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Health Monitoring For Cantilever Crane Frame Using Residual Error Method

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Abstract

In the present research, a crane frame has been investigated by using finite element method. The damage is simulated by reducing the stiffness of assumed elements with ratios (10% and 20 %) in mid- span of the vertical column in crane frame. The cracked beam with a one-edge and non-propagating crack has been used. Six cases of damage are modeled for crane frame and by introducing cracked elements at different locations with ratio of depth of crack to the height of the beam (a/h) 0.1, 0.20. A FEM program coded in Matlab 6.5 was used to model the numerical simulation of the damage scenarios. The results showed a decreasing in the five natural frequencies from undamaged beam which means the indication of presence of the damage. The direct comparison gives an indication of the damage but the location of the damage, is not detected. The method based on changes in the dynamics characteristics of the beam structures are examined and evaluated for damage scenarios. The results of the analysis indicate that the residual error method performs well in detecting, locating and quantifying damage in single and multiple damage scenarios.

Keywords: Damage, crack, damage location, beam, error, frequencies.

1. Introduction

In general, the structures are submitted during their useful life to deterioration processes that, depending on the intensity, may affect their performance and load capacity and consequently their safety. In this case, it is necessary to accomplish an inspection in order to evaluate the conditions of the structure and to locate and quantify the intensity of the damage. The ability to monitor a structure and detect damage at the earliest possible stage is of outmost importance in mechanical, civil and aerospace engineering communities. Structural damage is considered as a weakening of the structure that negatively affects its performance. Damage may be also defined as any deviation in the structural original geometric or material properties that may cause undesirable stresses, displacements, or vibrations on the structure. These weakening and deviation may be due to cracks, loose bolts, broken welds, corrosion, fatigue, etc. [1]. Many structural components are now decaying because of age, deterioration, and lack of maintenance or repair.

Current nondestructive damage detection (NDD) technique are either visual or are based on experimental methods. Visual inspection has always been the most common method used in detecting damage in a structure, but the size and degree of complexity of today's structures being built provide less scope for visual inspections. The experimental methods such as acoustic or ultrasonic techniques, magnetic field procedure, radiography, eddy current, etc. All of these experimental methods require that the damaged region be identified a priori, and that the segment of the structure being examined must be easily accessible, subjected to these limitations, these methods can detect on or near the surface of the structure. The methods are obviously "local" inspection approaches [2].

One way to overcome the previously mentioned limitations is by using global damage detection methods. Structural damage identification based on changes in dynamic characteristics provides a global way to evaluate the structural condition. These methods are based on the idea that modal parameters (i.e., natural frequencies, mode shapes and modal damping ratio) are a function of the physical properties of the structure stiffness, damping, mass and boundary conditions [3]. Therefore, changes in the physical properties will cause detectable changes for the changes in the modal parameters. The parameterized stiffness, damping and mass matrices of the finite element model are determined using input residuals in the frequency domain. In spite of common model reduction techniques, the Projective Input Residual Method serves for the adjustment of incomplete measured response data with regard to the number of degrees of freedom of the finite element model. The major advantage of the method is its sensitivity to modifications in system parameters, thus providing high prediction accuracy for the estimates of such parameters [4]. In this study, a method to identify and to quantify damage in structures, called Residual Error Method in the Movement Equation [5] is evaluated, by a numerical analysis, to verify its efficiency when applied to crane frame structures. This method is based on the alteration, produced by damage, in the dynamic properties of the structures. The location of the damage is done observing the error in the movement equation of the intact structures. The structures are discretized in finite elements and the damage is introduced by a stiffness and area reduction of the elements' cross-sections. Observing the obtained results, the Residual Error Method in the Movement Equation is efficient in the damage location and quantification of the studied structure.

2. Modeling the Stiffness Matrix of the Cracked Element

It is assumed that the damage in the beam structure will affect only the stiffness matrix and not to the mass matrix. This assumption is consistent with those used by [6] and [7].

The beam is divided into elements and the behavior of the elements located to the right of the cracked element regarded as external forces applied to the cracked element, while the behavior of elements situated to its left as constraints, see Fig.1. Thus the flexibility matrix of a cracked element with constraints can be calculated. The strain energy of undamaged element in case of bending [8] is:

$$W^{(0)}=\int_0^L \frac{M_1^2\,dx}{2EI} \qquad \ldots(1)$$

$$M_1=(px+M) \qquad \ldots(2)$$

Substitute Eq. (2) in (1) to get

$$W^{(0)}=\int_0^L \frac{(px+M)^2}{2EI}\,dx \qquad \ldots(3)$$

$$W^{(0)}=\frac{1}{2EI}\left[\frac{p^2L^3}{3}+pML^2+M^2L\right] \qquad \ldots(4)$$

Where:

$W^{(0)}$: The strain energy of undamaged element.

E : Elastic modulus.

I : Moment of inertia of undamaged element.

L : Length of the finite element.

p : Internal shear force at the right end of beam.

M : Internal bending moment at the right end of beam.

$$[K_u]=\frac{E\,I}{L^3}\begin{array}{ccccc} u_i & \theta_i & u_{i+1} & \theta_{i+1} & \\ 12 & 6L & -12 & 6L & u_i \\ & 4L^2 & -6L & 2L^2 & \theta_i \\ & & 12 & -6L & u_{i+1} \\ sym & & & 4L^2 & \theta_{i+1} \end{array}$$

$\ldots(5)$

The stiffness matrix of undamaged element $[K_u]$is the same that developed by [9] for undamaged beam element with rectangular cross-section given by Bernoulli-Eular theory has two nodes with two degreeof freedoms (2 d. o.f.s), $\{u,\theta\}$ at each node, as seen in Fig. 2, the mass matrix for anelement without crack is

$$[M_u]=\frac{\bar{m}L}{420}\begin{bmatrix} 156 & 22L & 54 & -13L \\ & 4L^2 & 13L & -3L^2 \\ & & 156 & -22L \\ sym & & & 4L^2 \end{bmatrix}$$

$\ldots(6)$

Where $\bar{m}$ is the mass per unit length. According to the principle of Saint-Venant, the stress field is affected only in the region adjacent to crack. However, the calculation of the additional stress energy of a crack has been studied in fracture mechanics and the flexibility coefficient expressed by a stress intensity factor can be derived by applying the Castigliano's theorem in linear-elastic range.

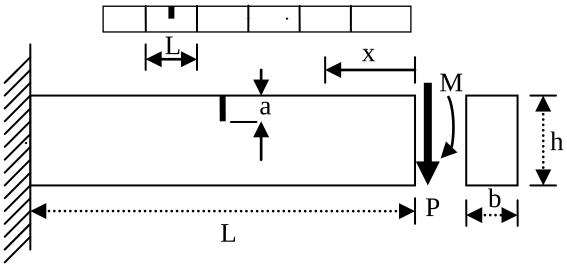


Fig.1. Diagram of a Generic Element.

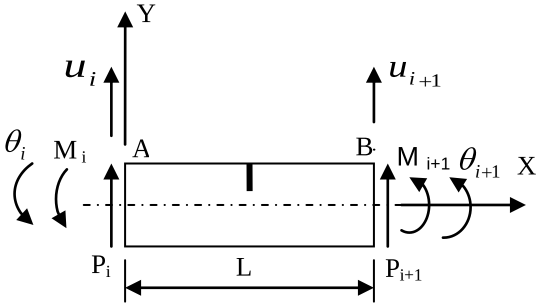


Fig.2. Equilibrium Condition of a Generic Element.

From the condition of equilibrium, the stiffness matrix of the cracked element in the free-free state can be derived. For a rectangular beam having width b and height h the additional strain energy $W^{(1)}$ due to the crack, [2] can be written as

$$W^{(1)} = \int_0^{Ac} \frac{\partial W^{(1)}}{\partial A} dA = \int_0^{Ac} J\, dA \qquad \ldots(7)$$

Where Ac is the area of the crack surface. The idea of relating J, strain energy release rate to the stress intensity factor K was proposed by [10] for the three modes, who gave the general formula of J as a function of stress intensity factor K as:

$$J = \frac{\beta}{E} K_I^2 + \frac{\beta}{E} K_{II}^2 + \frac{1+v}{E} K_{III}^2 \,,$$
$$\beta = \begin{cases} 1 & for\ plane\ stress \\ 1-v^2 & for\ plane\ strain \end{cases} \qquad \ldots(8)$$

Where K_I ,K_{II} ,K_{III} is the stresses intensity factors for fracture mode of I , II , III which are opening, sliding and tearing types respectively, and v is the Poisson's ratio. The stress intensity factor K_i is:

$$K_i = \sigma_i \sqrt{\pi a}\; F(a/h) \qquad \ldots(9)$$

Where σ_i is the stress for the corresponding fracture mode, a is the depth of the crack, $F(a/h)$ is the correction factor for the finite specimen. Substituting Eq. (8) into Eq. (7) gives the additional strain energy due to the crack $W^{(1)}$

$$W^{(1)} = b\int_0^a \left(\frac{(K_I^2 + K_{II}^2)}{E_p} + \frac{(1+v)K_{III}^2}{E} \right) da$$

where $dA = b \times da$ …(10)

$E_p = E$ For plane stress, $E_p = E/(1-v^2)$ for plane strain and b is the width of the beam.

The case of plane stress or plane strain, it depends on the dimensions of the beam, and this study take into account the plane stress since the beam is thin (slender) when the length is more than (10) times its least lateral dimensions [8].

Taking into account only bending including the opening (I) and sliding (II) modes, the Eq. (10) becomes;

$$W^{(1)} = b\int_0^a \left\{ \left[(K_{IM} + K_{IP})^2 + K_{IIP}^2 \right] / E_P \right\} da \qquad \ldots(11)$$

Where K_{IM}, K_{IP}, K_{IIP} are stress intensity factors for opening-type and sliding mode cracks due to M and P, respectively and by using Eq. (9)

$$K_{IM} = (6M/bh^2)\sqrt{\pi a}\;\; F_I\,(s)$$
$$\text{where} \quad \sigma = \frac{My}{I} = \frac{Mh/2}{bh^3/12} \qquad \ldots(12)$$

$$K_{IP} = (3PL/bh^2)\sqrt{\pi a}\;\; F_I(s)$$
$$\text{where} \quad \sigma = \frac{My}{I} = \frac{PL/2 \quad h/2}{bh^3/12} \qquad \ldots(13)$$

$$K_{IIP} = (P/bh)\sqrt{\pi a}\;\; F_{II}(s)$$

$$\text{where} \quad \sigma = \frac{P}{A} = \frac{P}{bh} \qquad \ldots(14)$$

Where $F_I(s)$ and $F_{II}(s)$ are the correction factors for crack mode I and mode II, $(s = a/h)$ is defined as the ratio between the crack depth a and the height of the element h, the correction factor from [7] as

$$F_1(s) = \sqrt{(2/\pi s)\tan(\pi s/2)} * \frac{0.923 + 0.199[1-\sin(\pi s/2)]^4}{\cos(\pi\ s/2)} \quad \ldots(15)$$

$$F_{II}(s) = (3s-2s^2)\frac{1.122 - 0.561s + 0.085s^2 + 0.18s^3}{\sqrt{1-s}} \quad ...(16)$$

And the additional flexibility coefficients due to the presence of the crack $C_{ij}^{(1)}$ are

$$C_{ij}^{(1)} = \frac{\partial^2 W^{(1)}}{\partial P_i \partial P_j} \quad \ldots(17)$$

$P_1 = P, \quad P_2 = M, \qquad i, j = 1,2$

Substituting Eq. (11) into Eq. (17) and integrate over the crack height, we get the coefficients $C_{ij}^{(1)}$ which can be expressed in matrix form as

$$\left[C^{(1)}\right] = \frac{b\pi a^2}{E_p}\begin{bmatrix} 9\beta_1^2 L^2 + \beta_2^2 & 18\beta_1^2 L \\ 18\beta_1^2 L & 36\beta_1^2 \end{bmatrix} \quad \ldots(18)$$

Where

$\beta_1 = F_1(s)/bh^2$ and $\beta_2 = F_{II}(s)/bh$

The total flexibility coefficients C_{ij} for the element with an open crack are

$$C_{ij} = C_{ij}^{(0)} + C_{ij}^{(1)} \quad \ldots(19)$$

The total flexibility matrix $[C]$ for the element with an open crack can be expressed as

$$[C] = \left[C^{(0)}\right] + \left[C^{(1)}\right] \quad \ldots(20)$$

The stiffness matrix of the cracked element $[K_c]$ can be written as

$$[K_c] = [T][C]^{-1}[T]^T \quad \ldots(21)$$

With program coded in Maple **7**, the coefficients of the stiffness matrix $[K_c]$ are calculated as

$$[K_c] = \begin{bmatrix} k_{11} & k_{12} & k_{13} & k_{14} \\ k_{21} & k_{22} & k_{23} & k_{24} \\ k_{31} & k_{32} & k_{33} & k_{34} \\ k_{41} & k_{42} & k_{43} & k_{44} \end{bmatrix} \quad \ldots(22)$$

$$[K_C] = \begin{bmatrix} k_{11} & k_{12} & -k_{11} & k_{14} \\ k_{12} & k_{22} & -k_{12} & k_{24} \\ -k_{11} & -k_{12} & k_{11} & -k_{14} \\ -k_{14} & k_{24} & -k_{14} & k_{22} \end{bmatrix} \quad \ldots(23)$$

The coefficients values of the matrix $[K_C]$ calculated as in appendix A

3. Eigenvalues and Eigenvectors

For free vibration with undamped system, the equation of motion expressed by matrix form is

$$[M]\left\{\ddot{x}\right\} + [K]\{x\} = \{0\} \quad ...(24)$$

Where:

K: Stiffness matrix of the system.

M: Mass matrix of the system.

$\{x\}$: Mode shape vector.

$$M\ddot{X} + KX = 0 \quad \ldots(25)$$

By using Eigen Value Problem algorithm EVP, the natural frequencies and mode shapes are obtained.

4. Residual Error Method in the Moment Equation

The residual error method in the movement equation was proposed by [5]. This method is used to identify damage present in a structure and locate it by observing the error present in the movement when the stiffness and mass matrices of the undamaged beam and the modal parameters of damaged beam in the crane frame are used.

$$E_r = [K_u][x^*] - ([M_u][x^*])[\Lambda^*] \qquad ...(26)$$

Where:

$$E_r = [e_1\ e_2\ e_3\ e_4.........e_n] \qquad ...(27)$$

$$[x^*] = [\{x^{(1)^*}\}\{x^{(2)^*}\}\{x^{(3)*}\}...........\{x^{(n)^*}\}...(28)$$

$$[\Lambda^*] = \begin{bmatrix} \omega_1^{2*} & 0 & \dots & 0 \\ 0 & \omega_2^{2*} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \omega_n^{2*} \end{bmatrix} \qquad ...(29)$$

K_u : Stiffness matrix of undamaged beam.

M_u : Mass matrix of the undamaged beam.

$\{x^*\}$: damaged mode shape vector.

$[\Lambda^*]$: Diagonal natural frequencies.

Each column of matrix E_r is a vector corresponding to one mode shape and each value of this vector represents the error that occurs in some positions of the beam, then the highest error will indicate the damage position to a mode shape. This method has been applied for the scenarios which listed in Table 2.

5. Crane Frame

A crane frame has been used to study the damage effect on modal parameters (frequencies and mode shapes).

The free vibration of a crane frame with and without damage is performed. Modal responses of the crane frame are generated using finite element models before and after damaging episode cases. The dimensions and material properties of the crane steel frame are listed in Table 1 and Fig .3 illustrates the model of the crane frame.

Table 1,
Dimensions and Material Properties for Crane Frame.

Vertical column	L_v = 254 cm
Horizontal column	L_h =127 cm
Cross section width	b = 5.08 cm
Cross section Height	h = 12.7 cm
Elastic modulus	E = 199.95 GPa
Mass density	ρ = 7808 kg / m^3

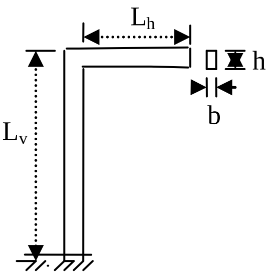


Fig. 3. Crane Frame.

For Finite Element Analysis purposes, the vertical column in the crane frame is divided into 40 elements and the horizontal column divided into 20 elements. Here, six damage scenarios are investigated, as summarized in Table 2. In the first two cases (1, 2), the damage is simulated by reducing the stiffness of assumed elements (21). In cases (3 to 6), the damage is simulated in the form of cracks. The finite element model of the beam uses the stiffness matrix of the cracked element described in Eq. (30) as in appendix A.

Table 2,
Damage Scenario for Crane Frame

Damage scenario	Damaged Position in vertical column	Stiffness Reduction (%)	Crack depth ratio a/h
Case1	21~ (0.5L)	10	
Case2	21~ (0.5L)	20	
Case3	21~ (0.5L)		0.1
Case4	21~ (0.5L)		0.20
Case5	5~(0.125 L),25~ (0.625L)		0.1
Case6	5~(0.125L),25~ (0.625L)		0.20

6. Results and Discussion

The results for the first five frequencies are listed in Table 3 for the damage scenarios considered in Table 2 for crane frames.

The results of the proposed method for the damage scenarios case1 and case2 are shown in Fig. 4 as in (a) and (b) is calculated using only two modes shapes. The peak occur at damage location for crane frame with reduction in stiffness ratio in (a) and (b) for single damage scenario and its observed that the peak became larger when the damage ratio 20% in case 2 which is the location of damage. (c) , (d) And (e) shows the damage location for single crack, as expected, the error are larger in case 4 damage, since this correspond to a larger crack depth for the same cross section for the three modes.

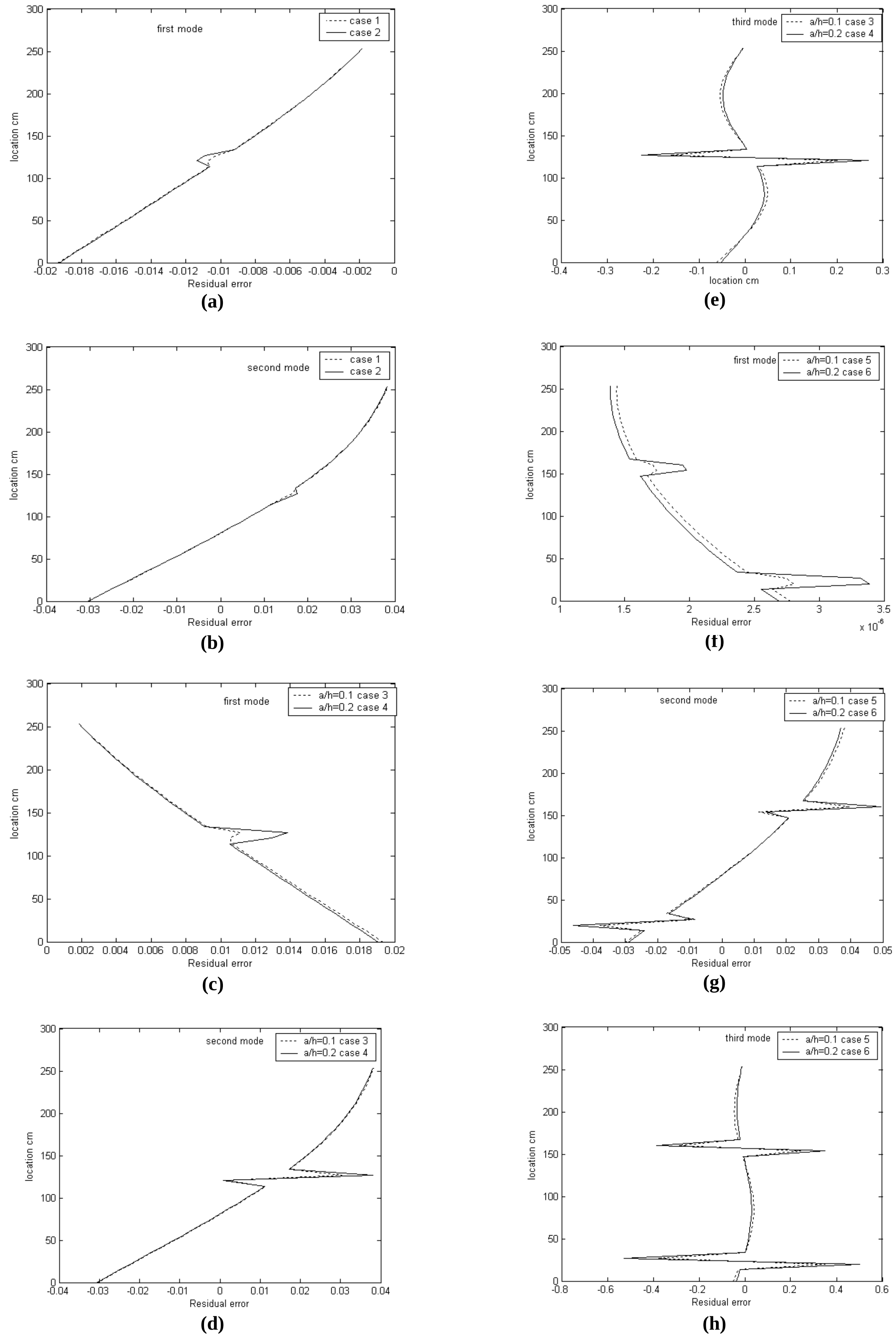
When two cracks are induced in the vertical column in crane frame (damage scenarios case 5 and case 6), the proposed method is capable of detecting the location of the two cracks, as evidenced by the peaks as shown in (f) , (g) and (h) and its also the peak became bigger for crack ratio a/h = 0.2 in case 6. For the cases 5 and 6 when the two cracks induced, the peak which is near the fixed end is bigger than the other one which is far away from the fixed end and this because the maximum bending in the fixed end. From the results above, the residual error method is a good method to detect the location of the damage especially for multiple damage case compared with other methods failed to detect the multiple damage for frames or for simple beam like the Damage Detection from Changes in Curvature Mode Shapes method in [3]. As in Fig.5 the curvature at a point of an element with bending deformation, is given by:

$$\upsilon'' = \frac{M}{EI}$$

In which υ'' is the curvature at a section, M is the bending moment at a section, E is the modulus of elasticity and I is the second moment of the cross-sectional area. the Residual Error Method in the Movement Equation is efficient in the damage location and quantification of the studied structures because the method that depend on the curvature mode shape didn't detect the two region of damage in the first mode shape because its clear one large peak as in Fig.5 (k), which detect the damage and in the second mode shape as in Fig. (L), there is two peaks, one of them large and the other small but in the third one the two peaks of damage are more clear than the second as in the Fig (m).

Table 3,
Natural frequencies of the crane frame

Damage Scenario	**Natural Frequency (rad/sec)**									
Present Undam-aged	**Mode 1**	**Discrep-ancy %**	**Mode 2**	**Discrep-ancy %**	**Mode 3**	**Discre-pancy %**	**Mode 4**	**Discre-pancy %**	**Mode 5**	**Discr-epancy %**
	54.6114	0	221.336	0	644.429	0	$1.5358*10^3$	0	$1.7672*10^3$	0
Case 1	54.5540	0.105	221.252	0.037	643.238	0.184	$1.5353*10^3$	0.032	$1.7657*10^3$	0.084
Case 2	54.4824	0.236	221.147	0.085	641.767	0.413	$1.5346*10^3$	0.078	$1.7638*10^3$	0.192
Case 3	54.4999	0.204	221.019	0.143	642.151	0.353	$1.5124*10^3$	1.523	$1.6916*10^3$	4.277
Case 4	54.2499	0.661	220.464	0.393	636.371	1.25	$1.5017*10^3$	2.22	$1.6737*10^3$	5.29
Case 5	54.2258	0.706	220.401	0.422	641.264	0.491	$1.4576*10^3$	5.09	$1.6284*10^3$	7.854
Case 6	53.2267	2.535	218.413	1.32	633.918	1.631	$1.4189*10^3$	7.611	$1.6053*10^3$	9.16



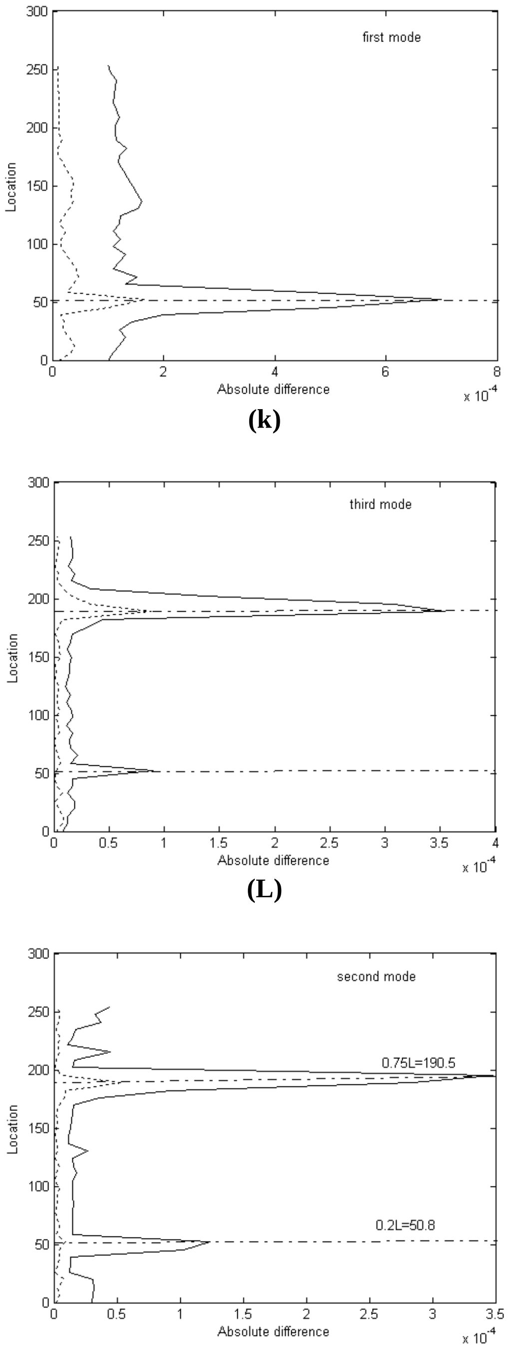
(a) **(e)**

(b) **(f)**

(c) **(g)**

(d) **(h)**

Fig.4. Residual Error Method for the Two and Three Modes of the Crane Frame.



(k)

(L)

(m)

Fig.5. Absolute Difference Curvature Mode Shape Method for Crane Frame for the First, Second and Third Mode.

7. Conclusion

The main conclusions from the present work according to the adopted data may be stated as follows:

1- Based on assumption that the damage will change the stiffness reduction only and the mass of the beam be consistent, the increased severity of the damage will decrease the frequencies of the damaged beam.

2- It’s observed that, the damage representation as stiffness reduction 20% is not equal to the damage represented by crack ratio 20%, accordingly it is obvious that the crack is more sensitive than stiffness reduction in representing the damage.

3- Changes on natural frequencies give the indication of damage but it can’t detect the location of the damage.

4- The residual error method performs well in detecting, locating and quantifying the damage in single and multiple damage scenarios.

5- The residual error increased in value with the increasing of the damage ratio.

6- The residual error peak is batter clear when it’s near the region with maximum bending moment.

Nomenclature

$W^{(0)}$	The strain energy of undamaged element.
E	Elastic modulus
I	Moment of inertia of undamaged element.
L	Length of the finite element
p	Internal shear force at the right end of beam.
M	Internal bending moment at the right end of beam.
K_{IM}, K_{IP}, K_{IIP}	stress intensity factors for opening-type and sliding mode cracks due to M and P
$[K_c]$	The stiffness matrix of the cracked element
$\bar{m}$	The mass per unit length
a	The depth of the crack
$[C]$	The total flexibility matrix for the element with an open crack
ν	The Poisson's ratio
σ_i	The stress for the corresponding fracture mode
Ac	The area of the crack surface

$[K_u]$	The stiffness matrix of undamaged element
J	The strain energy release rate
$[M_u]$	The mass matrix for an element without crack
K	Stiffness matrix of t he system
M	Mass matrix of the system.
$\{x\}$	Mode shape vector
EVP	Eigen Value Problem algorithm
K_u	Stiffness matrix of undamaged beam
M_u	Mass matrix of the undamaged beam
$\{x^*\}$	damaged mode shape vector
$[\Lambda^*]$	Diagonal natural frequencies
E_r	A vector corresponding to one mode shape and each value of this vector represents the residual error

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Appendix A : Stiffness Matrix of Cracked Element

$$k_{11} = 12 \frac{E\,I\,E_P}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2}$$

$$k_{12} = 6 \frac{E_P\,E\,I\,L}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2}$$

$$k_{13} = -12 \frac{E\,I\,E_P}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2} = -k_{11}$$

$$k_{14} = 6 \frac{E_P\,E\,I\,L}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2}$$

$$k_{21} = k_{12}$$

$$k_{22} = 4 \frac{(L^3\,E_P + 27 b\pi\,a^2\,EI\,\beta_1{}^2 L^2 + 3\,b\pi\,a^2\,E\,I\,\beta_2{}^2)EI\,E_P}{(L\,E_P + 36 b\pi\,\beta_1{}^2\,a^2\,E\,I)(L^3\,E_P + 12\,b\pi\,a^2\,E\,I\,\beta_2{}^2)}$$

$$k_{23} = -6 \frac{E_P\,E\,I\,L}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2}$$

$$k_{24} = 2\,\frac{(L^3\,E_P + 54 b\pi\,a^2\,EI\,\beta_1{}^2\,L^2 - 6\,b\pi\,a^2\,E\,I\,\beta_2{}^2)EI\,E_P}{(L\,E_P + 36 b\pi\,\beta_1{}^2\,a^2\,E\,I)(L^3\,E_P + 12\,b\pi\,a^2\,E\,I\,\beta_2{}^2)}$$

$$k_{31} = k_{13} = -k_{12}$$

$$k_{32} = k_{23}$$

$$k_{33} = k_{11} = 12 \frac{E\,I\,E_P}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2}$$

$$k_{34} = -6 \frac{E_P\,E\,I\,L}{L^3\,E_P + 12 b\pi\,a^2\,E\,I\,\beta_2{}^2} \quad = -k_{14}$$

$$k_{41} = k_{14}$$

$$k_{42} = k_{24}$$

$$k_{43} = k_{34} = -k_{14}$$

$$k_{44} = 4 \frac{(L^3\,E_P + 27 b\pi\,a^2\,EI\,\beta_1{}^2 L^2 + 3\,b\pi\,a^2\,E\,I\,\beta_2{}^2)EI\,E_P}{(L\,E_P + 36 b\pi\,\beta_1{}^2\,a^2\,E\,I)(L^3\,E_P + 12\,b\pi\,a^2\,E\,I\,\beta_2{}^2)} = k_{22}$$

Therefore:

$$[K_C] = \begin{bmatrix} k_{11} & k_{12} & -k_{11} & k_{14} \\ k_{12} & k_{22} & -k_{12} & k_{24} \\ -k_{11} & -k_{12} & k_{11} & -k_{14} \\ -k_{14} & k_{24} & -k_{14} & k_{22} \end{bmatrix} \qquad ...(30)$$

مراقبة الصحة في الهيكل الرافعة بإستعمال طريقة الخطأ المتبقي

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الخلاصة

في هذا البحث تم دراسة الهيكل البابي باستخدام طريقة العنصر المحدد. الضرر قيم بتخفيض متانه العناصر المفترضة وذلك بنسبة 10 % و20 % في وسط العتبة العموديه في الهيكل الرافعة. العتبة المشقوقة المستخدمة ذات شق واحد بالحافة بدون تقدم للشق. إنّ الضرر(Damage) يتمثل بستة حالات في الهيكل الرافعة وكذلك يتمثل عن طريق شق عمودي في العناصر المفترضة في المواقع المختلفة بنسبة عمق الشقّ إلى إرتفاع العتبه (a/h) 0,10و 0,20 لنفس العتبة في الهيكل الرافعة. تم استخدام برنامج Matlab5،6 لتمثيل المحاكاة العددية لسينيوهات الضرر. اظهرت النتائج نقص في الترددات الطبيعية الخمسة نسبه للعتبه السليمه و الذي هو إشارة لوجود الضرر. تعطي المقارنة المباشرة إشارة الى وجود الضرر لكن موقع الضرر غير محدد. الطريقة المحدده لايجاد الضرر التي تم استخدامها هي مستندة على التغييرات في خصائص ديناميكة تراكيب العتبة و الطريقة فحصت وقيّمت حالات الضرر. نتائج التحليل تشير إلى ان طريقة الخطأ المتبقي Residual error تعمل بصورة جيدة في إكتشاف وتحديد مكان الضرر في سيناريوهات الضرر damage scenarios الوحيدة الموقع والمتعدّد المواقع.