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LETTERS TO THE EDITOR

DYNAMIC DISPLACEMENTS OF A TRANSDUCER ELEMENT SUBJECTED TO FORCED EXCITATION

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1. Introduction

Transverse vibrations of the structural element shown in Figure 1 are of interest from the point of view of the design of certain ultrasonic transducers. The problem has originated several publications dealing with free [1–3] and forced vibrations [4]. These studies have dealt with variational solutions which employed very convenient polynomial co-ordinate functions.

The present note deals with an independent solutions of the forced vibrations situation, obtained by means of a standard finite element code. The dynamic displacements are obtained at the plate center for two types of ideal, extreme boundary conditions: rigidly clamped and simply supported, and the results are compared with those evaluated analytically [4].

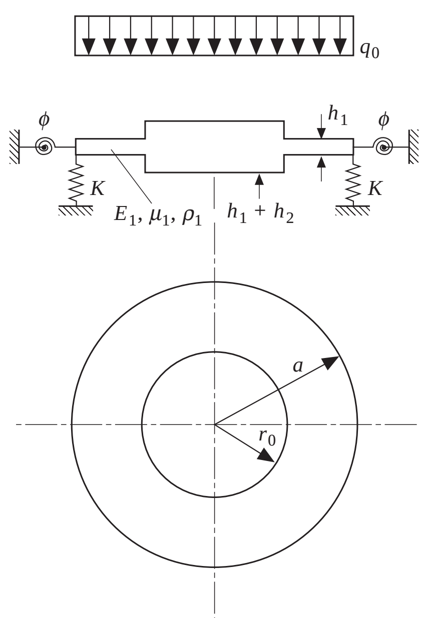

Figure 1. Vibrating structural element subjected to $q_0 \cos \omega t$ type excitation.

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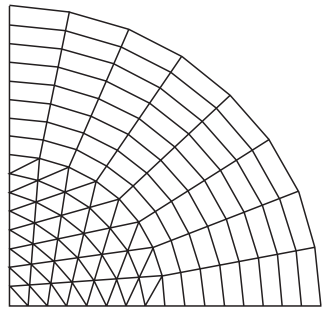

Figure 2. Finite element mesh.

2. FINITE ELEMENT SOLUTION

The discretized model is shown in Figure 2: 64 quadrangular elements for the plate of thickness h_1 and 64 triangular elements for the plate portion of thickness $(h_1 + h_2)$ have been used. The total number of nodes is 117, each one with three degrees of freedom: displacement, W, and rotations: θ_x (corresponding to the x-axis) and θ_y (corresponding to the y-axis). Due to symmetry considerations only one quarter of the system was considered.

TABLE 1

Comparison of dynamic displacement amplitudes at the plate center

h_2/h_1	Ω_{00}	Ω_{01}	α	$W/(q_0a^4/D_1)$ Analytical (I)	Finite Element (II)	Boundary Conditions
0	10·215	39·77	0·2	0·01630	0·0162	(A)
			0·4	0·01872	0·0186	
			0·6	0·02479	0·0247	
			0·8	0·04461	0·0445	
	4·935	29·72	0·2	0·06640	0·0662	(B)
			0·4	0·07603	0·0758	
			0·6	0·10010	0·0998	
			0·8	0·17875	0·1784	
1/2	11·214	46·94	0·2	0·00938	0·0094	(A)
			0·4	0·01078	0·0108	
			0·6	0·01426	0·0144	
			0·8	0·02572	0·0259	
	5·902	35·20	0·2	0·03372	0·0349	(B)
			0·4	0·03862	0·0400	
			0·6	0·05089	0·0527	
			0·8	0·09099	0·0944	
1	12·191	54·62	0·2	0·00618	0·0066	(A)
			0·4	0·00710	0·0075	
			0·6	0·00941	0·0100	
			0·8	0·01694	0·0181	
	6·518	41·87	0·2	0·02205	0·0251	(B)
			0·4	0·02526	0·0287	
			0·6	0·03328	0·0379	
			0·8	0·05949	0·0677	

Note: (I): Approximate values determined by means of a variational approach [4]. (II): Results obtained using the finite element method. (A) Clamped, (B) Simply supported.

3. NUMERICAL RESULTS

All calculations have been performed for Poisson's ratio (μ) = 0·30 and for $r_0/a = 1/2$. The results obtained in the present study are shown in Table 1, which also contains the first two natural frequency coefficients corresponding to axisymmetric modes ($\Omega_{0j} = \sqrt{\rho h/D_1}\omega_{0j}a^2$). The dynamic displacement at the plate center has been determined for $h_2/h_1 = 0$ (constant thickness case) 1/2 and 1.

Excellent agreement is attained for $h_2/h_1 = 0$ for all the values of the parameter $\alpha = \Omega/\Omega_{01}$, where $\Omega = \sqrt{\rho h/D_1}\omega a^2$ (exciting frequency coefficient).

Very good engineering agreement is observed for $h_2/h_1 = 1/2$ (the maximum difference is of the order of 5% in the case of the simply supported plate for $\alpha = 0{\cdot}8$).

The agreement is not as good when $h_2/h_1 = 1$ (admittedly the overstep is rather exaggerated now). Nevertheless in the case of the clamped plate the analytical approach yields a result which is 6% lower than the finite element value (presumably more accurate) for $\alpha = 0{\cdot}8$ while, when the plate is simply supported, the difference is of the order of 11% for the same value of α.

It is observed that for the cases studied the agreement is always better when the plate is clamped. It is important to point out that the results obtained in reference [4] were calculated using four polynomial co-ordinate functions. The accuracy can be improved using a larger number of approximating functions. One may conclude by saying that the analytical approach yields, in a simple fashion, useful results from the point of view of determining natural frequencies and first-order sound radiation determinations.

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