Free Vibration of Square Plate under Periodic Transverse and In-Plane Loads

Md Mozaffar Masud[1], A K L Srivastava[2]

[1]Student, [2]Professor
Department of Civil Engineering,
NIT Jamshedpur, Jharkhand, India

***Abstract*: Many engineering structures need stronger design and higher service life associated with savings in weight which are fulfilled by thin walled structures; but such structures undergo large deformations under transverse loads. The rectangular plates are considered as the structural element and their vibration and instability behaviors are studied under periodic transverse loads. The effect of geometric non-linearity on the natural frequencies of a rectangular plate under uniformly distributed and concentrated transverse loads are obtained. In case of dynamic stability study, the boundaries of the primary instability region become wider at higher excitation frequency. The effect of geometric non-linearity predominates and large amplitude of vibration is more dangerous than that of small amplitude.**

***Keywords*: Free Vibration, Square Plate, In-Plane Load, Dynamic Stability**

Introduction

The behavior of plate like structures subjected to in-plane dynamic load attracts considerable attention as such structures, in addition to in-plane vibration, may experience transverse vibration. The behavior of dynamically unstable structure is somewhat similar to that of a structure under large amplitude or non-linear vibration. Non-linearity in plate vibration problems may arise out of both material non-linearity and geometric non-linearity. The first one is due to the non-linear stress-strain behavior of material, whereas large deflections give rise to geometric non-linearity. Static and dynamic responses of solid bodies governed by non-linear ties complicate the analytical investigation. Benamar et al [1,2] examined the dynamic behavior of fully clamped rectangular plates at large vibration amplitudes, both theoretically and experimentally. Duffield and Williams [3] compared numerical experimental results for a stiffened rectangular plate with periodic loads to see the effects of stiffeners. Ganapati et al. [4] have studied the non-linear instability behavior of plates subjected to periodic in-plane load using C^1QARD-8 shear-flexible plate element. Han and Petyt [5] have done free vibration analysis and forced vibration analysis of laminated rectangular plates with clamped boundary conditions using hierarchical finite element method. Hazell and Mitchell [6] have compared their experimental eigen values and mode shapes with the existing theoretical results of the researchers.

A considerable amount of research has been carried out on plates undergoing free nonlinear vibration. Kadir et al. [7] have solved the large vibration amplitude problem, numerically by reducing it to a set of non-linear algebraic equations. Leissa [8] investigated the same problem and presented accurate free vibration frequencies by expanding the plate displacement.

Result and Discussion

The objectives of the work are to determine the natural frequency of a rectangular plate and to determine the vibration amplitude and frequency of the plate due to in-plane loading.

The static compressive load used here taken for CFCF plate is 30 kg and that for CSCS plate is 100 kg. Numerical study are carried out on a square plate made on mild steel in Table 1. The detailed dimensions of the plate used here are furnished in the table below. The widths of instability region have been observed for CFCF plate at 30 kg load but in case of CSCS plate it is not significantly observed with the same load. That's why a higher static load (100 kg) is used for satisfactory results.

Table 1: Dimensions of the plate specimen

Actual plate dimension in mm	Effective plate dimensions (a×b) in mm	Thickness used in mm
480×420	420×420	2.16

The study here has been focused mainly on the identification of boundaries of the primary instability region that occurs in the vicinity of simple resonance of first and higher modes. The results obtained are shown here in Table 2.

Table 2: Natural frequencies (Hz) of free vibration of the plate mentioned

Boundary Condition	Natural freq. of free vibration (Hz) for different vibration mode					
	1	2	3	4	5	6
CFCF	12	32	47	54	67	96
CSCS	40	57	91	108	149	207

It is observed that resonance frequency (Hz) vs vibration amplitude for the plate having CSCS boundary condition shows the same results for the plate under CFCF boundary condition.

Conclusion

Geometric non-linearity is imposed by the application of uniformly distributed pressure on the plate. Dynamic stability study is mainly focused to identify the boundaries of primary instability regions that occur in the vicinity of resonance of first and higher modes. The width if instability regions for CFCF plate are found too wider than that of CSCS plate**.**

References

[1] Benamar R., Bennouna M. M. K., White R. G., The effect of large vibration amplitude on the fundamental mode shape of thin elastic structure, Part-1: Simply supported and clamped-clamped beam. Journal of sound and vibration, 149, 179-195,1991
[2] Benamar R., Bennouna, M. M. K., White R. G., The effect of large vibration amplitude on the fundamental mode shape of thin elastic structure, part-II: Fully clamped rectangular isotropic plates. Journal of sound and vibration, 164 (2), 295-316, 1993
[3] Duffield R. C., Williems N., Parametric resonance of stiffened rectangular plates. Journal of applied mechanics, Vol. 39, No 1, 879-899, 1972
[4] Ganapathi M., Patel B. P., Boisse P., Touratier M., Non-linear dynamic stability characteristics of elastic plates subjected to periodic in-plane load. International Journal of non-linear mechanics, 35 (2000) 467-480
[5] Han W., Petyt M., Geometrically non-linear vibration analysis of thin plates using the hierarchical finite element method-II: first mode of laminated plates, Computer & Structure, 63, 2, 309-318, 1997
[6] Hazell C. R., Mitchhell A. K., Experimental Eigen values and Mode shape for clamped plates. Experimental mechanics, 26 (4), 337-344, 1986
[7] Kadir M. E. I., Benamar R., White, R.G., The non-linear free vibration of fully clamped rectangular plates: second non-linear mode for various plates aspect ratios. Journal of Sound and Vibration, 228 (2), 333-358, 1999
[8] Leissa A. W., The free vibration of rectangular plates. Journal of sound and vibration, 31 (3), 257-293, 1973