Noise Control Using Green Materials

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Global competition has led manufacturers of household appliances to explore the use of ecofriendly, biodegradable, low-cost materials for noise control. A case study is presented on noise control of a domestic clothes dryer, where 6 dB of noise reduction has been obtained by using a natural-occurring plant fiber (jute and its derivatives). The acoustical and thermal properties of this material has been measured and reported as well.

Today's customers and appliance users are more aware of the product noise level than few decades ago. In a globally competitive environment, manufacturers are serious about the noise emitted by the products they manufacture. The manufacturers also have to abide by local regulatory standards for emitted noise levels. In addition, the customer also demands a better product sound quality. There are instances when the products, particularly home appliances like washing machines, dish washers, vacuum cleaners, refrigerators, food processors and room air-conditioners, are kept and operated in confined spaces in small apartments in many parts of the world. The noise from these home appliances is an important issue. In fact, some of these appliances have no or very poor noise control materials in them for noise reduction.

Product designers are now using concepts of engineering to reduce noise levels, for example:
- Low-speed operation
- Low-pressure operation
- Low-impact impact situations
- Closer manufacturing tolerances with better surface finish
- Adequate lubrication
- Vibration damping materials, etc.

In addition, to reduce radiated noise, structural engineers also use ribbed structures that have low sound radiation efficiency along with damping materials. For sound blocking, heavy sheet metal and thick elastomer sheets are used as barrier materials. Traditionally the noise control materials used for sound absorption have been open-cell polyurethane foams and fiberglass. In many parts of the world, the use of fiberglass for noise absorption has been phased out, since the glass particles are brittle, break at the slightest load and are harmful for humans to breathe.

Due to concerns of global warming and significant climate changes, manufacturers are looking for alternative noise control materials that are ecofriendly and leave less carbon residue. Researchers around the world are exploring the possibility of using ecofriendly, biodegradable materials like jute, hemp, cotton, coir, kenaf and banana leaf for noise control applications.[1-3] The acoustical properties like the normal specific sound absorption coefficients of these materials have been reported. Some of these green materials can also be made into composite panels using a suitable resin for sound barrier applications. The composites reinforced with natural fibers like jute, sisal, banana and coir have been subjected to intense study for their low density and low-cost application in contrast to synthetically reinforced composites. These materials have the potential to replace traditional synthetic noise control materials because of their comparable acoustical and mechanical properties.

These materials have to be engineered and implemented for noise control applications. Some of these green materials also have acceptable fire-retardant properties, and in some cases, additional chemical treatment can be done to improve their fire-retarding properties. These materials have been successfully used in noise control of domestic appliances like vacuum cleaners and domestic clothes dryers. They can also be used for improving building acoustics instead of traditional gypsum-based ceiling tiles. These materials can be used to line enclosures and HVAC ducts for noise control purposes.

It has also been reported that some of these green materials are being used in automobile interiors for improvement in NVH. In recent years, there is a growing interest in developing new materials that enhance optimal utilization of natural resources, and particularly, of renewable resources. Research on natural fiber is in the forefront due to its significant economic, biodegradable, recyclable and eco-friendly properties. For instance, in the year 2013, about 25 kg of raw jute fiber can be procured in India for $1.

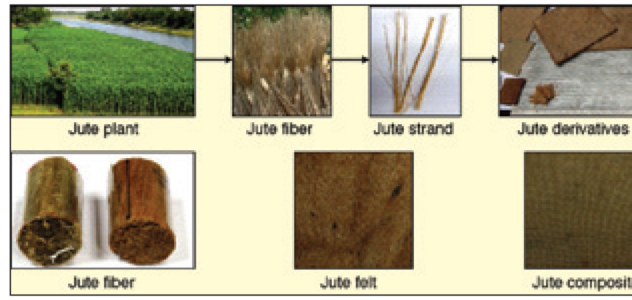

Figure 1. Jute and its biocomposite derivatives for noise control applications.

In this article, research is presented from the Indian Institute of Technology, Kharagpur, on using jute for noise control in a domestic clothes dryer.

Jute

Jute is a naturally occurring plant fiber and has been promoted as the most readily available, environmental friendly, abundant, economic and bio-renewable source. It is specifically cultivated in large quantities near large bodies of water in the eastern part of India and Bangladesh and are exported all over the world for use in various applications. Jute is a lignin-cellulose fiber that is composed primarily of the plant materials: cellulose (major component of plant fiber) and lignin (major component of wood fiber). It falls into one of the bast fiber categories (fiber collected from the bast or skin of the plant) along with kenaf, industrial hemp, flax (linen), ramie, etc.

Jute is used in various forms for noise control applications. After cleaning, the raw jute fiber is used to produce jute yarn by a spinning process. The jute yarn is then woven to make jute textile or cloth. Stacks of jute yarn laid in a random or a definite sequence are pressed under temperature to produce jute felt. The jute felt/fiber in turn can be chemically treated with a bonding agent (usually natural rubber latex as a resin) and pressed under certain temperature to form jute-based biocomposite panels. In few instances the raw fibers after appropriate processing can be chopped and used as fills in noise control blankets and pads.

In jute mills, where jute-based textiles are manufactured, waste material is produced during the trimming operation of these textiles. These materials can also be used as acoustical fill for noise control. All of these forms of jute derivatives as manufactured through various processes from the raw jute plant are shown in Figure 1.

Properties of Jute

To apply these jute-based derivatives to various industrial applications for noise control, some of its important properties like mechanical strength, fire retardant properties, acoustical properties, and chemical stability at extreme temperatures have been measured and reported.[4-5]

In general, jute fibers have an aspect ratio (length/diameter) above 1000 and can be easily woven and spun into coarse and strong threads. These fibers are mostly used for fishing nets, sacks, bags, ropes and as a filling for mattresses and cushions. In general, bast fibers (skin fiber collected from plants) have good thermal and acoustical insulation properties.

However, there are a few drawbacks associated with the ap-

Figure 2a. 300-ton hydraulic press used for compression moulding.

Figure 2b. Chemically treated jute felt before and after the compression.

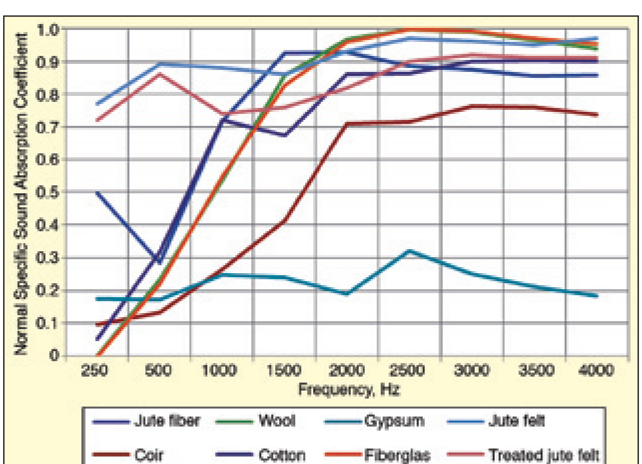

Figure 3. Sound absorption of noise control materials.

plication of jute fibers. The primary one is lack of consistency in fiber quality due to presence of hydroxy and other polar groups in various constituents. Another one is high moisture absorption, which causes dimensional instability to the composites. The compatibility between matrix and fiber is poor, which requires surface or alkali treatment. These limitations in the performance of jute-based fiber composites can be greatly improved through chemical modification techniques.[6]

Fabrication of Jute Composites

The natural-rubber-based jute composites are prepared by the following procedure:

1. Jute felt of 400 gsm (gram per square meter) specimens are dried in an oven for 1 hour to remove the water content in the specimen.
2. The jute felt is treated with 1% NaOH (alkali) solution for 1 hour. This alkali treatment is used to remove the impurities in the specimens.
3. These alkali treated jute felts are again washed by water till they become alkali free.
4. The washed jute felts are dried in an oven at 80^0 C for an hour.
5. The dried felt is then dipped in 1% (by volume) natural rubber solution for 1 hour.
6. Excess rubber latex is drained off, and the rubber-treated jute felts are dried in a dry room for 1 hour.
7. Jute-based natural rubber latex composite is prepared by compressing 10 pieces of natural-rubber-treated jute felts in a hydraulic press at 140^0 C with a load of 8 tons for 15 minutes. Similarly 2.5% natural rubber, 5% natural rubber and 10% natural rubber jute composites are prepared keeping all other parameters same.

In all the sample preparations, natural rubber is used as bonding agent between the interfaces of the fibers. Figure 2a shows a view of the hydraulic press used for fabricating the jute composite panels. Figure 2b shows the chemically treated jute felt before and after the compression.

Thermal Properties of Jute

Limiting oxygen index, flame propagation, thermal conductivity, a thermogravimetric test and smoke density tests are performed on the jute derivatives at the facilities of the Indian Institute of Technologym, Kharagpur, as per various international standards. Based on a limiting-oxygen-index test, it is observed that the minimum concentration of oxygen that will support flaming combustion of jute is 30%. And natural rubber latex-based jute composite shows poor flame propagation speed when a 1% sodium phosphate fire retardant is added to the jute composite. (The flame propagation speed for synthetic cotton is approximately 24 times higher.)

Comparing the natural rubber latex jute composite with fiberglass, natural rubber latex jute composite shows the least smoke density rating and better performance in maximum light absorption. The thermal conductivity of jute felt is 0.064 W/m-K in the temperature range from 50 to 80° C. Thermogravimetric tests have shown that jute and its derivative can be used in applications up to a temperature of 260^0 C, which can be further enhanced with suitable chemical treatment.

Sound Absorption Coefficient

The normal specific sound absorption coefficient measured per ASTM E-1050 standard in the laboratory of some of the sound absorbing materials used for noise control are shown in Figure

Table 1. NRC Values of untreated and NR-sprayed jute felts (400 gsm).

Treatment	Density, kg/m^2	NRC
Untreated	117	0.85
1% natural rubber	219	0.80
5% natural rubber	311	0.78

Table 2. Measured transmission loss of 5 mm natural-rubber-treated jute composite.

Sample	Treatment	Mass, kg	Surface Density, kg/m2	STC
1	1% rubber	0.075	3.3	37
2	2.5% rubber	0.076	3.3	38
3	5% rubber	0.098	4.2	39
4	10% rubber	0.098	4.2	40
5	15% rubber	0.096	4.2	40

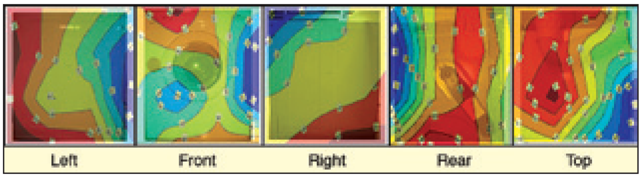

Figure 4. Sound intensity level in dBA of domestic dryer without acoustical treatment.

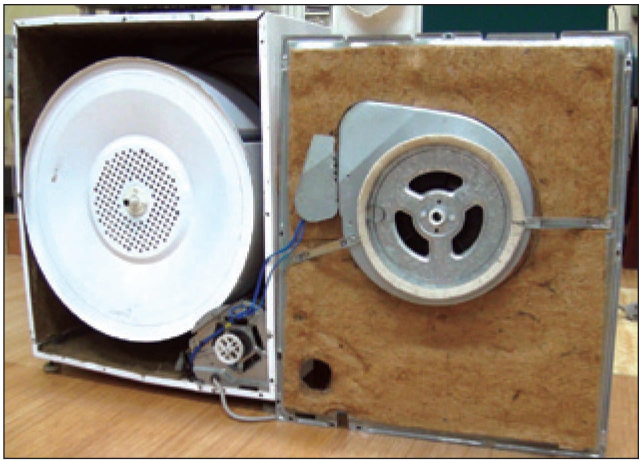

Figure 5. Inside view of the dryer shell with jute treatment.

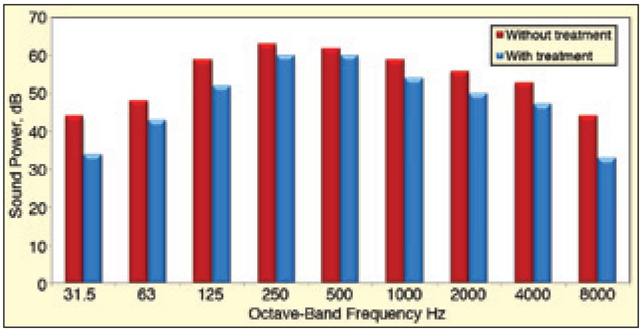

Figure 6. Octave-band spectra of the radiated sound power of the dryer.

3.[7,8] Each material in Figure 3 is 25 mm thick with a rigid backing. The normal specific sound absorption coefficient of all the materials increases with frequency. Fiberglass and glass wool have high sound absorption coefficients. Gypsum board has a low sound absorption coefficients, since it is denser with less porosity. The natural materials like jute, cotton and coir also have relatively high sound absorption coefficient. Polyurethane open cell foam has a sound absorption coefficient higher than that of gypsum, though less than the porous natural materials and fiberglass.

Usually in certain applications, when air flows over the jute fibers at grazing incidence, the fibers may come out of the jute felt with the air flow. To prevent the fibers from separating, natural rubber is sprayed on to the jute felt surface. However this coating of natural rubber may close some of the pores of the jute felt and decrease its sound absorbing capability. So rubber spraying has to be done with caution. Table 1 shows that untreated jute felt (density 117 kg/m^3) has a higher noise reduction coefficient value (0.85) as compared to sprayed 1% natural rubber latex jute felt (density 219 kg/m^3).

Acoustic Transmission Loss

The acoustic transmission loss of 5 mm natural rubber-based jute composite fabricated from 400-gsm jute felt is measured per SAE J1400 in the laboratory and are reported in Table 2.[9] The transmission loss of these materials improves with an increase of surface density.

Noise Control in a Domestic Dryer

The physical dimensions and mass of the clothes dryer in which noise control measures were implemented are 530 mm × 600 mm × 720 mm and 26 kg respectively. Motor rating and heater rating are 300 W and 1.8 kW, respectively. The drum used inside the dryer for placing the wet clothes is epoxy coated; a maximum of 5.5 kg of wet clothes can be dried in this dryer in an operation cycle. The dryer has a safety cut-off that limits the temperature inside the drum to 105° C. All experimental trials were done in the clothes dryer while running empty.

For noise source identification of the dryer, a sound-intensity-based mapping was done using a two-microphone sound-intensity probe. The measured sound-intensity contours of the five surfaces of the dryer are given in Figure 4. Overall sound power was measured in the frequency range of 31.5-8000 Hz at each of the grid points by a sound intensity probe held at distance of 150 mm from the dryer surface.[10]

Figure 4 shows that the region around the motor driving the drum by a belt drive was the most dominating noise radiator, followed by the dryer exhaust at the rear top location. The overall sound intensity level in the region around the motor was 68.6 dBA and 67 dBA around the dryer exhaust.

Application of jute-based acoustical materials to the dryer was carried out for two configurations. In the first configuration, jute felt lining was applied to the rear inner wall of the outer shell of the dryer (see Figure 5). With such a treatment, there was a marginal reduction to 68.7 dBA. In the next configuration, all the inner walls were lined with 5 mm jute felt, and the inner top was backed with a jute composite panel. There was a reduction of 5.9 dB in the overall sound power level, and the overall sound power level reduced to 63.5 dBA. The octave-band sound power spectra of the dryer with and without the jute material treatment is shown in Figure 6.

Conclusions

Noise control in home appliances has to be economic, simple and easily implemented, since there is global competition among manufacturers. New ecofriendly materials for noise control are being explored, and their acoustical, thermal and mechanical properties are being studied to determine the efficacy in using them for product noise control.

A naturally occurring bio-degradable material, jute and its derivatives have been used to bring about an overall noise reduction of 6 dB in a domestic clothes dryer. The jute derivatives can be used as either a sound-absorbing material or a sound barrier. These jute derivatives can be manufactured by simple compression molding techniques. These materials are economical and have potential for noise control applications in other home appliances, automobiles and for building acoustics.

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