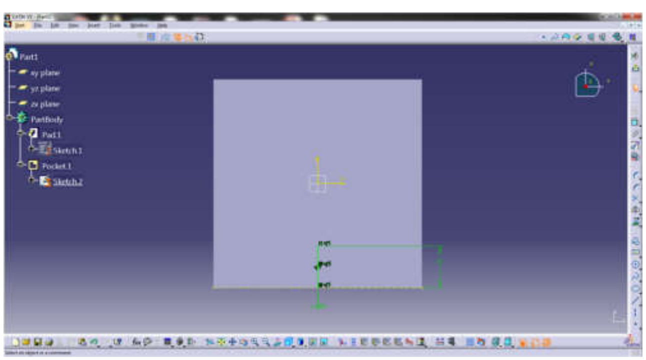
STEP 1 : Rectangular sketch created in catia whose width is 250mm



STEP 2: Internal crack c/a 0.2 is created using sketch



STEP 3: Edge crack c/a 0.2 created using sketch



ANALYSIS OF RECTANGULAR PLATE

The finite element method has become a powerful tool for the numerical solution of wide range of engineering problems. Applications range from deformation and stress analysis of automotive aircraft, building, and bridge structures to field analysis of heat flux, seepage and other flow problems, with advances in computer technology and CAD systems, complex problems can be modelled with relative ease.

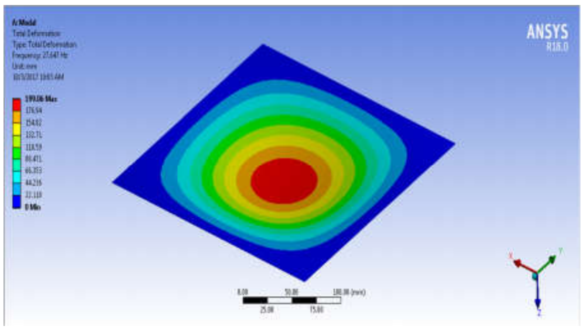
MODEL ANALYSIS

Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis.

Modal analysis is used to determine the natural frequencies and mode shapes of a structure. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. They are also required to do a spectrum analysis or a mode superposition harmonic or transient analysis. Another useful feature is modal cyclic symmetry, which allows reviewing the mode shapes of a cyclically symmetric structure by modelling just a sector of it.

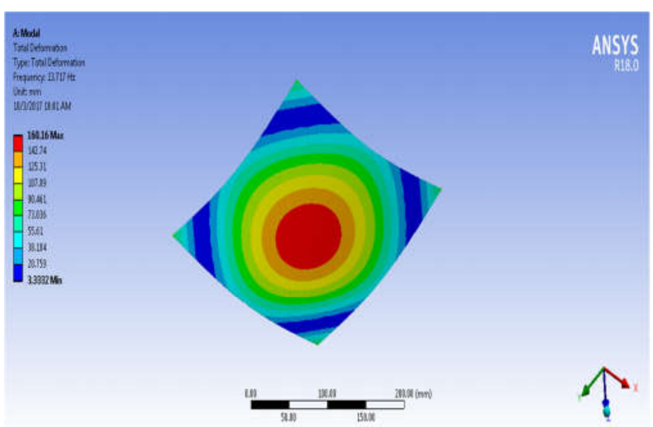
In our present work the following set of analysis are made for mode 1 only considering different cases of the plate.

Analysis 1: Rectangular plate model without crack condition and which is clamped on four sides is analysed for frequency.



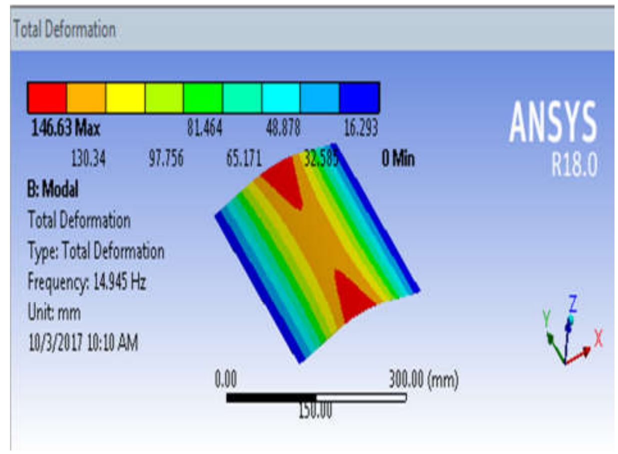
1st mode of without cracked rectangular plate (CCCC)

Analysis 2: Rectangular plate model without crack condition which is four edges are simply supported is analysed for frequency.



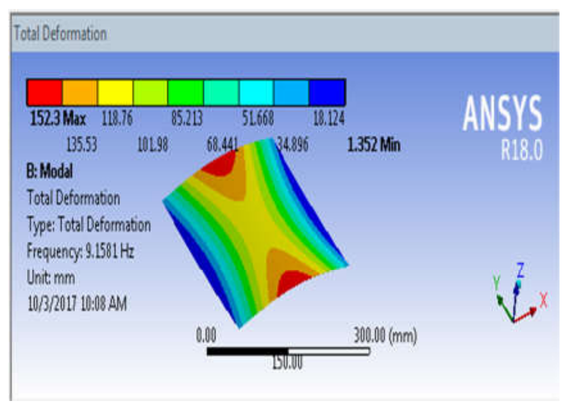
1st mode of without cracked rectangular plate (SSSS)

Analysis 3: Rectangular plate model without crack condition in which two edges are clamped is analysed for frequency.



1st mode of without cracked rectangular plate (CFCF)

Analysis 4: Rectangular plate model without crack condition in which two edges are simply supported is analysed.



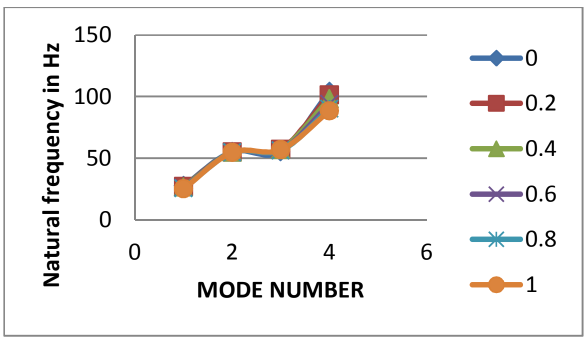
1st mode of without cracked rectangular plate (SFSF)

RESULTS AND DISCUSSIONS

Four edges are clamped support and centered crack results.

C-C-C-C different c/a ratio						
mode no	0	0.2	0.4	0.6	0.8	1
1	27.6	27	26.5	26	25.5	25.24
2	55.2	55	54.9	54.8	54.8	54.73
3	55.2	57.3	57.1	56.2	56.2	56.88
4	104	101.5	98.2	94	90.2	88.38

TABLE: Natural frequencies at different internal crack ratios

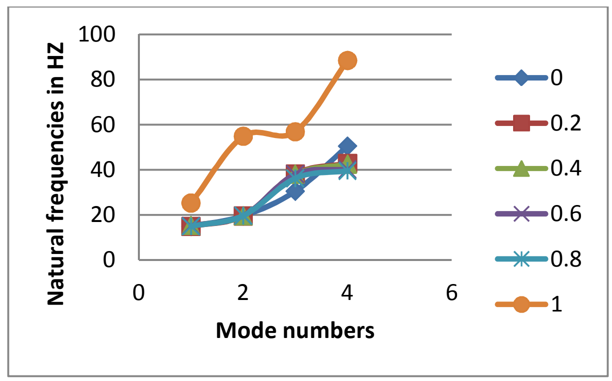


The above graph shows the natural frequencies of centered crack square plate with different crack to length ratio and CCCC supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value. if we increase the crack ratio of centered crack plate, natural frequencies decreases. nearly 15% of frequencies are reduces if we increase the crack ration.

Two oposite edges are clampe supported and centered crack results

C-F-C-F different c/a ratio						
mode no	0	0.2	0.4	0.6	0.8	1
1	14.9	14.9	15.2	15.1	14.9	14.951
2	19.5	19.5	19.5	19.608	19.608	19.608
3	30.5	38.2	38	38	36.2	37.951
4	50.4	42.8	42.4	40.1	39.5	38.58

Natural frequencies at different internal crack ratios



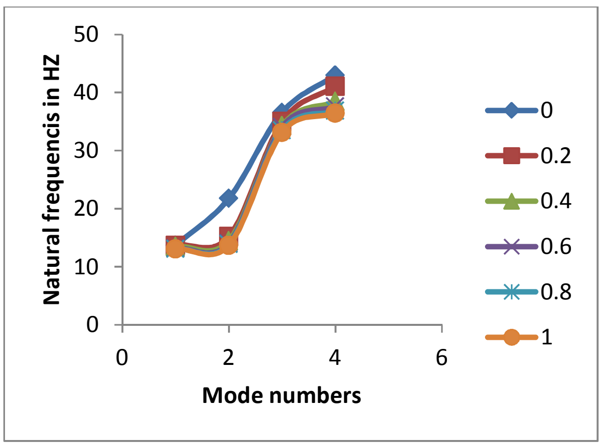
Natural frequencies at different internal crack ratios.

The above graph shows the natural frequencies of centered crack square plate with different crack to length ratio and SFSF supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. Here at crack ratio 1, we are getting more natural frequencies as compared to remaining crack lengths.

Four edges are simple supported and centered crack results.

S-S-S-S different c/a ratio						
mode no	0	0.2	0.4	0.6	0.8	1
1	13.7	13.7	13.5	13.2	13.1	13.097
2	21.79	15.2	14.5	14.1	13.9	13.72
3	36.6	35	34.3	34.1	33.5	33.16
4	43	41.1	38.5	37.6	36.9	36.45

Natural frequencies at different internal crack ratios

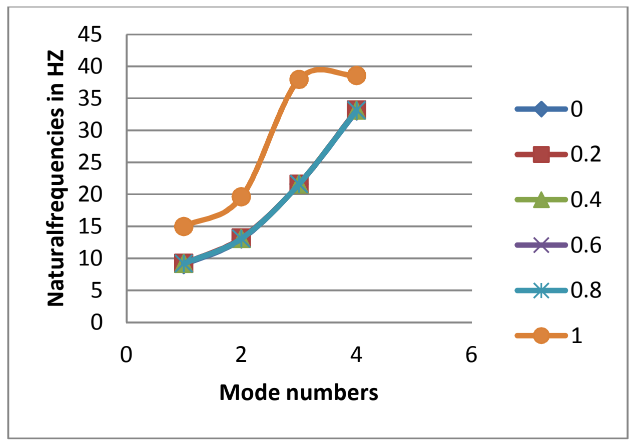


The above graph shows the natural frequencies of centered crack square plate with different crack to length ratio and SSSS supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value. if we increase the crack ratio of centered crack plate, natural frequencies decreases. nearly 15.23% of frequencies are reduces if we increase the crack ration.

Two oposite edges are simple supported and centered crack results

S-F-S-F different c/a ratio						
mode no	0	0.2	0.4	0.6	0.8	1
1	9	9.21	9.18	9.18	9.17	9.1598
2	13	13.2	13.1	13.1	13.1	13.097
3	21.6	21.6	21.6	21.6	21.6	21.6
4	33	33.2	33.18	33.15	33.12	33.104

Natural frequencies at different internal crack ratios

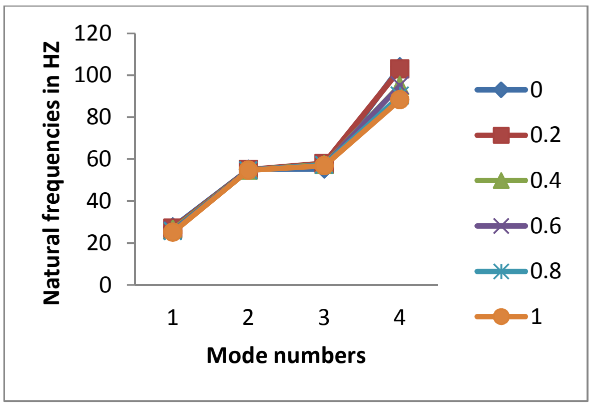


The above graph shows the natural frequencies of centered crack square plate with different crack to length ratio and SFSF supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value.

Four edges are clamped support and edge crack results

C-C-C-C different c/a ratio						
mode no	0	0.2	0.4	0.6	0.8	1
1	27.6	27.1	26.5	26	25.6	25.246
2	55.2	55	54.8	54.8	54.7	54.773
3	55.24	58	57.4	57.2	57.2	56.889
4	104	103	95.2	95.1	90.2	88.381

Natural frequencies at different Edge crack ratio

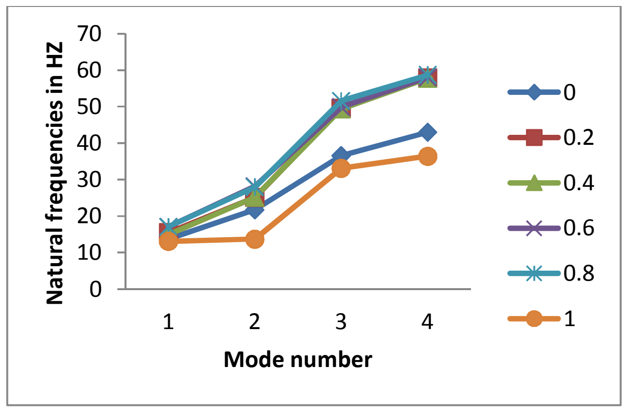


The above graph shows the natural frequencies of Edge crack square plate with different crack to length ratio and CCCC supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value. if we increase the crack ratio of centered crack plate, natural frequencies decreases. nearly 15% of frequencies are reduces if we increase the crack ration.

Four edges are simple supported and edge crack results

S-S-S-S different c/a ratio						
mode no	0	0.2	0.4	0.6	0.8	1
1	13.7	15.5	15	17.1	17.1	13.097
2	21.79	25.1	25.2	28.2	28	13.72
3	36.6	49.6	49.4	49.9	51.6	33.16
4	43	57.9	57.8	58	58.7	36.45

Natural frequencies at different Edge crack ratios

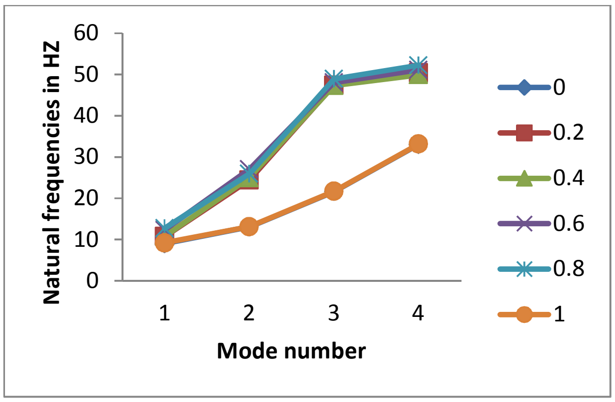


The above graph shows the natural frequencies of Edge crack square plate with different crack to length ratio and SSSS supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value. if we increase the crack ratio of centered crack plate, natural frequencies decreases. nearly 15.1% of frequencies are reduces if we increase the crack ration.

Two oposite edges are simple supported and edge crack results

S-F-S-F different c/a ratio						
Mode no	0	0.2	0.4	0.6	0.8	1
1	9	10.7	10.8	12.3	12.7	9.1598
2	13	24.4	25	27	25.9	13.097
3	21.6	47.4	47.3	48	48.9	21.669
4	53	50.39	49.9	51.1	52.2	33.104

Natural frequencies at different Edge crack ratios

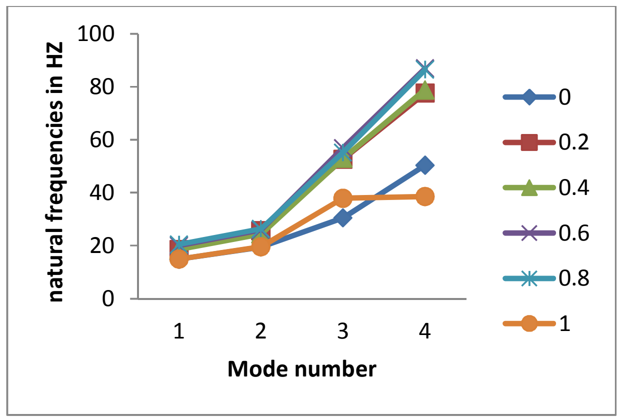


The above graph shows the natural frequencies of Edge crack square plate with different crack to length ratio and SFSF supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value. if we increase the crack ratio of centered crack plate, natural frequencies decreases. nearly 37% of frequencies are reduces if we increase the crack ration.

Two oposite edges are clamped supported and edge crack results

C-F-C-F different c/a ratio						
Mode no	0	0.2	0.4	0.6	0.8	1
1	14.9	18.6	18.6	20	20.5	14.951
2	19.5	25.7	24.4	25.9	26.4	19.608
3	30.5	52.7	53	56.9	55.2	37.951
4	50.4	77.59	78.8	86.9	86.47	38.58

Natural frequencies at different Edge crack ratios



The above graph shows the natural frequencies of Edge crack square plate with different crack to length ratio and CFCF supported. here X direction shows the frequency mode number. and Y direction shows the natural frequency in HZ. all natural frequencies are almost nearly same value. if we increase the crack ratio of centered crack plate, natural frequencies decreases. nearly 23% of frequencies are reduces if we increase the crack ration.

CONCLUSION

The presence of crack location, crack-edge ratio the analysis of dynamic properties of the plate is done by performing Modal Analysis. The following conclusions are drawn from the present investigation of simply supported plate, fixed plate and rectangular plate subjected to vibrate freely with simple cracks using Finite Element Method (FEM) in ANSYS 18.

- It is shown that the natural frequency changes substantially due to the presence of cracks. The frequencies of vibration of cracked plate decrease with increase of crack ratio due to reduction of stiffness for any particular crack location.
- The change in natural frequencies of structures depends on the location and size of cracks.
- When, the crack position shifts from the supported end to the center, the natural frequency decreases.
- The most significant conclusion is that the natural frequencies of plate decrease with increase in relative crack ratio.
- The mode shapes for different modes of vibration changes considerably due to the presence of crack.
- Clamped plate having more natural frequencies as compared to reaming supports.

From the above discussions, it is clear that cracks cause the reduction of natural frequency. The presence of cracks weakens the plate from the point of view of reduction in natural frequency. So cracks play a critical role on the vibration behavior of the structures. The vibration behavior of cracked plate is influenced by the geometry, location and size of cracks. The figures dealing with variation of the frequencies are recommended for identification of crack location and intensity circular and rectangular cross section beams. The vibration characteristics of the cracked plate can be used as a tool for structural health monitoring, identification of crack location and extend of damage in plate and also helps in assessment of structural integrity of the structures.

SCOPE FOR FUTURE STUDY

- Comparison of the analytical results of present analysis can be done with experimental results using Fourier Fast Transform (FFT) Analyzer
- The dynamic response of the cracked plate can be analyzed for different crack orientations.
- Stability study of the cracked plate can be done with three degrees of freedom per node.
- The cracked plate can be analyzed under the influence of external forces.

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