MODAL ANALYSIS OF CENTRAL CRACK STAINLESS STEEL PLATE USING ANSYS PROGRAM

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ABSTRACT
The purpose of this research is to detect the cracks in stainless steel plates. The modal analysis of free vibration on central crack plate was done. The finite element analysis was performed in ANSYS 18.2 program workbench. The final mesh was generated in square plate with total number of nodes and elements.

The plate was cracked on the central as a percentage of its length (10-40%), four cases of crack’s plates studies with different boundary conditions. The result of natural frequencies as a function of crack’s length was estimated for three modes. Finally, the prediction in cracks of stainless steel plates was done by study the various in dynamic response of structures which provide a benefit method to investigate central cracks in stainless steel plates.

Keywords: Modal analysis, FEM, crack’s length, stainless steel plate, natural frequency.
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1. INTRODUCTION
Plates are one of mostly structures have been used in many industries. Crack in the plate structure causes reduction in local stiffness therefore it reduces the plates strength. Any changes in the stiffness of structure have an influence in the modal parameters, such as natural frequencies and mode shapes. The natural frequencies and mode shapes are important parameters in the design of the plates structures for dynamic loading conditions. (Biancolini et al, 2005) performed free vibration of thin orthotropic plates where natural frequencies and mode shape were estimated. (Chen and Shen, 1993) the finite element analysis was applied on the cracked plate with verity of cracks. (M.L. Pavan et al, 2017) This finite element was performed in ANSYS and the vibration characteristic of problem was calculated in different boundary conditions. Many researchers (Refs. [5,6]) the free vibration was solved on
rectangle plates with mixed of different boundary conditions. (Frantisek and Josef, 2017) the natural frequencies and mode shapes of cracked rectangle plates were estimated using modal analysis in ANSYS. (Ramesh, 2003) the effect of the crack on the natural frequencies of plate studied. Recently, (Refs (8,9 & 10)) the crack length and it is location are factors effected on the natural frequencies of cracked plates.

2. MODEL DESCRIPTION
In this paper subspace method is used to find the first three natural frequencies and mode shapes for square cracked plate on the central with dimensions $30 \times 30 \times 0.1 \text{ cm}$ as shown in Figure 1.

![Figure 1 Plate with central crack parallel to x-axis.](image1)

To facilitate the modeling of two coincident faces, a very small opening of the crack needs to be created. A recommended geometry of the opening is shown in Figure 2.

![Figure 2 A small crack opening [12].](image2)

The material of model is Stainless Steel and the mechanical properties are given below in table.1.

<table>
<thead>
<tr>
<th>Table 1 Mechanical properties of Stainless Steel (ASME BPV Code, 1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Properties</strong></td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
</tr>
<tr>
<td>Tensile Yield Strength</td>
</tr>
<tr>
<td>Ultimate Tensile Strength</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
</tr>
</tbody>
</table>
The cracked square plate was performed in ANSYS 18.2 software with toolbox modal. The mesh was generated with total number of nodes and elements. The triangle element was performed in this analysis as shown in Figure 3.

![Figure 3 Mesh of crack’s plate by triangle elements.](image)

### 3. MODAL ANALYSIS

By using modal analysis the undamped equation is (Hussain, 2005)

\[
[M][\ddot{x}] + [k][x] = 0 \tag{1}
\]

The equation (1), (Ali, 2011):

\[
\ddot{x}_i = \ddot{X}_i \sin(n(\omega_i t + \alpha_i)), (i = 1, 2, 3, \ldots, n) \tag{2}
\]

By differentiating equation (2) twice with respect to \( t \), the mode shape can be:

\[
\dddot{x}_i = -\omega_i^2 \ddot{x}_i \sin(\omega_i t + \alpha_i) \tag{3}
\]

It can be eliminate the term \( \sin(\omega_i t + \alpha_i) \) by substituting equations (2) & (3) into (1) which leaves:

\[
([k] - \omega_i^2 [m])\ddot{x}_i = 0 \tag{4}
\]

From the theory of homogenous equations, the determinate of the coefficient matrix is equal to zero in order to find nontrivial solutions. Thus,

\[
|[k] - \omega_i^2 [m]| = 0 \tag{5}
\]

Expansion of the determinate in equation (5), this produced polynomial of order \( n \) called the characteristic equation (eigenvalues). Alternatively, any column of the adjoint matrix \([H_i^p]\) of the characteristic matrix \([H_i]\) used to find each eigenvector, estimated from equations (3&4), (Timoshenko et al, 2008) as follow:

\[
[H_i]\ddot{x}_i = 0 \tag{6}
\]

Where

\[
[H_i] = [k] - \omega_i^2 [m] \tag{7}
\]

equations (5), (6) & (7) are suitable to estimated structures with few number of degrees of freedom (DOF). However, In the present work, ANSYS 18.2 program is adopted to calculate the eigenvalues and eigenvectors of the system for large number of (DOF) using subspace method.
4. RESULTS
By using finite element analysis in ANSYS 18.2 program, the final mesh model was performed in stainless steel cracked plate with total number of 9370 nodes and 4436 elements. The crack propagation on the central was computed numerically as a function of plate's length (range 4 to 16 cm). Considering different boundary conditions, the results of natural frequencies of three modes with various crack length can be summarized in Table 2. The total deformation in first mode with various boundary on the cracked plates was studied as shown in Figure 4.

Table 2 The results of natural frequencies in cracked stainless steel plates for first three modes.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Hz</th>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( f_3 )</th>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( f_3 )</th>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( f_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Percentage</td>
<td>Length [cm]</td>
<td>C-C-C-C</td>
<td>C-F-F-F</td>
<td>F-C-F-C</td>
<td>C-F-F-F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>4</td>
<td>77.545</td>
<td>155.89</td>
<td>157.14</td>
<td>41.934</td>
<td>55.214</td>
<td>106.94</td>
<td>41.713</td>
<td>55.408</td>
<td>106.89</td>
</tr>
<tr>
<td>20%</td>
<td>8</td>
<td>82.052</td>
<td>170.59</td>
<td>173.62</td>
<td>43.536</td>
<td>58.937</td>
<td>115.72</td>
<td>42.909</td>
<td>57.166</td>
<td>111.27</td>
</tr>
<tr>
<td>30%</td>
<td>12</td>
<td>86.742</td>
<td>188.79</td>
<td>202.06</td>
<td>43.948</td>
<td>63.472</td>
<td>124.27</td>
<td>43.605</td>
<td>60.191</td>
<td>115.3</td>
</tr>
<tr>
<td>40%</td>
<td>16</td>
<td>93.555</td>
<td>206.09</td>
<td>220.54</td>
<td>47.194</td>
<td>68.011</td>
<td>138.6</td>
<td>44.617</td>
<td>67.058</td>
<td>123.85</td>
</tr>
</tbody>
</table>

(a) C-C-C-C with crack 20% of plate length  
(b) C-F-F-F with crack 20% of plate length  
(c) C-F-C-F with crack 20% of plate length  
(d) F-C-C-F with crack 20% of plate length

Figure 4 The total deformation through various boundary conditions.

Figures 6 and 7 shows the relation between natural frequencies and crack length for different boundary conditions for three modes.
Firas T. Al-Maliky and Dhurgham Aiham Kadhim Alshakarchi

(a) The crack length with natural frequency for three modes in C-C-C-C

(b) The crack length with natural frequency for three modes in C-F-C-F

(c) The crack length with natural frequency for three modes in F-C-F-C

(d) The crack length with natural frequency for three modes in C-F-F-F

**Figure 5** The effect of crack length with natural frequency for three modes with various clamped conditions.

(a) Crack Length with Natural Frequency for Mode 1

(b) Crack Length with Natural Frequency for Mode 2
5. CONCLUSIONS
An analytical model was proposed for internal crack started on the central and continuous in line parallel to the center of the plate. Based on the results of the study presented in this paper, the following conclusions could be made:

- Modal analysis showed that the presence of crack decrease the natural frequencies and increase peak amplitude. This decrease in frequencies is maximum when the crack is propagation to the direction of the edge plate and is minimum when the crack is near center plate.

- For all boundary conditions, the effect of (C-C-C-C) constraint increase natural frequency compared with the other conditions while the natural frequencies are similar in (C-F-C-F & F-C-F-C) and it is reduced in (C-F-F-F) condition.

- The total deformation is maximum in (C-C-C-C) compared with the other boundary conditions.

- From above cases it may be concluded that plate with crack 40% of plate's length and constraints from all edges (C-C-C-C) produced high natural frequencies for three modes in comparison with other boundary conditions.

REFERENCES


