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FREE VIBRATIONS OF THICK PLATES; ANALYSIS OF A DISPLACEMENT-BASED FORMULATION

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A model [2, 4] describing the dynamic behaviour of a laminated plate (*e.g.* Fig. 1) during its free vibrations is taken into account.

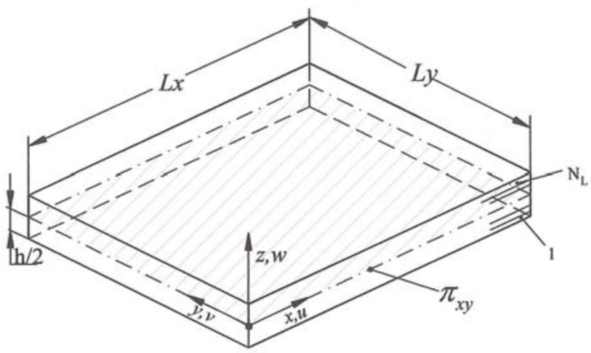

Figure 1. Multilayered composite plate: nomenclature

With respect to three-dimensional models, which have rarely been solved in an exact form in engineering vibration problems, all the several two-dimensional models have inherent limitations; however, three-dimensional models, also based on FE schemes, very often require a huge and, therefore, impractical number of degrees of freedom for solving problems of engineering interest. In this perspective several 2D-theories have been introduced in order to model multilayered composite plates (e.g., [1-4]); all these theories can be seen within the frame of mixed and displacement-based formulations.

In reference [2] free vibrations of multilayered plates through a mixed-variational approach, were investigated by also developing a two-dimensional model of multilayered plates in a global sense: *i.e.* through a theory that had allowed the researchers to deal with multiple layers as only one single layer. The mentioned challenge was tackled by introducing a special functional base (GPSFs) that expanded unknown functions through the whole thickness of the laminate. In such a situation, the approximating process does not suffer at all around the discontinuous points (*i.e.* type Gibbs's phenomenon). The idea was subsequently extended to models [4] based on assuming only displacements (*i.e.* eqs. (1)). The numerical results showed the capability of such a displacement based model to approach the exact three dimensional results even though the enforcement of the continuity conditions only regarded the displacement field.

This work takes into account the numerical stability, the convergence rate (Figs 2, 3) and, finally, the accuracy of the mentioned displacement-based model when the eigenvalues are evaluated through a reduced part of the functional base made up of the linear part of GPSFs (Tab.1). In particular, along with the idea to use a functional base made up of GPSFs, the possibility of adding different bases (of which the GPSFs are only a part), is investigated by ranging over a number of multilayered cross composite plates. The importance of this investigation relies on the need to know the computational effort of the model in challenging engineering problems when a low or high number of layers are involved in the multilayered structure of the plate.

$$\begin{cases} U(x,y,z;t) = \sum_{j=1}^{n} \varphi(z)_{1j}\, u(x,y;t)_j \\ V(x,y,z;t) = \sum_{j=1}^{n} \varphi(z)_{2j}\, v(x,y;t)_j \\ W(x,y,z;t) = \sum_{j=1}^{n} \varphi(z)_{3j}\, w(x,y;t)_j \end{cases} \tag{1}$$

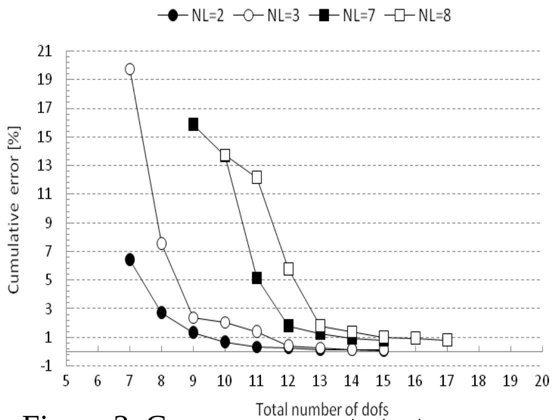

Figure 2. Convergency rate test

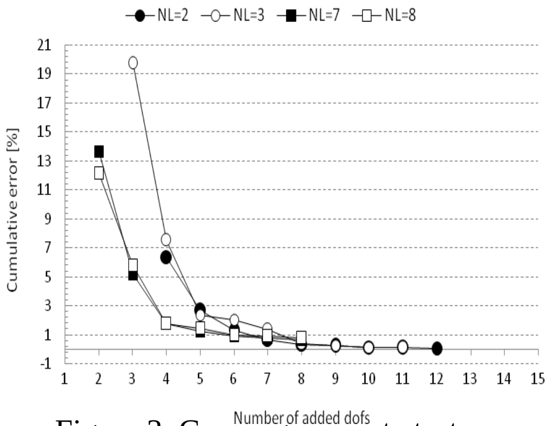

Figure 3. Convergency rate test

Tab. 1. Minimum dofs required to achieve a cumulative† error minor than 1% (ref [2,5]; m,n=1,1; [2] Tables 2, 3 & eq. (44))

	N_L=2 [0/90]		N_L=3 [0/90/0]		N_L=7		N_L=8	
No freqs (kHz) *h*= 1 cm, ρ=2000 kg/m^3	GPSFs & polynomials	GPSFs	GPSFs & polynomials	GPSFs	GPSFs & polynomials	GPSFs	GPSFs & polynomials	GPSFs
10(230)	10	9	12	10	14	15	15	17
8(160)	9	7	7	7	13	15	14	17
6(86)	6	5	7	7	10	15	11	17
4(80)	5	5	6	7	10	15	10	9
2(34)	5	5	6	7	9	8	10	9

† *cumulative: sum of the errors evaluated with respect to all the first compared frequencies*

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