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Natural Frequency and Dynamic Stability Region Study

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***Abstract*- The dynamic instability regions are analysed using Hill's infinite determinants system. The excitation frequency of plates with different boundary conditions, or aspect ratios, was investigated. The results are determined using the bending displacements of plate and stiffener. The results show that the principal excitation frequency regions have a significant effect considering and neglecting in-plane displacements.**

***Keywords*- Finite element method, vibration, Dynamic instability, In-plane load.**

I. INTRODUCTION

Structural elements subjected to in-plane periodic forces may induce transverse vibration, which may be resonant for certain combinations of natural frequency of transverse vibration, the frequency of the in-plane forcing function and the magnitude of the in-plane load.

Trotsky [1] has extensively reviewed the literature pertaining to rectangular stiffened plates for static, dynamic, and stability analysis that are based on orthotropic plate idealization.

Timoshenko and Gere [2] presented numerical tables for buckling load of rectangular plates stiffened by longitudinal and transverse ribs.

Laura [3] has used the minimization of energy functional to determine the natural frequency of stiffened plates with various elastic restraints along the edges.

Bhat [4] has studied the effect of the spacing of stiffeners on the natural frequencies of the plate using the Rayleigh-Ritz method and the equation of optimization technique.

Shastry and Rao [5] studied the free vibration of plates with arbitrary oriented stiffeners using the triangular plate-bending element. The finite element is applied to analyze the dynamic stability of the plates subjected to uniform edge loading.

The analysis is linear and the plate is assumed to be with no initial imperfections as it has less effect in problem involving dynamic instability.

II. MATHEMATICAL FORMULATION

The basic configuration of the problem considered here is a stiffened plate as shown in Figure 1, subjected to uniform harmonic in-plane edge loadings. The alignment of the stiffeners, concentric and eccentric is shown in figure.

The equation of equilibrium for an elastic system undergoing small displacements at the instant of buckling may be written in matrix form as:

$$[M]\{\ddot{q}\}+[[K_e]-P[K_G]]\{q\}=0 \quad \textbf{(1)}$$

In the above equation, the in-plane load factor P(t) is periodic and can be expressed as:

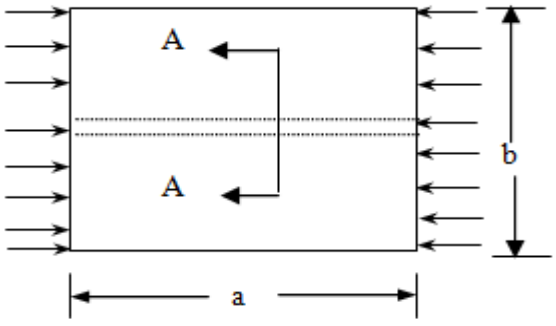
$$P(t)=P_S+P_t\cos\Omega t \qquad \textbf{(2)}$$

Where is the static portion of P(t), is the amplitude of the dynamic portion of and is the frequency of excitation. Using Equations (2) and (3), the equation of motion (1) may be expressed as:

$$[M]\{\ddot{q}\}+[[K_e]-\alpha P_{cr}[K_G]-\beta P_{cr}[K_G]\cos\Omega t]\{q\}=0 \quad \textbf{(3)}$$

III. RESULT AND DISCUSSION

The problem considered here consists of a rectangular plate (a x b) with stiffener of cross-section as shown in Figure 1.



(a)

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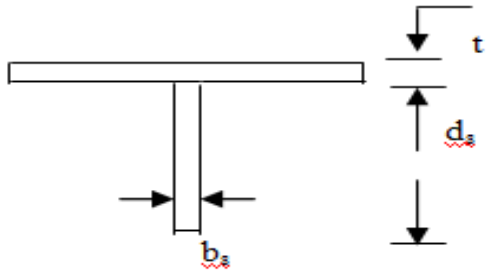

(b)

Fig 1. Stiffened plate cross-section.

1. Convergence and validation studies with previous results:

The convergence studies have been carried out on free vibration for an eccentrically stiffened clamped square plate and results obtained is compared with the results of spline finite strip method proposed by Sheikh [2] in Table I. The data used for its geometry are as: a = 600mm, b = 600mm, t = 6mm, bs = 3.31 mm and ds = 20.25 mm (Fig 1). The results are found to agree well.

The simply supported stiffened plate of Timoshenko [2], Laura [3], Bhat [4] has been analyzed to study the effect of in-plane displacements and compared the obtained results in Table II.

It can be concluded that the in-plane displacements affect the natural frequencies. After validating the vibration, buckling results and free vibration results for both cases considering and neglecting in-plane displacements for various boundary conditions for stiffened plates and also dynamic instability results for unstiffened plates, studies are now extended for dynamic instability of stiffened plates.

Some new results are presented here for various boundary conditions, aspect ratios and various stiffener parameters considering and neglecting in-plane displacements.

Table 1. Convergence of the Natural Frequency ( ) in rad/sec for Clamped Square Stiffened Plate.

Frequency (ω)						
	Mesh Division					
	3 x 3	4 x 4	6 x 6	8 x 8	9 x 9	10x10
Sheikh [2] Mode 1 Mode 2	324.70 403.14	319.92 406.99	317.43 401.62	316.94 400.61	316.94 400.36	316.79 400.32
Present Mode 1 Mode 2	342.47 410.06	325.62 420.62	318.64 404.53	317.66 401.66	317.25 403.10	316.79 400.32

Table 2. Principal dynamic Instability regions for stiffened plate with one central longitudinal stiffener considering in-plane displacements.

Excitation frequency parameter (Ω)							
		SSSS		CCCC		SSCC	
α	β	U	L	U	L	U	L
0.2	0	59.42	59.42	123.51	123.51	73.19	73.19
	0.2	62.96	55.64	129.95	116.55	77.55	68.53
	0.4	66.29	51.57	135.94	108.94	81.67	63.50
	0.6	69.45	47.13	141.57	100.49	85.58	58.03
	0.8	72.46	42.20	146.87	90.94	89.29	51.95

IV. CONCLUSION

The results from a study of the instability behavior of isotropic stiffened plates subjected to uniform periodic in-plane compressive loading can be summarized as follows: The onset of instability occurs later with narrow zones of instability with addition of restraint at the edges. Due to static components, the instability regions tend to shift to lower frequencies, showing a destabilizing effect on the dynamic stability behavior of the stiffened plate.

The onset of instability occurs earlier for rectangular than square stiffened plate but with a wider instability region.

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