Acoustic isolation of Jute and Kapok fiber reinforced Polypropylene composites

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Abstract. For the requirements of human health initiative especially when emerging of advanced composite material technology, manufactures of high efficient acoustical materials are necessary to regulate the noise pollution. The objective of this study is to fabricate the jute and kapok fiber reinforced polypropylene composites and to analyze the comparison of acoustic isolation effect of jute and kapok fiber reinforced polypropylene composites. To produce these two types of composites material, the raw materials went through a different stage of procedure such as, blending, mixing and heat compression molding process. Polypropylene was filled with jute and kapok fiber at various loading at 0, 10, 20, 30 and 40% each. The composites were prepared by using Brabender Torque Rheometer Plastograph machine and the hot press at temperature 180°C with 50 rpm. The acoustic test was conducted by using insertion loss method in sine wave tube device to measure the different sound level, loss in these two composites material. Based on the result observed, the higher of weight percentage of jute and kapok fiber in each composition, the better of the performance for each material and the optimum result for each composite are determined to be 30% filler loading. It also can be conclude that the used of jute fiber reinforced polypropylene composites give an outstanding result in term of sound absorption and transmission loss compared to kapok reinforced polypropylene composites.

1. Introduction

Both human health and behaviour which lead to hypertension, hearing loss, high stress levels, tinnitus, sleep disruption, and other pernicious effects are caused by noise pollution related. This will give advantage to researcher and manufacturer to produce a new type of composite material with different kind of properties for different kind of application purposes. Composition of petrochemicals based synthetic substantial material such as glass wool, rock wool, polyurethane (PE) which is usually in forms of porous structure generally expensive to make for acoustic application of modern sound absorption material. Unfortunately, most of them are not degradable and synthetic fiber have potential hazard to human health, environment which is why scientist and researcher focus their attention more on environmental friendly and renewable natural alternative. Cheap, lightweight, abundant, biodegradable, and eco-friendly nature are the main considerable factor why currently started from a few years back, the natural fiber reinforced resin or polymer composites have received so lot of attention compared to fiber glass composites [1]. The biodegradability of plant fibers can contribute to a healthy ecosystem while their low cost and high performance fulfill Is the economic interest of
industry [2]. Recent tendency towards the environmental protection stimulates the utilization of natural materials as sound absorbers, e.g. random cut rice straw, coconut coir, bamboo, and tea leaf-fibre [3-6].

Naturally fiber can be simplified as the manmade or non-synthetic version of fiber, where it’s naturally come from plants or animal [7]. It can be defined as a material that consist of high strength natural fibre like kenaf, oil palm, flax, jute and oil palm, and embedded with any polymer matrix like, polypropylene, polyurethane and others matrix [8]. One of renewable natural material is jute fiber. Recently, many engineering applications used jute fiber as composite material in development of reinforced plastic as it has properties like abundant, inexpensive, bio-degradable and reasonable mechanical properties make it preferable reinforcement material in development of polymer matrix composites. Thus, most widely used synthetic fiber (Glass, Kevlar) reinforced composites could be replaced with jute reinforced composites in numerous engineering application [9-10]. The properties of composite can be improved by the rise of fibre content [11]. One of the major drawbacks of using jute fiber as reinforcing material is its hydrophilic nature, responsible for moisture absorption and consequent deformation of the product. Several researchers have conducted chemical treatment of jute fiber to improve its hydrophilic nature and the mechanical properties of the jute fiber reinforced polymer composites [12-16].

Kapok fiber is belonging to natural cellulosic fibers and can be obtained from kapok tree (Ceiba Pentandra) seed hair. The unique microtube morphology, naturally exist in kapok structure have ability to void content, usually can be high as 80% to 90%. Kapok fiber is abundant and easy to obtain, bio-degradable, environmental friendly and its full potential in many applications as most commonly known worldwide, and attract more researchers from the academic institution or industrial field to study. As it’s consist of air filled lumen in their structure, kapok fiber also well known for its ability to act as heat and acoustic insulation and as well as buoyant material. Furthermore, it increases the anticipation of friction between sound waves and fibers, special structure of kapok fiber would also be beneficial for the sound absorption. It has potential applications in noise reduction field due to outstanding chemical stability [17].

The outstanding and promising results in mechanical, physical and thermal properties make the polypropylene is choose with jute and kapok natural fibers. Due to inimitable properties and ability to adapt various manufacturing methods make it extensively used and preferable choice for wide range of uses and still remain a major player in plastic industry nowadays and has been rapidly growth sustained over the years [18-23].

2. Experimental

2.1. Materials and experimental procedures

The raw materials used in this experiment are polypropylene, jute fiber, kapok fiber. All materials must be blend in its required size or until it’s become powder. For jute and kapok fiber, its suitable length must be 0.5mm and below, while for matrix polypropylene, it’s readily came with pellet form. Jute and kapok fiber went through drying process for about 120 degrees Celsius in half an hour. The mixing of the composites was carried out by using Brabender Torque Rheometer Plastograph machine, which is high torque and performance machine to make sure all material properly mixes well. The temperature used was 180°C and rpm was set to 50. Also, torque required in this process is 0.3 Nm with total time 10 minute per sample. The formulations for jute and kapok fiber reinforced polypropylene composites are listed in Table 1 below:

| No. | Materials  | Percentage |
|-----|------------|------------|
| 1   | Polypropylene (%) | 100,90,80,70 |
| 2   | Jute (%)    | 0,10,20,30,40 |
| 3   | Kapok (%)   | 0,10,20,30,40 |
Heat compression technique was used in order to produce a sample with square panel with desired size and thickness. The machined used was a hot press Labtech LP50 series, semi-automatic function, equipped with 3 separation process, which is heating, hydraulic compression and cooling process. Complete cycle time for one sample was set automatically for 13 minute each. The size required for this experiment was 15 x 15 cm in squared shape and thickness was 0.1 cm for each sample.

2.2. Testing method: Acoustic test
The sheet samples were transformed into round shape. The insertion loss method was used in this with the software of Room EQ wizard (REW) v5. The sample material will act as a barrier inside the tube chamber between main source (Speaker) and receiver (Condenser microphone). Software automatically, produced a sine wave sound in different range of frequency to be captured by the receiver. Rubber material was applied to the sample panel to avoid sound leak to the receiver through any small gap presented in chamber. The frequency setting used in this experiment was limit to 350 Hz to 550 Hz in range.

3. Results and discussion
Jute fiber reinforced polypropylene and kapok fiber reinforced polypropylene with different weight percentage went through test to compare the loss in acoustic. The data measure started with open air (no barrier) to be set as datum, followed by 100% polypropylene which acts as a control sample. Then the data is measured for 10% to 40% of jute sample panel followed by 10% to 40% of kapok sample panel as a sound barrier.

![1/6 Octave smoothing insertion loss with different weight percentage in kapok reinforced polypropylene](image)

**Figure 1.** Different weight percentage of kapok fiber reinforced polypropylene composites in acoustic test strength.
Figure 2. Different weight percentage of jute fiber reinforced polypropylene composites in acoustic test.

Figure 3. Optimum weight percentage comparison of jute and kapok reinforced polypropylene in acoustic test.
Figure 1 shows the acoustic loss in decibel (dB) of different weight percentage of kapok fiber reinforced polypropylene composites. The graph consists of 10, 20, 30 and 40% of kapok fiber in each sample. The lower decibel value shows better insertion loss of the test material. It is clearly show that the sound different between no barrier test and the barrier applied with composite material panel drop significantly. The no barriers however, keep decrease when increase in frequency range, but still, more superior in sound level compared to when material applied. More than that, the 100% polypropylene shown much better in sound insertion loss compared to kapok filler 10% and equivalent level with kapok filler 20% respectively. However, when amount of kapok filler increases to 30%, the result show better in sound insertion loss compared to polypropylene. Nevertheless, increasing kapok filler to 40 % perceives not much different when compare to kapok filler 30%.

Figure 2 shows the acoustic loss in decibel (dB) of different weight percentage of jute fiber reinforced polypropylene composites. The graph consists of 10, 20, 30 and 40% of kapok fiber in each sample. It demonstrates that the insertion loss for no barrier result is lowest compared to when panel was applied. Other than that, the graph certified that, jute fiber reinforced polypropylene composites much better and superior in term of insertion loss compare to 100% polypropylene. The graph indicates that, the 10% jute fiber loading is better that polypropylene alone, then supersede by 20% and 30% jute fiber loading respectively. However, when jute filler increases to 40%, there is no significant change in term of insertion loss.

Figure 3 shows the comparison result between these two composites material, jute fiber reinforced polypropylene and kapok fiber reinforced polypropylene. The 30% filler of jute and kapok fiber were selected due to optimal result from the test. Based on the figure above, it’s clearly illustrated that the jute fiber reinforced polypropylene is far more superior in term of insertion loss when compare to kapok fiber reinforced polypropylene. Both jute and kapok fiber at weight percentage 30% have great in term of sound absorption and insertion loss and the range is within 20 to 60 decibel.

Kapok fiber contains a small amount of air trap or void inside their structure, hence small content of kapok filler is not enough to cover the whole panel and provided loophole in polypropylene matrix. Therefore, 100% of polypropylene was performed a way better compared to 10% kapok filler. However, when quantity of kapok filler increases to 30%, better quality of sound reduction panel is obtained due to supplementary of void content inside panel. For jute fiber, due to previous background research, describe that the jute void structure content is bigger and compactness with higher value of density when compared to kapok fiber. This is why sound absorption of jute is increase when the jute filler is increase. Hence, the jute fiber reinforced polypropylene is greater in term of sound absorption and transmission loss when compared to the kapok fiber reinforced polypropylene.

4. Conclusion
The uses of jute fiber reinforced polypropylene composite give an outstanding result in term of sound absorption and transmission loss compared to kapok reinforced polypropylene composites. Based on the result observed, the higher the weight percentage of jute and kapokfiber in each composition, the better the performance for each material. And the optimum result for each composite is determined to be 30% filler loading. This emphasizes that, amount of the weight percentage of natural fiber filler play an important role in outcomes of acoustic isolation test. The effect of acoustic isolation and the comparison of optimum result of jute and kapok fiber reinforced polypropylene composites were successful conducted and studied.

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