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Sound and vibration damping characteristics in natural material based sandwich composites

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ABSTRACT

Recently, considerable attention has been paid on the utilization of natural materials in structures. Utilizing natural materials over traditional, synthetic structures results in a reduction of carbon emissions from material synthesis; such a source of materials could also be renewable and recyclable. Currently, few reports exist on sound and vibrational properties in sandwich composites with the use of natural materials. Sandwich composites are commonly used in structures for their superior strength and stiffness-to-weight ratios, but from these same properties, they radiate noise efficiently. Here, in this study, the sound and vibration damping properties of natural material based sandwich composites were explored and characterized. It was experimentally observed that utilizing a balsa wood core with a natural fiber based face sheet has a 100% improvement in coincidence frequency, a metric of acoustic performance, and the combination of a natural fiber based face sheet with a Rohacell 51 WF synthetic core exhibits a 233% increase over a fully synthetic sandwich composite. As these improvements in acoustic performance are achieved with only small sacrifices in bending stiffness, these results suggest that, if optimized, natural material based sandwich composites could be an environmentally friendly solution to the sandwich structure-noise radiation problem.

1. Introduction

Traditional fiber reinforced composite materials consist of either glass or carbon fibers, coupled with a resin. These materials are strong, stiff and light-weight, often providing superior mechanical performance at a reduced weight compared to their metallic counterparts. Utilizing these materials as face sheets for sandwich structures provides an even greater improvement in mechanical performance and are preferred in many applications with weight constraints; Fig. 1a shows a schematic of a sandwich composite beam. Unfortunately, the light-weight and stiff properties of sandwich structures make them efficient noise radiators compared to metallic structures. Acoustic properties are often a secondary design criteria in sandwich composite structures, whereas mechanical performance and weight are primary concerns. Thus rather than sacrificing mechanical performance, common state-of-art methods involve the addition of sound absorbing material, which is expensive, labor-intensive, and adds more weights to the structure; this often raises the issue of structural integrity.

Over the last couple of decades there is an increasing demand for materials that are more environmentally friendly. There have been many studies performed on natural material based sandwich composites [1–13], which take advantage of both natural materials as well as superior mechanical performance over metallic structures. These "natural" materials could essentially be grown for the purpose of sandwich composite fabrication, in turn providing such benefits as being both biodegradable and recyclable. Moreover, replacing synthetic materials with natural materials results in a reduction carbon emissions, since oil and other carbon products are needed for the fabrication of synthetic structures. Dwieb et al. [3] showed that structured sandwich panels made from natural resins and fibers can be combined with recycled materials to maintain the panel's superior stiffness. Bamboo is a popular fiber to be used when it comes to natural materials, since it has superior stiffness as bamboo shoots in nature. Murali Mohan Rao [7] compared different types of natural fibers, and found that bamboo-based composites have superior strength amongst the natural fiber composites in the study. Kim et al. [5] has used both wood and cotton fiber in polypropylene natural fiber composites at various fiber volume percentages. Another popular natural material is kenaf fibers [12]; both kenaf and other natural materials such as cotton and flax are being used in composite structures for interior materials of automotive structures [12,13].

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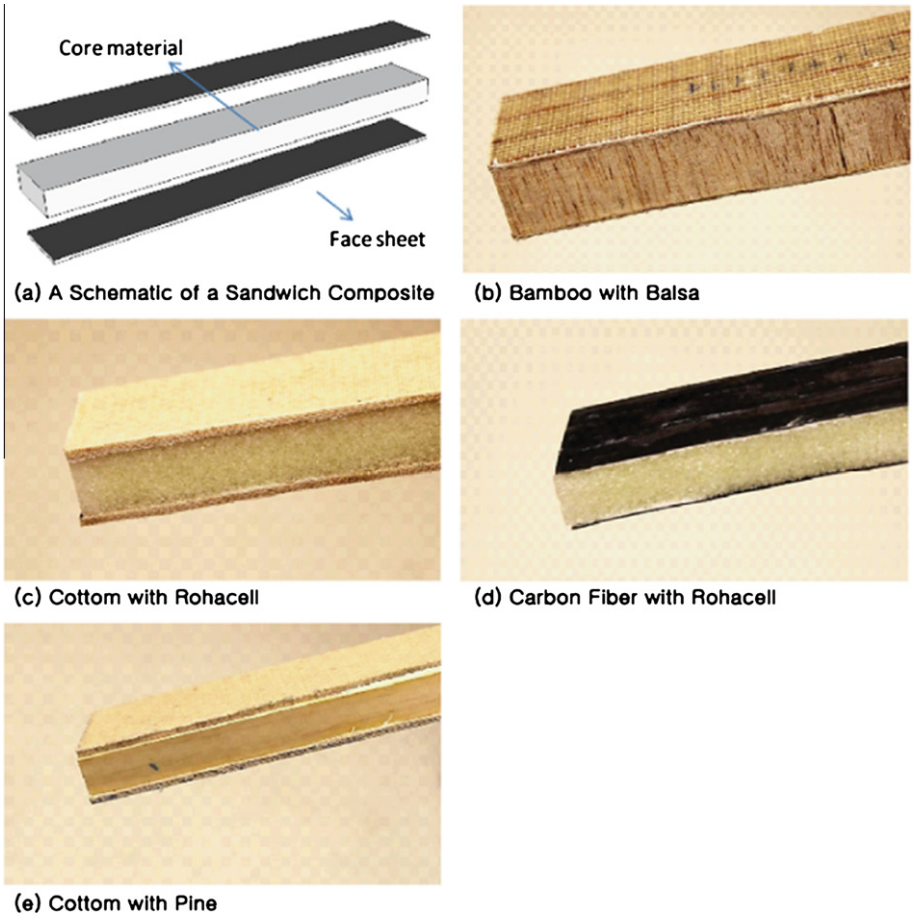

Fig. 1. (a) A schematic of a sandwich composite. (b) Bamboo face sheet with Balsa wood core sandwich beam. (c) Cotton face sheet with Rohacell foam core sandwich beam. (d) Carbon fiber face sheet with Rohacell foam core sandwich beam. (e) Cotton face sheet with Pine wood core sandwich beam.

One previous study [11] showed the promise of natural cork agglomerate as a core material, couple with carbon fiber face sheets, in sandwich structures. Results showed vastly improved sound and vibration performance over traditional synthetic sandwich structures. In this study, more combinations of other types of natural materials are explored in a sandwich structure configuration. Cotton, bamboo, and carbon fiber based composites are chosen as face sheets, while balsa wood, pine wood and synthetic Rohacell foam are used as core materials in sandwich composite materials. As previously mentioned, these natural materials have been used in the past to create composite structures, and are often used as secondary structures (i.e. non-critical structures), such as automotive interiors. Even though natural material based sandwich composites are receiving increased attention and usage in application, few studies have been performed on the acoustic and vibrational properties of natural fiber sandwich composites, especially with regard to noise radiation and structural damping. Such a problem is essential to investigate, since nearly all current and potential applications are exposed to a wide range of vibrations.

The goal of this study is to explore the acoustic response and damping properties of sandwich composite beams composed with natural materials and compare them over commonly used traditional sandwich composites, such as carbon fiber face sheet based Rohacell core sandwich composites. By utilizing such materials in the fabrication of sandwich structures, significant reductions in carbon emissions could be achieved, along with the ability to have materials which are renewable, recyclable and biodegradable. Natural material based sandwich composites with improved acoustic performance and damping properties will be an environmentally friendly solution to the sandwich structure-noise radiation challenge.

2. Experimental

2.1. Materials and fabrication

This study utilizes two types of natural fiber composite face sheets (bamboo and cotton with vinyl ester resin), and one synthetic face sheet (carbon fiber with epoxy). The carbon fiber-epoxy face sheet was supplied as a fully cured 0–90° laminate from the M.C. Gill Corporation, and consequently no further curing or fabrication was required. The purpose of selecting such a material is that it is often used in applications, such as commercial aircraft, and provides an excellent baseline for current state-of-art face sheet materials. For the two natural fiber face sheets, the method of manufacturing was Vacuum Assisted Resin Transfer Method, or VARTM. A stainless steel table was cleaned and prepared with the fiber sheets cut and oriented for infusion. Both the bamboo and cotton layups were a 0–90–90–90° orientation; the extra laminae (compared to the 0–90° for the carbon fiber) were added to increase the laminate's elastic modulus. After the fibers were oriented, the entire layup was then bagged and placed under a vacuum to have the resin properly infused. The resin used in this fabrication process was Derekane 510-A Vinyl Ester Resin, mixed with Methyl Ethyl Ketone Peroxide, Cobalt Naphthalene, and 2,4-P