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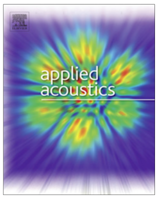

Application of composite materials to the chenda, an Indian percussion instrument

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ABSTRACT

An acoustically and structurally effective drum shell is developed for a traditional Indian drum. The basic design concept is a sandwich structure composed of carbon fibre/epoxy face sheet and balsa core on which the drum head is attached. The drum shell structure was fabricated by wet lay-up and a vacuum molding technique. Sound characteristics were analysed for both composite and wooden drums. Measured acoustical performance shows that the frequency response of the composite drum is comparable with that of a traditional wooden drum. It seems promising that composite materials with high damping characteristics could replace wooden structures used in musical instruments. Further, composite manufacturing helps in bringing standardisation and uniformity to musical instrument structures.

1. Introduction

Drums are the oldest musical instruments [1]. Historically, the material of construction of a drum shell is limited to certain species of hardwoods. The way in which these are fabricated by musical instrument builders working in small-scale operations is labour-intensive and is very much dependant on the skill of the craftsman. Drum shells are used to support the drum head membranes in place and also act as a resonating structure. Recently the availability of quality hard woods for making musical instruments has decreased. Dimensional stability is another major reason why wood alternatives are attractive in musical instrument structures. Warpage is a big concern for the drum bodies as it can cause the contact surface with the skin to be either out-of-plane or oval, which can have serious audible consequences. Cracking of the wood due to sudden changes in temperature or humidity is also a common occurrence in drum shells. To overcome these issues, this study is aimed at replacing the hardwoods used in traditional instruments with composite structures to produce consistent quality drum shells.

Controllable mechanical properties in different directions as well as high stiffness-to-weight ratio and environmental stability have made composite materials a desirable material for many high performance applications such as aerospace, military and marine applications [2]. Over the years, the demand for new composite products has pushed the manufacturers to use low cost manufacturing methods, such as vacuum molding (VM). The vacuum molding process makes use of atmospheric pressure to consolidate the material while curing. The laminate in the form of pre-impregnated fibres or fabric is placed on a single mold surface. The lay-up is covered by a flexible membrane, which is sealed around the edges of the mold and the air is drawn out by a vacuum pump. The main advantage of this process is that shell moldings can be made by this process at very low cost [3].

Recently, research on alternative materials for musical instruments has attracted many researchers. Phillips and Lessard developed a flax fibre composite sandwich structure for stringed musical instruments [4]. From the above work it is clear that the design and the manufacturing of structures from composite materials is a complex, but feasible process. It was shown that the target values for material properties can be designed and achieved within a relatively good precision. Applying this kind of design considerations will be an important part of the evaluation process of composite materials for use in musical instruments structures.

Ono et al. have developed wood plastic composite structure for a traditional Japanese drum; however the alternative material has a higher density than that of the wood [5]. Composite materials have already found applications in saxophone reeds, neck stiffeners, and sound boards. But the use of the same for the structural

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part of musical drums is not yet investigated. The study was motivated by exploring the link between acoustical performances and manufacturing details of a traditional drum. The major requirement for drum shell structures are: (1) to match the acoustic behaviour of a wooden one and (2) to obtain good mechanical strength and damping properties.

This paper reports the design and manufacturing aspects of a traditional Indian drum called the chenda (Fig. 1) and the acoustic testing of the manufactured instrument. The drum shell is traditionally made from a hollowing out solid tree trunk. The Jackfruit tree is widely used for the drum shells and other musical instrument structures in India [6]. For the purpose of simplicity a cylindrical drum was considered in this study. This paper also provides key results from a comprehensive study looking at the effect of changes in drum shell material on the sound characteristics of a drum, with particular emphasis on damping. The design procedure of the drum shell is explained in the following section.

2. Basic design concept

Drum shell structures are designed for compressive loads due to the presence of the drum heads resting on them under high tension. Based on experience, a value of 9000 N/m was chosen to represent the axial compressive load that represents the load carried by the tensioning ropes.

The sandwich structure consists of two relatively dense and stiff face sheets that are bonded to either side of a low-density core. The face sheets carry bending-induced axial loads, and the core sustains shear stresses. It also helps to resist buckling of the face sheets under axial compressive loading. The core usually has low in-plane and flexural stiffness compared to the face sheets, but it can have significant transverse stiffness and shear stiffness. The loading condition in end compression and failure mechanisms of edgewise compression loaded sandwich structures are explained in [7]. A CAD model illustrating the basic design concept of a sandwich drum shell is shown in Fig. 2.

3. Materials and methods

Carbon/epoxy laminate, due to its high specific modulus and high density is selected for the face sheet material. The mechanical properties of the materials used in the design of the drum shell are shown in Table 1.

An epoxy resin system was selected in the present manufacturing process as it offers a better adhesion to the core than polyester. Sikadur-300 epoxy supplied by Sika Corporation was used in this study. This resin system is a high strength, high modulus and room temperature curing system and suitable for the wet lay-up process.

Among the various core materials available, balsa wood was selected for the drum shell application. Commonly, the composite structures are more lightly damped as compared to the wooden ones; in this regard, it is desirable in our application to choose a core material that provides a higher damping. Balsa wood is selected for this purpose which is more damped than the conventional honeycomb core [8]. Hence the use of honey comb and foam core is not investigated further. Enhanced core materials with foam filled honey comb structure are beyond the scope the study and could be investigated as future work.

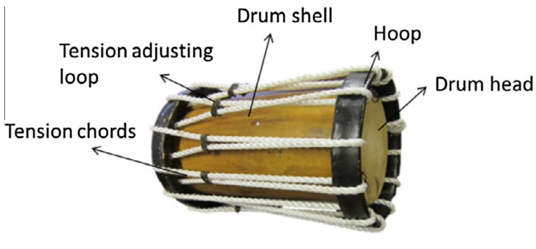

Fig. 1. Traditional Indian drum (chenda).

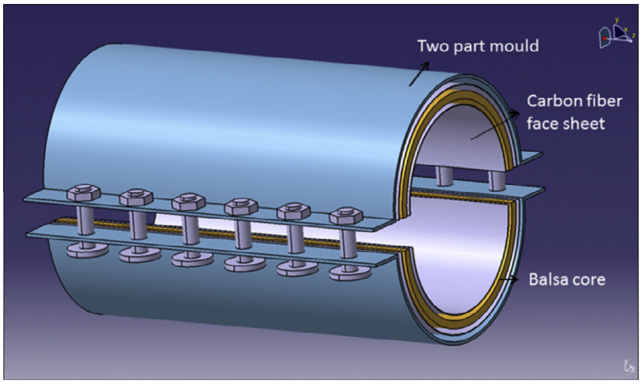

Fig. 2. CAD model of the lay-up.

Table 1
Material properties of layers.

Material	Properties
Carbon/epoxy[UD] [a]	Elastic modulus: 175 GPa Tensile strength: 1000 MPa Density: 1.60 g/cm^3
Balsa wood[a]	Elastic modulus: 3.35 GPa Tensile strength: 12.6 MPa Density: 0.155 g/cm^3

[a] Properties measured in grain direction.

Before designing the layup, damping studies were carried out on rectangular specimens for both jackfruit wood and composite. Wood samples are collected from the local instrument builder Jayan, Kerala, India and the composites samples were prepared by vacuum bagging technique. All the specimens are in the form of bars with a rectangular cross section. The average dimensions of the specimens were 150 mm (L) by 12 mm (W) by 1.8 mm (H). Dynamic Young's modulus E_L and internal friction Q_L^{-1} were analysed by non-contact forced-released flexural vibration of free-free beams as described in reference [9]. The frequency range of measurements was about 200–1150 Hz and the measurements were made at about 20 °C and 65% relative humidity. E_L was calculated from the resonance frequency and Q^{-1} from the damping. The density was finally obtained by dividing the calculated volume by the mass of the sample.

The average values of density, Young's modulus and damping coefficient in the axial direction are shown in Table 2. Classical laminate theory was used to predict the in-plane and bending stiffness of the laminate so that it could be tailored to that of Jackfruit wood. The final shell ply sequence was [0*u*] *s* (where *u* = unidirectional and s = symmetric) with a core thickness of 10 mm. This was

Table 2
Mechanical and acoustical properties of jackfruit and composite.

Specimens	Density (g/cm^3)	E_L (GPa)	$Q_L^{-1} \times 10^{-3}$
Jackfruit	0.635	9.86	7.6
Balsa carbon sandwich[a]	0.307	21.35	5.7

[a] Carbon fibre kept perpendicular to wood axial (*L*) direction and measured along the fibres.