Journal of Sound and Vibration (2001) **241**(2), 315–318
doi:10.1006/jsvi.2000.3240, available online at http://www.idealibrary.com on IDEAL®

LETTERS TO THE EDITOR

FREE VIBRATION ANALYSIS OF AN ORTHOGONALLY SUPPORTED MULTI-SPAN CURVED PANEL

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(*Received* 14 *June* 2000)

1. INTRODUCTION

Vibration-induced fatigue and excessive noise radiation are serious problems of periodically supported curved panels, which are encountered in aerospace and ship structures. A method of analysis to determine multi-supported curved panel frequencies using high-precision triangular finite element is presented in this paper.

Multi-span stiffened curved panels continuous in circumferential direction have been analyzed by Henderson and McDaniel [1] using transfer matrices approach Petyt and Fleischer [2] using finite strip method and Sinha and Mukhopadhyay [3] using high-precision triangular finite element of reference [4]. Orthogonally stiffened curved panel results are also presented in references [3, 5]. However, no literature can be found where the curved panels are continuous in both directions and rests on simple supports. The purpose of this note to present the free vibration results of a multi-supported finite curved panel continuous in circumferential and axial directions which can be used to compare the results obtained from a current ongoing research related to periodic shell vibration.

2. PROPOSED FINITE ELEMENT

The governing equation of motion for the undamped free vibration of an elastic structural system undergoing small displacements can be expresses as

$$[M]\{\ddot{q}\} + [K]\{q\} = \{0\}, \tag{1}$$

where $[M]$ and $[K]$ are the global mass and stiffness matrices, respectively, of the total structural system. $\{\ddot{q}\}$ and $\{q\}$ are the global acceleration and displacement vectors. Putting

$$\{q\} = \{\bar{q}\}e^{i\omega t} \tag{2}$$

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into equation (2), equation (1) becomes

$$[[K] - \Omega^2[M]]\{\bar{q}\} = \{0\}, \tag{3}$$

where

$$\Omega^2 = \frac{\rho R^2 \omega^2 (1 - \nu^2)}{E}. \tag{4}$$

The basic shell element employed here is the conforming higher order arbitrary triangular-shaped shallow shell finite element of Cowper *et al.* [4]. The element stiffness matrix [4] and mass matrices [3] are presented elsewhere for the shell element.

3. NUMERICAL EXAMPLE

A triangular finite element [4] is used to model a 3×3 ($N_x \times N_y$) span orthogonal array line-supported curved panel (Figure 1). The total length in axial and circumferential direction is considered equal to $N_x a = 0{\cdot}4105$ and $N_y b = 0{\cdot}1989$ m respectively. Each panel having axial length $a = 0{\cdot}135$ m, circumferential length $b = R \times \theta_0$ ($\theta_0 = \pi/18$), and thickness $h = 0{\cdot}559$ mm. The radius of curvature $R = 0{\cdot}381$. The material properties are $E = 70 \times 10^9$ N/m^2, $\rho = 2700$ kg/m^3, $\nu = 0{\cdot}3$. A 6×6 triangular mesh with 588 degrees of freedom is considered.

The free vibration results are obtained for four boundary conditions of the extreme edges: (1) four sides of the structure simply supported, (2) curved sides clamped and straight sides simply supported (S-C-S-C), (3) curved sides simply supported and straight sides clamped (C–S–C–S) and (4) four sides clamped (C–C–C–C).

Simulating the above model (Figure 1) in NASTRAN using a CQUAD4 element, comparison has been made with the proposed finite element model. The total number of

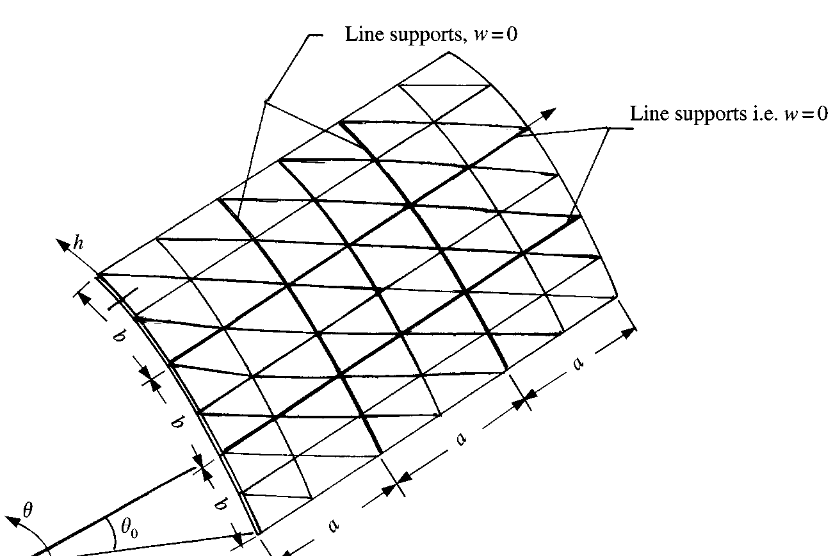

Figure 1. A 3×3 span orthogonally line-supported curved panel with 6×6 triangular mesh.

TABLE 1

Frequencies of a multi-supported orthogonal curved panel for different boundary conditions of extreme edges

Mode no.	SSSS Ω	SCSC Ω	CSCS Ω	CCCC Ω
1	0·2526	0·2716	0·3284	0·3332
	(0·2586)	0·2886)	(0·3284)	(0·3285)
2	0·2813	0·3148	0·3316	0·3629
	(0·2870)	(0·3210)	(0·3448)	(0·3501)
3	0·3118	0·3343	0·3336	0·3656
	(0·3201)	(0·3312)	(0·3473)	(0·3526)
4	0·3123	0·3517	0·4391	0·4463
	(0·3292)	(0·3468)	(0·4467)	(0·4476)
5	0·3408	0·3567	0·4929	0·5134
	(0·3414)	(0·3494)	(0·5075)	(0·5109)
6	0·4056	0·4315	0·5111	0·5273
	(0·4248)	(0·4256)	(0·5306)	(0·5334)
7	0·5049	0·5195	0·5465	0·5495
	(0·5028)	(0·5061)	(0·5696)	(0·5717)
8	0·5375	0·5414	0·5763	0·5981
	(0·5293)	(0·5321)	(0·5848)	(0·5988)
9	0·5410	0·5786	0·5859	0·6203
	(0·5685)	(0·5706)	(0·5890)	(0·6009)

Note: Results obtained from NASTRAN appear in parentheses

nodes and elements are 450 and 496, respectively, in the NASTRAN model. The comparison of first nine natural frequencies are presented in Table 1.

ACKNOWLEDGMENT

This work is supported under the grants-in-aid scheme of the Aeronautical Research and Development Board, Ministry of Defence, Government of India.

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APPENDIX A: NOMENCLATURE

a single curved panel length in the x direction
b single curved panel length in the circumferential direction

E	Young's modulus of elasticity
h	shell thickness
q	generalized global co-ordinates
R	shell mean radius
t	time variable
ω	radian frequency
ρ	shell material density
θ	circumferential co-ordinate
θ_0	angle subtended by a single curved panel at the center of cross-section
ν	the Poisson ratio
Ω	dimensionless frequency