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Experimental investigation on amplitude-frequency dependence of C-S-C-S rectangular plate 2nd mode shape

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***Abstract*—The theoretical of Benamar's method that based on Hamilton's principle and spectral analysis, has extended to study first and second mode shape of clamped-clamped beams in order to investigate dependence between the nonlinear fundamental frequencies, nonlinear mode shapes and the nonlinear bending stress. This model used and applied to investigate the dynamic behavior of fully clamped rectangular plates and of C-S-C-S and C-S-S-S rectangular plates, which published previously by Z.Beidouri. The amplitude frequency dependence has been investigated experimentally in part I carefully in case of C-S-C-S of the first mode shape and compared with those obtained numerically. This paper will explain the identification of the second mode shape and discuss the results obtained experimentally of the amplitude frequency dependence in the case of C-S-C-S rectangular plate. The transverse harmonic vibration has been provided by an electrodynamic exciter that excited the rectangular plate at the center near the second resonance frequency which allowing to identify the second mode shape and investigate the amplitude frequency dependence.**

Keywords—*second mode shape; resonance frequency; experimental study; geometrically nonlinear; nonlinear dynamic behavior.*

I. INTRODUCTION:

Mechanical structural like speed machines and thin structures are subject to vibrate under external vibration, which excites these structures, and the linear theoretical is no longer valid for determining all dynamic parameters. The presence of this phenomenon could have a significant impact on the structural and, hence, the service life of these structures [1].

Determination both of linear and nonlinear natural frequencies with associated mode shapes and bending stress are essential in structural dynamic analysis in order to design the efficient machines. The external vibrations loading and services condition may cause large displacements and rotations that lead to considerable pre-stress states in the structure. Consequently, the modal behavior of structures is evidently a property of the equilibrium state, natural frequencies are subjected to change. The vibration of thin structures have been widely studied by scientists and researchers, but the effects of geomerically nonlinearity remaind misunderstood, Benamar attempted to explain that and to give a mathematical model of that phenomenon, this model based on Hamilton's principle and spectral analysis that applied on beams [2] with various boundary conditions and fully clamped rectangular plates [3] and which valide experimentally in reference[4]. In the light of this model, the second mode shape has been investigated numerically at large vibration amplitudes free vibration [5] [6].

The present work concerns to identify, determine the resonance frequency and investigate the amplitude frequency dependence on the second mode shape in the case of C-S-C-S rectangular plate, which has been investigated numerically for the first mode shape free vibration [7].

The experimental study has made by exciting harmonically the rectangular plate at the center using an electrodynamic exciter that signal provides by a sine wave generator and amplified by a power amplifier which allowing to vary the vibration amplitudes in order to investigate the amplitude frequency.

II. Experimental Modal Analysis:

The experimental investigation is applied on the rectangular plate C-S-C-S boundary conditions as illustrated in fig.1. A thin elastic isotropic rectangular plate was excited harmonically at large vibration amplitudes at the coordination (x*,y*)=(0.5,0.5) of the plate. We summarize below the mechanical properties of the RP tested are used as input to the modeling:

- Material: Aluminum alloy
- Young Modulus: 7x1010 N/m2
- Density: 2410 kg/m3
- Poison modulus: 0.346
- Length (a): 240mm
- With (b): 360mm
- Thickness: 0.6mm
- Aspect Ratio (α=a/b): 0.66

A. *Experimental details:*

In order to prepare a C-S-C-S boundary conditions for the rectangular plate undergoing modal analysis, shown in fig.1 the plate (2) is placed between four boundary conditions (3,4) attached to a heavy structure (1), which minimizes the external vibrations. An electrodynamic exciter (shaker) excites the rectangular plate at the center and an accelerometer is attached to the test plate.

Fig.1: Diagrammatic layout of test rig

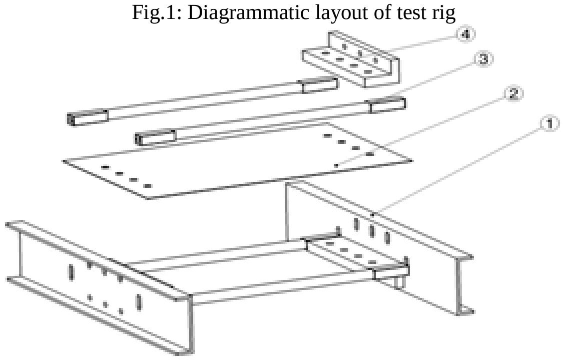
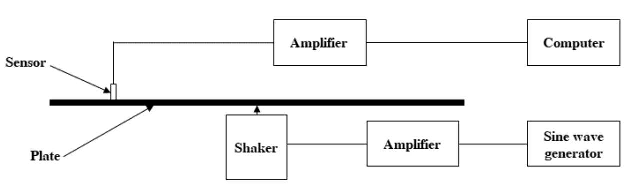


Fig.2 shows an overall schematic diagram of the experimental apparatus, the harmonic signal is generated by a sine wave generator, which that signal is amplified using power amplifier in order to excite the plate by the shaker and the response dynamic is measured by an accelerometer, finally treated using StudiVib software.

Fig.2: The experimental apparatus



B. *Identification the second mode shape:*

In this section, discusses the identification of the second mode shape in order to know coordination of the maximum vibration amplitudes that lead to investigate the amplitude frequency dependence.

This mode has identified using Benamar's model in the case of C-S-C-S rectangular plate which discussed referring to the thesis [8], which has been successfully applied to fully clamped rectangular plates [4,5].

Figure 3 illustrates the second mode shape obtained numerically in the case of C-S-C-S boundary conditions using MATLAB software [8] which obtained at 102.96Hertz corresponding to the fundamental resonance frequency, while for the experimental resonance frequency is obtained at 88Hertz. The difference due to the add mass of the accelerometer that glued on the plate.

Fig.3: Normalized of the second non-linear mode of rectangular plate, y*=0.5

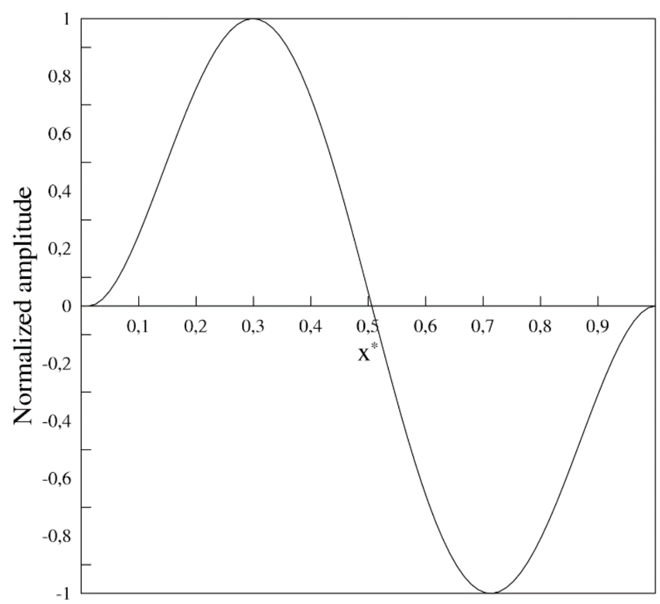
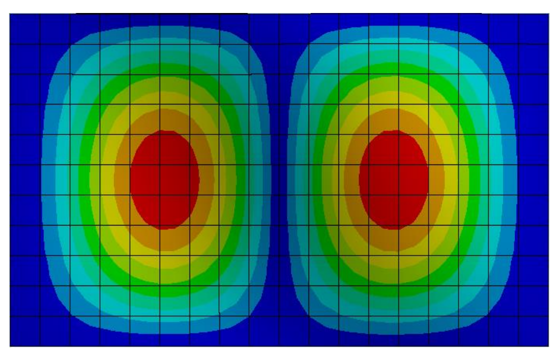


Fig.4: Finite element method of second mode shape.



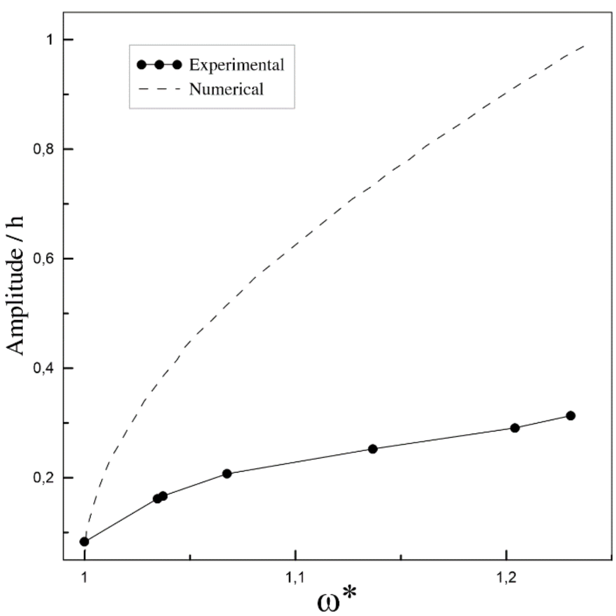
III. Amplitude Frequency Dependence

The second mode shape has identified experimentally by exciting the plate with the amplitude fix and changing the excitation frequencies gradually beyond the first fundamental resonance corresponding to the first mode shape. The maximum vibration amplitude is measured near the coordinates (x*,y*)=(0.75,0.5) for a normalized section.

The amplitude frequency dependence of the second mode shape for isotropic rectangular plate with the same ratio equal to 0.66 are plotted in fig.5 both of experimental measurements of C-S-C-S boundary conditions and numerical results read from the graph of fully clamped [5]. The curves show that the second experimental mode shape exhibits a less change in frequency with amplitude compared with that obtained for fully clamped isotropic rectangular plate of the same ratio which leads to valid our measurements. The large difference becomes from the add mass of the accelerometer that glued on the plate at (x*,y*)=(0.75,0.5) which amortize the peak amplitude.

The experimental investigation made for the vibration amplitude up to 0.3 time plate's thickness with the frequency up to 108 Hertz, that difference.

Fig.5: Experimental measurement of the 2nd mode shape and numerical results read from the graph of fully clamped isotropic plate with ratio=⅔ [5].



IV. Conclusion:

From the research that has been carried out it is possible to conclude that non-linearity geometric has been successfully investigated in second mode shape of C-S-C-S isotropic rectangular plate ratio equal to 2/3. That work is an extend of Z. Beidouri [7] applied on the first mode shape in the case C-S-C-S isotropic rectangular plate which investigated experimentally in the previous paper so called "Experimental investigation on amplitude-frequency dependence of C-S-C-S rectangular plate first mode shape".

The investigation made both of numerical and experimental show a margin between the resonance frequency associated to second mode shape due to mass of accelerometer add on the plate and maybe boundary conditions. The experimental pattern of amplitude frequency dependence obtained is similar to those published on fully clamped isotropic rectangular plate [5]. More research into geometric nonlinear on structure with adding mass is still necessary before obtaining a definitive answer to that comparison made between linear and nonlinear measurement.

References

[1] M. Amabili, Nonlinear Vibrations and Stability of Shells and Plates, Cambridge University Press, New York, 2008.

[2] R. Benamar, M.M.K. Bennouna, R.G. White, The effects of large vibration amplitudes on the mode shapes and natural frequencies of thin elastic structures part I: Simply supported and clamped-clamped beams, Journal of Sound and Vibration. 149 (1991) 179–195.

[3] R. Benamar, M.M.K. Bennouna, R.G. White, The Effects Of Large Vibration Amplitudes On The Mode Shapes And Natural Frequencies Of Thin Elastic Structures, Part II: Fully Clamped Rectangular Isotropic Plates, Journal of Sound and Vibration. 175 (1992) 377–395.

[4] R. Benamar, M.M.K. Bennouna, R.G. White, The Effects Of Large Vibration Amplitudes On The Mode Shapes And Natural Frequencies Of Thin Elastic Structures, Part III: Fully Clamped Rectangular Isotropic Plates—Measurements Of The Mode Shape Amplitude Dependence And The Spatial Distribution Of Harmonic Distortion, Journal of Sound and Vibration. 175 (1993) 377–395.

[5] M. El Kadiri, R. Benamar, R.G. White, the non-linear free vibration of fully clamped rectangular plates: second non-linear mode for various plate aspect ratios, journal of sound and vibration. 228 (1999) 333–358.

[6] M. El Kadiri, R. Benamar, improvement of the semi-analytical method, for determining the geometrically non-linear response of thin straight structures: part ii—first and second non-linear mode shapes of fully clamped rectangular plates, journal of sound and vibration. 257 (2001) 19–62.

[7] Z. Beidouri, R. Benamar, M. El Kadiri, Geometrically non-linear transverse vibrations of C–S–S–S and C–S–C–S1 rectangular plates, International Journal of Non-Linear Mechanics. 41 (2006) 57–77.

[8] BEIDOURI, Zitouni. "Contribution to a non-linear modal analysis theory, application to continuous structures and discrete systems with localized non-linearities", Thesis of doctorate in science technology. Mohammadia School of Engineering, Rabat, 2006.