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Damping Characteristics of Laminated Semi-Cylindrical Shells: Technical Note

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ABSTRACT:

The natural frequencies and damping co-efficient were obtained in a half-cylindrical shell made up of epoxy resin reinforced with glass fibre. The impact load is given by an impact hammer and the effect of impact load is sensed using an accelerometer, which is fixed at the edge of the cylinder. Results are manipulated directly by the system through the accelerometer. The laminated shells were tested with various boundary conditions such as free-free, fixed–fixed and simply supported end. The same tests were conducted on the shells with longitudinal stiffeners. The damping characteristics were compared. From the results it was found that shells without stiffener have a damping co-efficient of 0.177 and the shells with stiffener have a damping co-efficient of 0.311 in free-free end condition. Here it is understood that the shells with stiffener showed 43% improvement in damping co-efficient also. It was also observed that with the addition of rubber particles to the reinforcing polymer, the shells with stiffeners may lead to significant increase in damping co-efficient.

KEYWORDS:

Epoxy resin; Natural frequencies; Damping co-efficient; Laminated shells; Fiber Reinforced Plastics

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1. Introduction

Materials constitute nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount of weight reduction, will have a wider economic impact. Composite materials are proved to be a suitable substitute for steel with regards to weight reduction of the vehicle. Hence, a composite has been selected for cylindrical shell design. The commonly used fibres are carbon fibre, glass fibre, Kevlar, etc. Among these, the glass fibre was selected based on the cost factor and strength. The types of glass fibres are, C-glass fibre, S-glass fibre and E-glass fibre. The C-glass fibres are used in need of good surface finish, S-glass fibres are used in need of high modular strength, as in aerospace industries. The E-glass fibres are high quality glass fibres, which are used as standard reinforcement fibre for all applications. E-glass fibre is found to be an appropriate choice. In Fibre reinforcement plastics (FRP) a cylindrical shell's mechanical strengths is controlled by the matrix system used.

2. Material and methods

E-glass fibres are reinforced in the thickness direction. Hence, it does not influence the inter laminar mechanical strength. Many thermo-set resins such as polyester, vinyl ester, epoxy resin are being used for FRP fabrication. Among these resin systems, epoxies show better inter laminar strength and good damping properties [1-4]. Hence, epoxy resin is found to be the best to suit this application. Different grades of epoxy resins and hardener combinations are classified based on their mechanical properties. Among these grades, the grade of epoxy resin selected is LY-556, the grade of hardener selected is HY-951. LY-556 is a solvent less epoxy resin, which in combination with hardener HY-951 a low viscosity polyamine cures into a hard resin. Apart from the selection of material and design procedure, the selection of manufacturing process also determines the quality and cost of the product. Hand lay-up method is selected. The mould used for the fabrication of FRP half-cylindrical shells should satisfy the following requirements. The cavity of the mould should resemble the actual cylindrical shell's shape and dimension. It should have a continuous positive surface of resolution. It should be designed in a way that it can be rotated about an axis of revolution. Figs. 1 and 2 show the mould for shell without and with stiffener respectively.

Fig. 1: Mould for shell without stiffener

Fig. 2: Mould for shell with stiffener

After deciding the dimensions of the mould, it is manufactured using teak wood cylindrical shells as the pattern material. Mould is also made using composite with chopped strands and gel coat resins. Mould is smoothened as much as possible to get a good surface finish on the lamination. Then fibre mate is placed on the mould and IBC resin is applied uniformly before using metal roller. The resin is allowed to spread all over the area of mate and the excess resin is rolled out. The second layer is placed over the first layer again the resin is applied and rolled out uniformly. This process continued for three layers. After 3 layers laminated, wax coated mylar film was placed over the layers and finally, allowed to cure for 24 hours under room temperature. Figs. 3 and 4 show the unstiffened and stiffened shells after curing respectively.

Fig. 3: Unstiffened shell

Fig. 4: Stiffened Shell

3. Testing

Impact testing instrument consists of real-time analyser, accelerometer and the impact hammer. Two accelerometers are fixed at the edges of the half-cylindrical shells diagonally opposite to each other in the longitudinal direction. Fixed accelerometer and impact hammer is connected to the real-time analyser which in turn is connected to a computer, to display the results. It is possible to know the value of impact load applied on the testing samples, but during the testing usually the value of impact load is pre-set. For our testing it is taken as 50N. During testing, the real-time analyser predicts the vibration of the sample by obtaining the values of frequency and maintaining the amplitude range as 12 to 15 seconds. The real-time analyser starts to read the vibration only after the impact load reaches the value of 50N. Fig. 5 shows the impact testing instrumentation setup. For each cylindrical shell, three impact tests were conducted with different end conditions namely, free-free end condition, simply supported end condition and fixed end condition. For all the tests the instrumentation remains the same. Fig. 6 shows the half-cylindrical shell being freely hung with support of a thread.

Fig. 5: Impact testing instrumentation set up

Fig. 6: Free-free end condition

Fig. 7 shows the fixed end condition. Here all the four edges of the shells are fixed to get perfectly fixed boundary condition. Mild steel strips with 30mm width are selected for the fixture support. For each straight edge two strips are required to get fully fixed support. Bonded strips are placed inside and outside the cylindrical shell and bolted together tightly. Fig. 8 shows the simply supported end condition. Special metal blocks are used here. The metal blocks are sized to get a square shape. In one face of the black, groove is made with dimensions of width 5mm and depth 7mm. All the four metal blogs are placed at four corners of the cylindrical shell. For testing, accelerometers are fixed diagonally opposite to the blocks in the longitudinal direction.

Fig. 7: Fixed end boundary condition

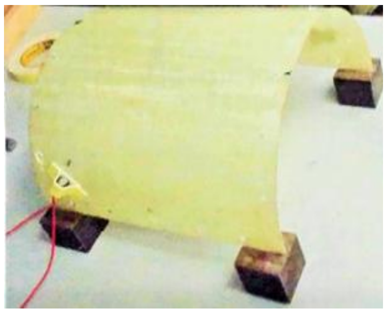

Fig. 8: Simply supported end condition

4. Results and discussions

The frequency and amplitude for free-free condition of a half cylindrical shell with and without stiffener are shown in Table 1. From the predicted values of frequency and amplitude, the damping co-efficient is calculated by magnitude factor method. Initially a graph is plotted keeping frequency in X axis and amplitude in Y axis. Totally 898 values are plotted. From the plot, first peak is selected to find the damping co-efficient in all the boundary conditions. From the peak, maximum amplitude is found. Another graph is plotted only for the first peak alone. At the half of maximum amplitude, a horizontal line is plotted. Intersection of both peak line and the horizontal line gives the frequency 1 (F_1) and frequency 2 (F_2) values. The frequency at which the maximum amplitude occurs is called natural frequency (F_N). Using the values of F_1, F_2 and F_N, the damping co-efficient is calculated [5]. Comparison of damping factor without and with stiffener is shown in Table 2. The damping factor of stiffened shell has increased significantly for all the boundary conditions studied.

Table 1: Frequency and amplitude of half cylindrical shell with and without stiffener

With stiffener		Without stiffener	
Frequency (Hz)	Amplitude (gn rms)	Frequency (Hz)	Amplitude (gn rms)
0	424.11	80	58.24
20	14.08	82	53.04
22	13.78	84	36.86
24	12.01	86	46.8
26	137.27	88	92.69
28	443.82	90	144.37
30	690.34	92	189.94
32	748.56	94	238.5
34	728.39	96	288.63
36	624.62	98	334.77
38	317.93	100	371.17
40	11.43	102	393.65
42	7.299		
44	17.67		
46	72.83		
48	124.61		
50	103.59		

Table 2: Comparison of damping factor without and with stiffeners

Boundary condition	Shell without stiffener			Shell with stiffener		
	F_N(Hz)	A_{max}	ξ	F_N(Hz)	A_{max}	ξ
Free - Free	102	393.65	0.177	32	748.56	0.311
Fixed	4	652.81	1.475	2	100.77	4.04
Simply supported	30	1093.9	0.25	4	567.62	1.362

5. Conclusion

The laminated semi-cylindrical shells were tested with boundary conditions such as free-free, fixed and simply supported ends. The damping characteristics were compared. Further to increase the damping, natural rubber was dispersed into the resin and the final results were obtained. From the results, it was found that the stiffener reduces the vibrations significantly. Therefore, adding stiffeners improves the damping on the shells. The addition of natural rubber also gave desirable results.

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