MODELING OF DYNAMIC PROPERTIES OF THE COMPOSITE SHELL FOR TV TOWER

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SUMMARY

Dynamic properties of composite shell have been investigated experimentally and numerically. Eigenvalues have been evaluated by impact testing from output signal in the mesh of points and their frequency spectrum. The eigenvalues have been further calculated numerically by QR iteration of the finite element method and compared.

Keywords: composites, modeling, testing ,dynamic properties, finite element method

INTRODUCTION

Fibre composites with polymer matrix have been already used on TV towers and transmitters. Polymer composites have outstanding dielectric and corrosion properties important for such an application. As an example have been chosen the composite shells for TV towers. Recently, composite shells have been used for cladding at the 3rd floor

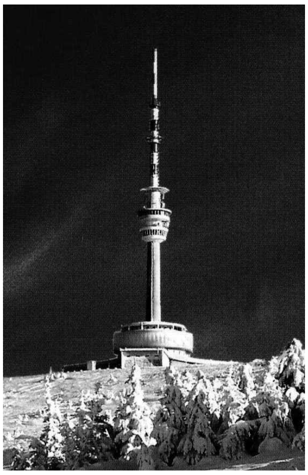

Fig.1 TV Tower Praded (1492 m above sea level)

gallery of TV Tower Praděd (1492 m above sea level, Fig.1). The shells of length 4500 mm, width 1684 mm and clearance 400 mm have been supported at top and bottom by steel structure of gallery, adjacent longitudinal edges have been unsupported. At the 3rd floor are located radio relay aerials and other equipment. The covering consists of 62 composite shells of special sinusoidal shape (Fig.2). Shape of the shells has been optimized to satisfy requirements for microwave transparency (2- 8 GHz), airflow and sufficient stiffness. The thickness of the shell should correspond to requirements for microwave permeability. Shells were fabricated from laminated G/UP composite with polyester isophtalic resin. Two alternatives of reinforcement have been evaluated: woven and unidirectional glass fabrics interlaced by mats.

Fig.2 Assembly of composite shells

MATERIAL PROPERTIES OF THE COMPOSITE

The mechanical properties of the composite have been found out from mechanical tests. Two alternatives of composites have been considered: (1) The composite with thickness 9.8 mm consisted of 6 layers of woven glass fabric 500 $g.m^{-2}$ or (2) 6 layers of unidirectional glass fabric Rovinap 42-08 interlaced by 10 layers of glass mat 450 $g.m^{-2}$ and both surfaces laminated by glass mat 300 $g.m^{-2}$. Polymer resin was isophtalic type Viapal VUP 4686 BET. The following Table 1 shows the obtained test data.

Tab. 1. Material properties

Property	**Unit**	**(1)**	**(2)**
Thickness	mm	9.8	9.8
Volume weight	$g.cm^{-3}$	1.492	1.521
Glass content	%	37.6	41.5
Strength in tension	MPa	141	193
E-modulus in tension	MPa	17273	25681, 17140
Shear modulus	MPa	5976	8870
Poisson's ratio	-	0.24	0.24

DYNAMIC STRUCTURAL ANALYSIS

The aim of dynamic analysis was to evaluate the dynamic properties of the composite orthotropic and layered shell. The analysis has been focused on first two eigenfrequencies and eigenmodes of the composite shell. The problem has been solved by finite element method according to CLT (classic laminate theory) and Lanczos`s subspace method with tridiagonalisation of matrix B in equation (1) as described by Hughes [1]:

$$(B - \mu . I)X = 0 \quad \text{with} \quad \mu = \frac{1}{\omega^2} \tag{1}$$

Equation (1) can be obtained from the standard form

$$(K - \lambda . M)\Phi = 0 \tag{2}$$

by changing the variable

$$\Phi = (L^{-1})^T X \tag{3}$$

where L is a lower triangular matrix

$$K = L.L^T \tag{4}$$

and assuming

$$B = L^{-1} M (L^{-1})^T \tag{5}$$

Eigenvalues have been calculated by iteration with QR method. The element used in finite element procedure was DKT (Discrete Kirchhoff Triangle), composite has been

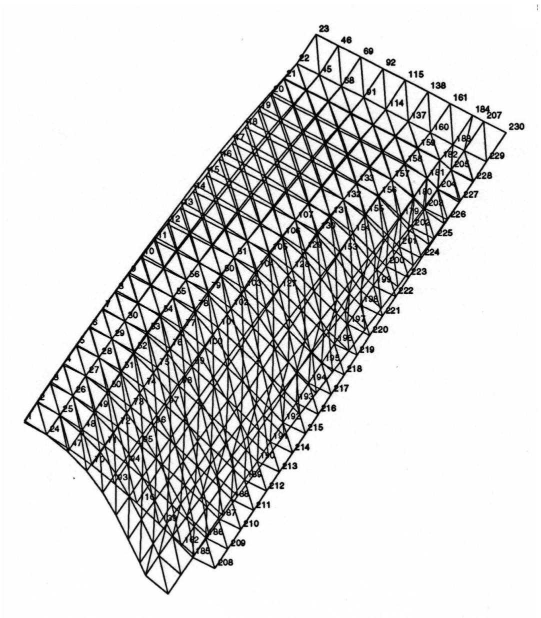

Fig.3 First eigenmode f_1=59.126 Hz

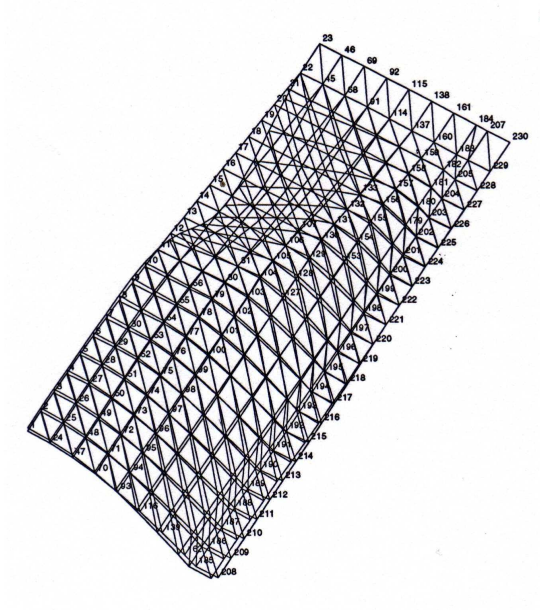

Fig.4 Second eigenmode f_2=151.97 Hz

modeled from individual layers with orthotropic properties. Analyzed shell has been simply supported along the curved edges, straight edges were free. Total number of elements and nodes on symmetrical part of the shell was 396 and 230 respectively.

Following alternatives have been evaluated (see Tab. 2):
(1) shell reinforced by woven glass fabric, material orthotropic (E_1=E_2)
(2) shell reinforced by unidirectional glass fabric, material orthotropic (E_1>E_2), E_1 along the free edge. Further, two alternatives of boundary conditions along adjacent edges have been considered:
(a) totaly free edge (case A)
(b) lap-joint of adjacent shells with edge cover plate (case B).
Some other details of the analysis are described at article of Cerny [2].

Tab. 2. Calculated eigenfrequencies (case A)

Eigenfrequency [Hz]	E_1=E_2 (1)	E_1>E_2 (2)
First	59.126	68.448
Second	151.97	180.530

First and second eigenmode of the shell (E_1=E_2, free edge, case A) are shown in the Figs.3 and 4 respectively. The calculated eigenfrequencies are shown in Table 2. The eigenfrequencies for case B are shown in Table 3.

Tab. 3. Calculated eigenfrequencies (case B)

Eigenfrequency [Hz]	E_1=E_2 (1)	E_1>E_2 (2)
First	119.16	134.50
Second	155.31	183.90

DYNAMIC TESTING

Recently, the dynamic properties of structures are measured by a measurement chain, consisting of sensor and measurement unit involving AD (analog- digital) converter. Dynamic measurements of shell structures are mostly realized by accelerometers. The described procedure has been already used to measure the dynamic properties of composite shell, as shown by Cerny [3].
The aim of dynamic testing was to evaluate some dynamic properties of the composite shell. The work has been focused on eigenvalues of the shell i.e. eigenfrequencies and eigenmodes. The eigenvalues have been evaluated by an impact method. Dynamic response on the hammer impact at the top of the shell has been measured at the same

time in two points. The output signal has been measured simultaneously in reference and current points of the mesh (No.001-513) by 2 accelerometers PCB333, see Fig.5, (Analog Devices, USA) and ADXL05 (Analog Devices, USA) and recorded by measurement system Hewlett- Packard 3852. Measured signal was digitised by high-

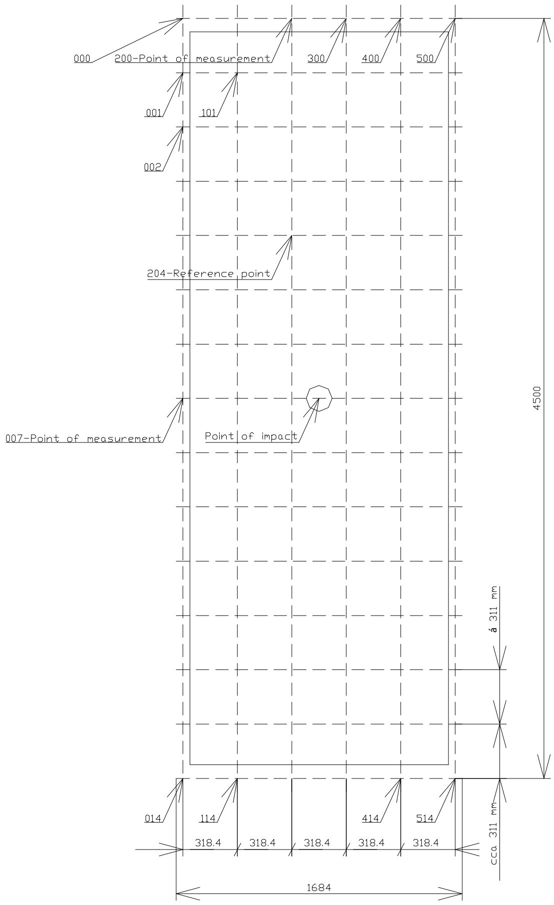

Fig.5 Mesh of points

speed voltmeter HP 44704A (speed up 100 ksa.s^{-1}) and high-speed multiplexer HP 44711A and stored in memory of PC Pentium. The frequency spectrum of signal in 78 points has been calculated by FFT analysis in LabWindows package (National

Fig.6 Dynamic measurement at Klokner Institute Facilities

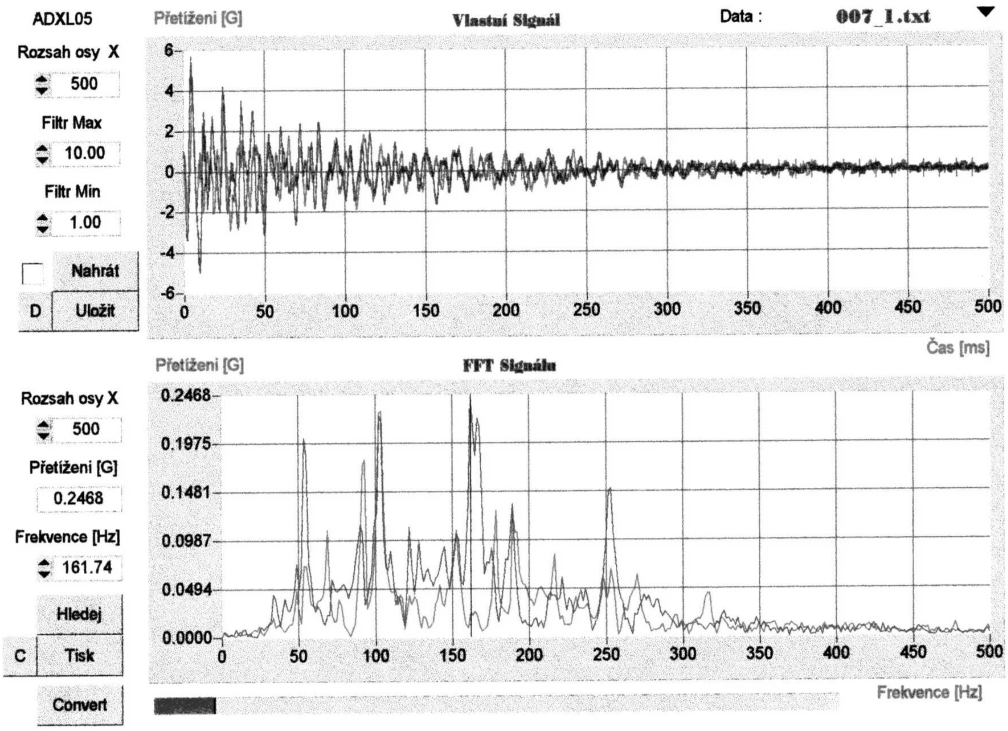

Fig.7 Measured signal and frequency spectrum of signal in typical point

Instruments, USA). The results of FFT analysis were used for determination of first two eigenfrequencies and eigenmodes. Eigenfrequencies have been found from the frequency spectrum as resonance frequencies. Eigenmodes have been evaluated by the modal analysis from ratio of accelerations in current and reference points on respective resonance frequencies.

The Fig. 7 shows the frequency spectrum in a typical point obtained by FFT analysis with three resonance frequencies, corresponding to eigenfrequencies of the composite shell, Table 4. The resonance frequency 100 Hz corresponds to response of supporting steel frame, what has been confirmed by a detailed modal analysis.

Tab. 4. Measured eigenfrequencies (case A)

Mode	**Unit**	**Frequency**
1	Hz	53.41
2	Hz	152.59

CONCLUSIONS

It has been found that the dynamic mechanical behaviour of composite shells is strong dependent on anisotropy of composite material.

Results of the analysis and measurement give following eigenfrequencies for case A: first eigenfrequency 59.126 Hz (measured 53.41 Hz) , second eigenfrequency 151.97 Hz (measured 152.59). Remarkable are advantageous high damping properties of the composite shells (see Fig. 7). In case of orthotropy $E_1>E_2$ (2) the calculated eigenfrequencies were 15- 18% higher than for orthotropy $E_1=E_2$ (1). Eigenfrequencies evaluated from test are in a good agreement with the calculation (less than 10% difference).

ACKNOWLEDGEMENTS

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