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TESTING THE VIBRATIONAL BEHAVIOUR OF JUTE FIBER BASED SANDWICH COMPOSITE

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Abstract

There has been a search for alternatives to steels and alloys for several years, to combat the high cost of repair and maintenance of structures damaged by corrosion and heavy use. Fibre reinforced polymer (FRP) is a relatively new class of composite materials manufactured from fibres and resins and has been proven efficient and economical. FRP composites are commonly produced by means of compression molding. To increase the effectiveness in manufacturing of FRP composites, the mold is incorporated with heating provision so as to avoid the problem of curing immediately when the resin is poured in the die assembly. As the name indicates, electrical power is used to produce the heat in an Electric die, heat and pressure is applied at the same time. Due to that a FRP composite with better strength can be obtained and avoid the chance to get delamination between the resin and the reinforcement because of uneven heating. Failure in material also happens because of non-vibrational withstanding nature of most of composite, thereby identifying a suitable natural fibre with good shock absorbing nature and also by incorporating shock absorbing foam between the FRP composite layers to form a sandwich composite. This paper mainly deals with producing a composite material with high shock absorbing capacity at cheaper rate compared to other materials and Vibration testing is carried over and analysing the way to improve the damping nature of the material.

Keywords- Sandwich Composites, Natural fibres, synthetic foam, FRP

I. Introduction

Composite materials, often shortened to composites or composition of materials, are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. Wood is a natural composite of Cellulose fibres in a matrix of lignin. The earliest man-made composite materials were straw and mud combined to form bricks for building construction. The ancient brick-making process can still be seen on Egyptian tomb paintings in the Metropolitan Museum of Art. Composites are made up of individual materials referred to as constituent materials. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties [1]. A synergism produces material properties unavailable from the individual constituent materials, while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination. Engineered composite materials must be formed to shape. The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mold cavity or onto the mold surface. The matrix material experiences a melding event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melding event can occur in various ways such as chemical polymerization or solidification from the melted state.

Most commercially produced composites use a polymer matrix material often called a resin solution. There are many different polymers available depending upon the starting raw ingredients. There are several broad categories, each with numerous variations. The most common are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK, Polyethylene and others [2]. The reinforcement materials are often fibres but also commonly ground minerals. The properties can be monitored by varying the resin content of the final product or the fibre content thereby better mechanical property can be achieved for vibration arresting. The term polymer is derived from two Greek words “poly” means many and the term “mer” means parts or units. Thus polymers are composed of a large number of repeating units of small molecule called monomers. In this research selection of polymer which is the toughest task was made based on the requirements for a composite material to achieve the need for study.

II. FIBRES AND ITS TYPES

Fibre (also spelled fiber) is classes of materials that are continuous filaments or are in discrete elongated pieces, similar to lengths of thread. They are very important in the biology of both plants and animals, for holding tissues together. Human uses for fibres are diverse. This can be spun into filaments, string, or rope, used as a component of composite materials, or matted into sheets to make products such as paper or felt [3]. Fibres are often used in the manufacture of other materials. The strongest engineering materials are generally made as fibres, for example carbon fibre and Ultra-high-molecular-weight polyethylene. Synthetic fibres can often be produced very cheaply and in large amounts compared to natural fibres, but for clothing natural fibres can give some benefits, such as comfort, over their synthetic counterparts. Classification of fibres is shown in Fig.1

A. Natural Fibres

Natural fibres include those produced by plants, animals, and geological processes. They are biodegradable over time [4]. They can be classified according to their origin:

Vegetable fibres are generally based on arrangements of cellulose; often with lignin examples include cotton, hemp, jute, flax, ramie, and sisal. Plant fibres are employed in the manufacture of paper and textile (cloth), and dietary fibre is an important component of human nutrition.

Wood fibre, distinguished from vegetable fibre, is from tree sources. Forms include groundwood, thermo mechanical pulp (TMP) and bleached or unbleached kraft or sulfite pulps. Kraft and sulfite, also called sulphite, refer to the type of pulping process used to remove the lignin bonding the original wood structure, thus freeing the fibres for use in paper and engineered wood products such as fibre board.

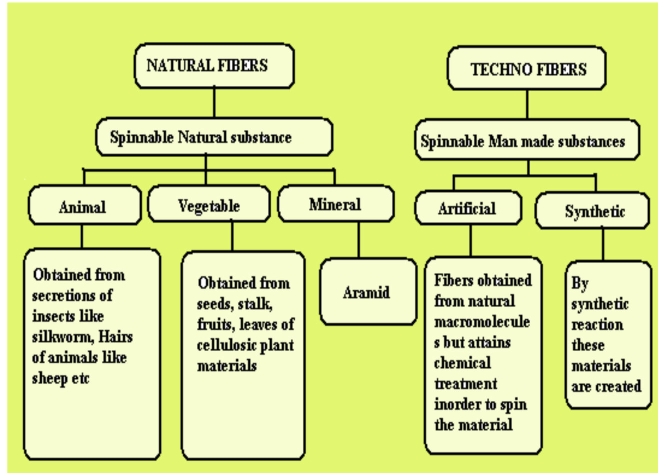
Animal fibres consist largely of particular proteins. Instances are spider silk, sinew, catgut, wool and hair such as cashmere, mohair and angora, fur such as sheepskin, rabbit, mink, fox, beaver, etc.

Mineral fibres include the asbestos group. Asbestos is the only naturally occurring long mineral fibre. Six minerals have been classified as "asbestos" including chrysotile of the serpentine class and those belonging to the amphibole class: amosite, crocidolite, tremolite, anthophyllite and actinolite. Short, fibre-like minerals include wollastonite and attapulgite.

B. Synthetic Fibres

Synthetic fibres are manufactured from natural cellulose, including rayon, modal, and Lyocell. Cellulose-based fibres are of two types, regenerated or pure cellulose such as from the cupro-ammonium process and modified cellulose such as the cellulose acetates [5]. Fibre classification in reinforced plastics falls into two classes: (i) short fibres, also known as discontinuous fibres, with a general aspect ratio (defined as the ratio of fibre length to diameter) between 20 to 60, and (ii) long fibres, also known as continuous fibres; the general aspect ratio is between 200 to 500.

FIG.1 (FIBRE CLASSIFICATION)



III. THE DIFFERENCE BETWEEN NATURAL AND SYNTHETIC FIBRES

A. Natural Fibre Properties

Natural fibres are obtained from plants or animals. It is an environmentally friendly choice for sewing projects because the fabric is created from renewable resources. Cotton, linen, wool, and silk are fabrics made with natural fibres The most common types of animals used in created natural fibre fabrics are sheep, alpacas, and silkworm, but other animals like goats and rabbits are also used. There is a variety of different plants used in creating natural fabrics. Cotton is, by far, the most commonly used plant in making natural fabric [6]. Bamboo is becoming increasingly popular because of its fast rate of renewal. Other plants used in creating natural fabrics are flax, hemp, and pineapple leaves [7].

B. Synthetic Fibre Properties

Synthetic fibres are a man-made product created through a chemical process. Chemicals are forced into spinnerets, which have tiny holes where the synthetic fibres are created. Polyester is the most common synthetic fabric created, but there is a huge list of other man-made fabrics. Acetate, nylon, and spandex are commonly used synthetic fabrics. Synthetic fabrics have a huge advantage over natural fabrics because they are more durable [8]. Natural fabrics, however, are better for beginners because they are easier to sew on. In general, the type of project should be taken into consideration before deciding whether a natural or synthetic fabric should be used.

IV. CHARACTERISTICS OF NATURAL AND SYNTHETIC FABRIC BLENDS

As its name would suggest, fabric blends are created by combining a natural fibre with a synthetic fibre. Using fabric that is created by combining two types of fibres is a great way to get the exact look or feel desired in a fabric. Natural fibres can feel scratchy to the skin but provide a lot of warmth. Combining a natural fibre with a synthetic fibre can give the fabric durability, warmth, comfort, aesthetic appeal, sheen, or any other number of combined qualities. Many different types of fabric blends are easily found in fabric stores. Cotton-poly blends are the most common and are a great choice for most sewing projects. Fabric blends, in general, are easier to take care of than natural or synthetic fibres on their own. This blending of fibres is called as hybrid fibres.

V.Composite and its classification

The term composite can be defined as a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual material that make up the composite. The two major classifications of composites are natural and synthetic. Figure 2 shows the three major classifications of composite materials. The most widely used meaning is the following one, which has been stated by, Jartiz "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form". The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures. Kelly very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them. Beghezan defines as "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings", in order to obtain improved materials. Van Suchetclan explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.Broadly, composite materials can be classified into three groups on the basis of matrix material. They are: Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC), and Polymer Matrix Composites (PMC)

A. Metal Matrix Composites

Metal Matrix Composites have many advantages over monolithic metals like higher specific modulus, higher specific strength, better properties at elevated temperatures, and lower coefficient of thermal expansion. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

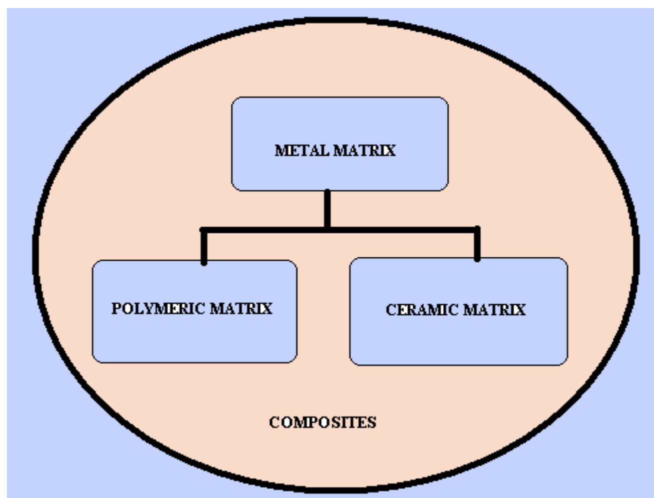
B. Ceramic matrix Composites

One of the main objectives in producing ceramic matrix composites is to increase the toughness. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites [9].

C. Polymer matrix Composites

Most commonly used matrix materials are polymeric. The reasons for this are twofold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and does not require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications. Composites are used because overall properties of the composites are superior to those of the individual components for example polymer/ceramic. Composites have a greater modulus than the polymer component but are not as brittle as ceramics.

Fig.2 classifications of composite materials



VI. Natural Fibre Reinforced Composites

The interest in natural fibre-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lingo cellulosic fibres, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites [10]. The natural fibre-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling panelling, partition boards), packaging, consumer products, etc.

A. Jute Fibre

Jute is a long, soft, shiny vegetable fibre that can be spun into coarse, strong threads. It is produced from plants in the genus Corchorus, which has been classified in the family Tiliaceae, or more recently in Malvaceae. Jute is one of the most affordable natural fibres and is second only to cotton in amount produced and variety of uses of vegetable fibres

Uses of Jute: Jute is the second most important vegetable fibre after cotton; not only for cultivation, but also for various uses. Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloth. The fibres are also woven into curtains, chair coverings, carpets, area rugs, hessian cloth, and backing for linoleum. While jute is being replaced by synthetic materials in many of these uses, some uses take advantage of jute's biodegradable nature, where synthetics would be unsuitable [11]. Examples of such uses include containers for planting young trees, which can be planted directly with the container without disturbing the roots, and land restoration where jute cloth prevents erosion occurring while natural vegetation becomes established. The fibres are used alone or blended with other types of fibre to make twine and rope. Jute rope has long been popular in Japan for use in bondage. Jute butts, the coarse ends of the plants, are used to make inexpensive cloth. Conversely, very fine threads of jute can be separated out and made into imitation silk. As jute fibres are also being used to make pulp and paper, and with increasing concern over forest destruction for the wood pulp used to make most paper, the importance of jute for this purpose may increase. Jute has a long history of use in the sackings, carpets, wrapping fabrics (cotton bale), and construction fabric manufacturing industry [12].Traditionally jute was used in traditional textile machineries as textile fibres having cellulose (vegetable fibre content) and lignin (wood fibre content). But, the major breakthrough came when the automobile, pulp and paper, and the furniture and bedding industries started to use jute and its allied fibres with their non-woven and composite technology to manufacture nonwovens, technical textiles, and composites. Therefore, jute has changed its textile fibre outlook and steadily heading towards its newer identity, i.e., wood fibre. As a textile fibre, jute has reached its peak from where there is no hope of progress, but as a wood fibre jute has many promising features. Figure 3 and 4 shows the images of jute plant and knitted jute fabric. Jute is used in the manufacture of a number of fabrics such as Hessian cloth, sacking, scrim, carpet backing cloth (CBC), and canvas. Hessian, lighter than sacking, is used for bags, wrappers, wall-coverings, upholstery, and home furnishings. Sacking, a fabric made of heavy jute fibres, has its use in the name. CBC made of jute comes in two types. Primary CBC provides a tufting surface, while secondary CBC is bonded onto the primary backing for an overlay. Jute packaging is used as an eco-friendly substitute.

Fig. 3 Jute plant   Fig. 4 Knitted Jute fabric

VII. How Fabric is made

Natural, synthetic, and fabric blends are all created in a similar way. Fabric is woven, non-woven or knit. Woven fabrics are the most durable, nonwoven fabrics are usually the least expensive, and knit fabrics are the most comfortable to wear. Woven – There are three different types of weaves used in woven fabrics, and they are plain, twill and satin. There are variations to each that create a different appearance. Muslin, poplin, and taffeta are examples of common woven fabrics. Nonwoven – Nonwoven fabrics are created by binding fibres together in a synthetic process. This type of fabric is not very strong and is used in crafts more than clothing. Felt is an example of a nonwoven fabric. Knit – Knit fabric has the ability to stretch which makes it the most comfortable fabric to wear. There are lots of different knit styles including jersey, interlock, stretch, and double knit. Both natural and synthetic fabrics can be found in knit variations [13]. All fabric is different and some is easier to work with than others. This makes it difficult to choose a fabric for a sewing project. There are suggested fabrics listed on the back of patterns to help aid in the decision making process. There is no one best fabric choice, because each has its advantages and disadvantages, so consider the sewing project before making a choice. Custom fabric can even be created online.

VIII. Fabrication of Jute fibre Polyethylene Composite

Natural jute fibre reinforced polymeric composite is fabricated by closed-mould system. Fig shows the individual view of male and female mould which is mainly used for composite fabrication. To make jute fibre composite, the fibres are weighed according to the fibre volume ratio. To maintain homogeneity, the fibres are arranged systematically according to the weight. Firstly, the weighed fibres are divided into two

Materials Type		Modulus (GPa)	Density ρ(kg/m3)	Tensile Strength(MPa)
Polyethylene	Fibre	E1 = 115	970	σ1 = 3500
	Laminate	E1 = 25.5	900	σ1 = 860

groups and they are knitted together as like a fabric mesh which represents a layer. The procedures are repeated for the second layers. Both layers are separated by polymeric resin placed inside the mould die along with the additives before fabrication as explained below. Initially the resin is measured according to the desired volume and the catalyst is measured for 0.9% by volume of the resin. A quarter of mixture is poured to the mould to ensure the mould surface is wetted. Then, the first layer of the fibres is laid gently without disturbing the fibre orientation. Then another quarter of mixture is poured to wet the fibres. Trowel is used to remove the air. Another quarter of mixture is poured before laying the second layer of the fibres. The last quarter of mixture is poured before the mould is closed and screwed by means of hydraulic press. The composite plate is removed from the mould after 24 hours. The procedures are repeated for all specimens. The specimen is ready for testing after 7 days of composite fabrication to ensure the resin is fully cured and hardened. Then the vibration testing is conducted for the material.

IX. Working process

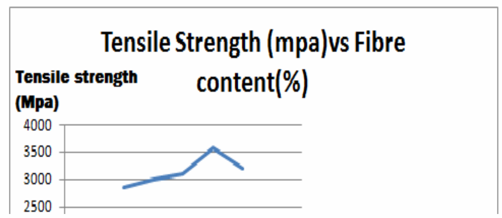
Figure 5 shows the compression molding process which is a method of molding where a preheated polymer is placed into an open, heated mold cavity. The mold is closed with a top plug and pressure is applied to force the material to contact all areas of the mold. Throughout the process heat and pressure are maintained until the polymer has cured. While the compression molding process can be employed with either thermosets or thermoplastics, today most applications use thermoplastic polymers. Advanced composite thermoplastics can also be compression molded with unidirectional

tapes, woven fabrics, randomly orientated fibre mat or chopped strand. Compression molding is a high-volume, high-pressure plastic molding method that is suitable for molding complex, high-strength objects. And with its short cycle time and high production rate, many organizations in the automotive industry have chosen compression molding to produce parts.

Fig. 5 Compression molding setup with heater

As a rule of thumb, lay up results in a product containing 60% resin and 40% fibre, whereas vacuum infusion gives a final product with 40% resin and 60% fibre content as shown in figure 6 by observing the graph it is very clear that when the fibre content reaches around 54% the tensile strength is maximum and when it crosses this percentage the strength goes on decreasing.. The strength of the product is greatly dependent on this ratio. Table 1 shows the tensile properties of fibre and laminates

Table 1 Tensile properties of fibre and laminates



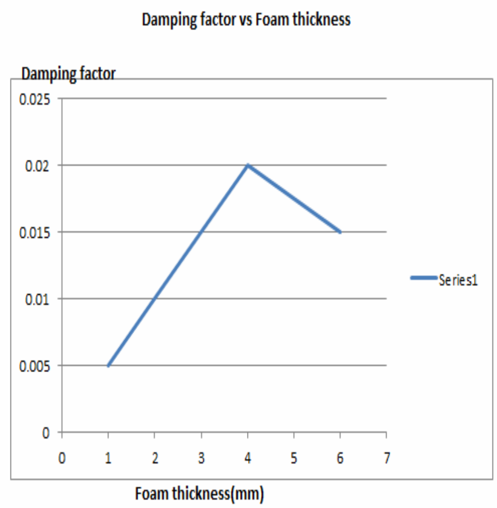


Fig. 6 Tensile strength vs Fibre content
Fig. 7 Damping factor VS Foam thickness

X. Vibration Testing

Vibration testing is accomplished by introducing a forcing function into a structure, usually with a special type of vibrator. Alternately, a DUT (device under test) is attached to the "table" of a shaker. For relatively low frequency forcing, servo hydraulic (electro hydraulic) shakers are used. For higher frequencies, electro dynamic shakers are used. Generally, one or more "input" or "control" points located on the DUT-side of a fixture is kept at a specified acceleration. Other "response" points experience maximum vibration level (resonance) or minimum vibration level (anti-resonance).Two typical types of vibration tests performed are random- and sine test. Sine (one-frequency-at-a-time) tests are performed to survey the structural response of the device under test (DUT). A random (all frequencies at once) test is generally considered to more closely replicate a real world environment, such as road inputs to a moving automobile. Most vibration testing is conducted in a single DUT axis at a time, even though most real-world vibration occurs in various axes simultaneously. MIL-STD-810G, released in late 2008, Test Method 527, calls for multiple exciter testing.

XI.VIBRATION ANALYSIS

The fundamentals of vibration analysis can be understood by studying the simple mass–spring–damper model. Indeed, even a complex structure such as an automobile body can be modeled as a "summation" of simple mass–spring–damper models. The mass–spring–damper model is an example of a simple harmonic oscillator. The mathematics used to describe its behavior is identical to other simple harmonic oscillators such as the RLC circuit. Figure 7 shows the damping factor rises to a limit of 4mm foam thickness then gradually decreases as the foam thickness increases

Note: In this article the step by step mathematical derivations will not be included, but will focus on the major equations and concepts in vibration analysis. Please refer to the references at the end of the article for detailed derivations. The Frequency can be calculated by using the below formula

$$f_i = \frac{\beta_i^2}{2\pi L^2}\sqrt{\frac{EI}{\rho \mathrm{A}}}$$

XI. CONCLUSION

Research and development work carried out by different agencies has recognized that, natural fibres due its technical superiority over the synthetic fibres have proved that it is a versatile material for application in rural areas to high tech applications. The need of the hour is to use these naturally available materials in order to save the environment and energy consumption which is required in the processing of man made synthetic composites. But, still more research and development is required for the extraction and characterization of the basic materials i.e. fibres so to avoid any set back during the finalization of the complete process for up scaling of technology from lab scale to commercial level

SCOPE FOR FUTURE WORK

This study leaves wide scope for future investigations. It can be extended to newer composites like Hybrid fibre composites using other shock absorbing elements like gel coat phases and the resulting experimental findings can be analyzed.

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