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Structural study and comparison of properties of hybrid green composites

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Abstract- The development of composites consisting of naturals fibers and resins offers not only an opportunity to utilize an abundant natural resource but also a means to alleviate the serious disposal problem. Since natural fibers are durable, light-weight, excessive, nonabrasive, harmless, and low priced, they can serve as an excellent reinforcer or extender for resin. Such composites are finding applications as pallets, storage bins, and construction components.

There is lot of work has been done on the recycling of natural fibers. Recycling of high performance fiber is the new field. In our project we compare the properties of virgen kevlar composites with the regenerated kavler composites. We use virgen kevlar fabric as reinforcement and epoxy as a metrix in virgen kevlar composites, regenerated kavler fabric as reinforcement and epoxy as a matrix in regenerated kavler composites, using vaccume bag molding technique for composite fabrication. We want to make it Green by recycling the virgen kavler waste and wants to make durable product that do not invovle the manufacturing processes again and again. The second purpose of this project is to develop the composites from the regenerated kavler fabric to make it cost effective and achive properties close to the virgen kavler composites. We use 1/1 plan weave for both types of composites and made eight composites samples having different no,s of layers and stacking sequence of the layers.

Index Terms-Composites, mechanical Properties, structural study, hybrid green composites, natural Fibers, high performance composites

I. Introduction

The concept of composites is very old even when people use things that are made up of 2 or more things. But the clear concept of composites comes from the some 1500s B.C. ago. When Egyptians' use mixture of mud and straw to build strong and durable building for their living purpose.

Late, 1200 A.D, Mongols invented the first bow that is made up of composites. In which he uses wood, bone and animal glue. These bows were pressed and warped with birch bark. These bows are extremely strong power full and accurate. That time these bows are considers most power full weapons until the invention of the gun powder."A composites material is formed when two or more different materials of different properties and nature are combined together to get a unique material that is superior in properties from its individual components from which it is made."In which one material is of continuous nature known as "Matrix" and the other material is of dis-continuous nature known as "Reinforcement" [1]**.** On the basis of matrix composites can be divided in to polymer, metal and ceramic matrix composites. While on the basis of reinforcement composites in to particle reinforced, fiber reinforced and structure reinforced composites [2]. For example concrete, Bath tub and shower stall (glass fibers, polyester, open molding), Fiberglass doors and Window frames.

Advantages of composites

The uses of composites increases day by day just because of their exceptional properties. They are using everywhere specially in automotive, air crafts, sports goods, military crafts, bullet proof vests, civil engineering etc. just because of these properties. Less weight, no corrosive behavior, non-conductor, low maintenance, low generation cost, long life, design flexibility [1].

Disadvantages of composites

There are few disadvantages of composites i.e. cost of material, cost of fabrication, Week transverse properties. Week matrix, low toughness, Reuse and recycle may be difficult, Analysis is difficult [1].

Types of composites

On the base of the nature of the matrix, and each type processes methods of fabrication. Composites can be categories in to four types are given below.

- Polymer matrix composites
- Metal matrix composites
- Ceramic matrix composites
- Carbon carbon matrix composites

Polymer matrix composites

The most advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be shaped into a variety of shapes and sizes. They provide great strength and toughness along with resistance to decomposition. They have also low cost, high strength and simple manufacturing technique.

Metal matrix composites

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The characteristic fibers comprise of carbon and silicon carbide. Metals are mainly strengthened to suit the requirements of project.

Ceramic matrix composites

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumino silicate reinforced by silicon carbide. The benefits of ceramics matrix composites have high strength, toughness, low density, chemical inertness and high service temperature limits for ceramics.

Carbon carbon matrix composites

CCMs use carbon fibers in a carbon matrix. Carbon-carbon composites are used in very high temperature environments of up to 6000 of, and are twenty times stronger and thirty times lighter than graphite fibers [3].

Composites parts

Reinforcement

The function of the reinforcement is to provide specific shape, stability and carry the major portion of the load. The textile preform is classified on the basis of different criteria. Such as yarn orientation, manufacturing processes and geometric features. They are classified in to four levels i.e. fiber, yarn, 2D fabric and 3D fabrics. There explanation is given in the below table [3],[4].

Table 1.1 Fiber architecture for composite

Level	Reinforcement System	Textile Construction	Fiber length	Fiber orientation	Fiber entangle-ment
1	Discrete	Chopped yarn	Discontinuous	Uncontrolled	None

2	Linear	Filament yarn	Continuous	Linear	None
3	Laminar	Simple fabric	Continuous	Planar	Planar
4	Integrated	Advance fabric	Continuous	3D	3D

3D preform is classified in to four different shapes that are solid, hollow, shell and nodal Solid contains multilayer, orthogonal and angle interlock. while hollow contains multilayer Shell contain single layer and multilayer nodal include multilayer, orthogonal and angle interlock [4].

Resin

The purpose of resin is to hold the fiber in place, transferring the stress between the fibers and protecting the reinforcement material from the adverse environment. There are two types of matrices that are thermoset and thermoplastics.

Thermoset matrices

Thermoset matrices are those matrices that are set once by heating they become hard and they are not moldable and recycle able. First consider a typical thermoset polymer such as epoxy. To make this material, one first starts with the epoxy molecules. The epoxy molecules are relatively small [on the order of about 20–30 carbon-carbon (C–C links]. This is relatively short as compared to the order of a few hundreds or thousands of C–C links for thermoplastic molecules. Since the length of the thermoset molecules is short, the material consisting of them usually has low viscosity and appears in the form of liquid at room temperature or moderately high temperature (about 100°C). Since the material appears in liquid form, in order to make a solid out of it, the molecules must be tied together with molecules of some other type. The tying molecule matrix materials are called the curing agents. They have good thermal stability and chemical resistant and show low creep and low viscosity. The disadvantages of thermoset polymer are long fabrication time and slow cross linking and solidifying processes [5]. They can be easily brittle and fail at low strain. The example of thermoset matrices are polyesters, epoxies, vinyl ester and phenolic.

Epoxy

Epoxy is a thermosetting resin containing one or more group of epoxide. A three member rings with one oxygen and two carbon atoms. They are used in resins for prepregs and structural adhesives. The advantages of epoxies are high strength and modulus, excellent adhesion, low shrinkage, good chemical resistance, and ease of processing. The disadvantages of epoxy are brittleness and the reduction of properties in the presence of moisture. The processing or curing of epoxies is slower than polyester resin. The cost of the epoxy is also higher than the polyesters.

Polyester

The term polyester is used for orthophthalic polyester resin or isophthalic polyester resin. These resins are generally inexpensive and fabrication processes is fast and they are generally used for low cost applications. The advantage of polyester is low cost and its ability to process quickly, thermal stability dimensional stability, creep resistant.

Phenolic

The phenolic polymers are condensation polymers that are based upon two types of chemical reaction. The reaction may contain excess of formaldehyde with a base catalyst and phenol and vice versa. The basic difference between these two chemicals is the no of methylol groups in the novolacs and the resulting need for an extension agent of paraformaldehyde, hexamethylenetetramine, or additional formaldehyde as a curative. These resins have higher molecular weights and viscosities than their parent materials.

Thermoplastic

Thermoplastic molecules can be very long. Each molecule may contain up to several hundreds or thousands of C–C links. Due to high molecular length, it is difficult for these molecules to move around at room temperature. In order for these molecules to be able to move relative to each other, high temperature needs to be applied. The viscosity of these resins is large even at high However when the material is cooled down, it becomes solid fairly quickly. The processing time should be much shorter (it takes several minutes) as compared to thermoset resins (it takes several hours or days).the time is required to complete the linking reactions. The advantages of thermoplastic resins in thermoplastic composites are given below

1) The thermoplastic resin does not become hard even they are place for a long time.
2) Short process cycle.
3) Thermoplastic resin has higher ductility.
4) Thermoplastic resin can be melted and reuse i.e. they are recyclable.
5) Defects in thermoplastic composites can be recover by heating [5].

Laminates

When there is a single ply or a lay-up in which all of the layers or plies are arranged in the same direction, the lay-up is called a lamina. When the plies are arranged at different angles, the lay-up is called laminate. Continuous-fiber composites are laminated materials in which the single layers or plies are oriented in the direction that increases the strength in the primary load direction. Unidirectional (0°) lamina is very strong and stiff in the 0° direction. However, they are very weak in the 90° direction because the load is carried by the weaker polymeric matrix. While the matrix distributes the loads between the fibers and stabilizes the fibers and prevents them from collapsing in compression. Fiber orientation has direct impact on the mechanical properties depends on that how many layers are present in the direction of load. It is necessary to balance the load bearing capacity in all direction i.e. $0^0, +45^0, \_45^0, +90^0, \_90^0$ directions. If the laminate contain equal layers in all directions is known as quasi-isotropic laminates [6].

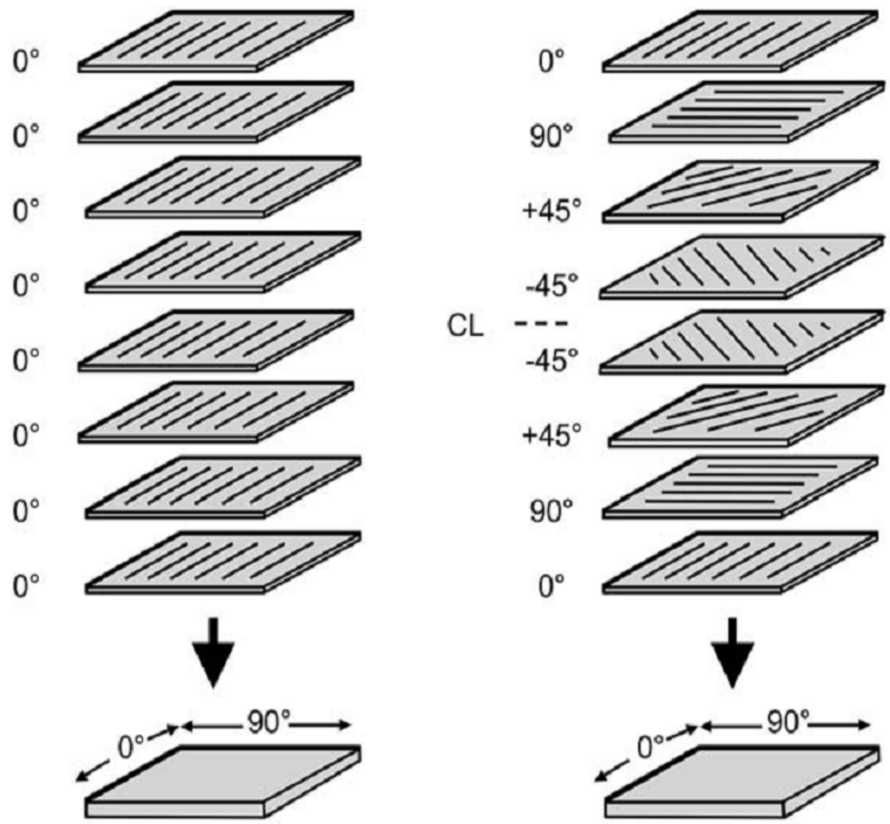


Figure 1.1 Unidirectional lay-up and quasi isotropic lay-up Processes

There are different methods for the fabrication of the composites that are given below

- Open Mold Processes.
- Close mold processes.
- Continuous processes.

There are two important stages in all molding processes:

(i) Laying
(ii) Curing

- **Laying**

The laying is the process in which molding materials are laid in the mold cavity or on the mold surface that conform the shape of the part to be fabricated.

- **Curing**

The process of curing helps the resin to set, thereby providing the fabricated part a stable structural form.

Open Mold Processes

Late in 1950's when resin is cured with the air develop the contact molding processes. This is used for manufacturing composites of all shapes sizes and complexities with relatively less investment. Only one mold is required male or female. There are three main techniques used in contact molding i.e.

- Hand lay-up.
- Spray lay-up.
- Roller saturator.

Gel coating

The durability of a composite molding depends on the quality of its exposed surface. The protection of the surface is achieved by providing resin rich outer layer. Special care should be taken while applying gel coat. While applying the coating we should take care of many things i.e.

(1) Thorough mixing of gel coat, particularly adding catalyst, an inadequate catalyst mixing results in uneven cure of gel coat. Poor mixing of pigment results in the imperfection of outer layer. In order to avoid the mixing problems, we use low shear stirrer.
(2) The gel-coat may be applied by brush or spray.
(3) The thickness of the gel-coat ranges from 0.4mm to 0.5mm using 450g to 600g/m^2 to get required thickness. If the thickness is too thin then it may not be perfectly cure and may also come in attack with solvent from resin. If the layer is too thick then crack may be produce and more sensitive to impact damage. Gel-coat of uneven thickness cures at different rates on the surface.
(4) In order to achieve full curing and optimum performance, we have to maintain the proper required conditions i.e. surrounding temperature must be 18^{o}c medium reactivity MEKP catalyst and always used 2% addition level.

Once the gel-coat cured completely then the next step in the contact molding is applying back laminating. The backing laminate is applied after this simple test to check that gel-coat is ready for coating touch the gel-coat with the clean finger if the coating feels tacky and your finger remain clean then it will be ready for laminating.

Laminating

Hand lay-up

When the layer of the gel-coat is cured sufficiently then apply the first layer of the resin with hand evenly as much possible. Then place the reinforcement on its place and consolidate it with brush or roller in this process. The resin is completely impregnate in to the reinforcement and further resin is added if required before applying the more layers make sure that the first layer is free of air bubbles. The amount of the resin apply is calculated by weighing the reinforcement. The impregnation of the reinforcement can be carried out with brush or polyester roller. If we use brush that work with stippling action and that may displace the fiber and destroy their random nature. So if we work on large scale then we use roller that are available in different piles i.e. long and short pile.

One above the other layers of resin and reinforcement are spread until the required thickness is not achieved. But make sure that each layer is thoroughly impregnated and solidified. In order to prevent from the exothermic heat it is recommended that four layers of resin and reinforcement are to be placed in one time because that heat produces cracks in the gel-coat and pre-release distortion. Where thick laminate is required then we follow the series of four layers and then cool and avoiding lengthy delay while placing the layers. In spite the resin with long green stage is not use.

In order to strengthen the mold the ribs should be reinforced in to the laminate that can be inserted at any stage depending on the shape and size of the mold. Generally it is best to reinforced before the last layer. Rib former is covered with the reinforcing material and thoroughly impregnated into the resin and then apply the last layer over the whole surface to get uniform appearance.

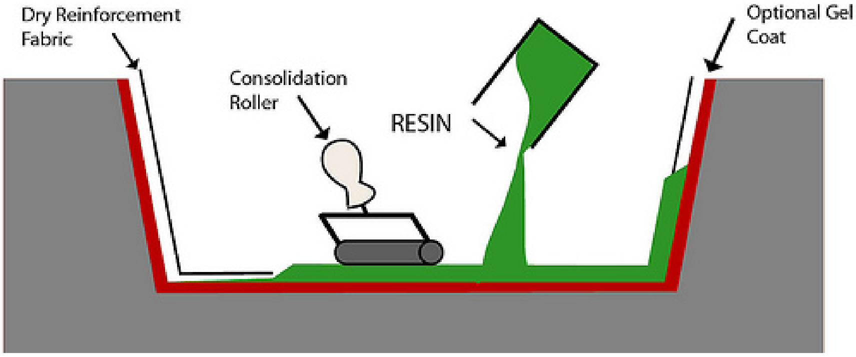


Figure 1.2 Line diagram of hand lay-up process

Spray lay-up

In this technique spray gun is used to deposit chopped glass and catalyzed resin onto the surface of the mold. Chopper gun is attached with the spray gun that chops glass roving into specific length and is directed toward the catalyzed resin as it exits the spray gun. The resin should be of low viscosity so that it can easily wet out the entire chopped stand and can easily atomize into desire pattern. Which allow the repaid solidification of the mold. In-order to remove the air bubbles thorough rolling of the laminate is necessary. Now a day many commercial pumps are available due to their higher output. For the production of large molding the pump system is more common.

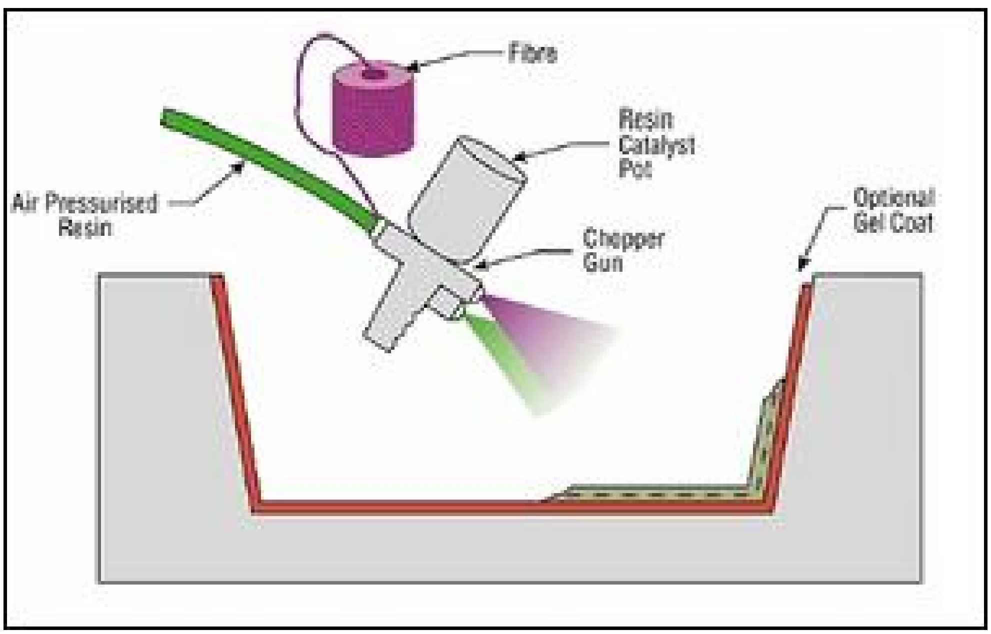


Figure 1.3 The line diagram of spray lay-up process

Roller/ saturator lay-up

Roller/saturator is an equipment that is use to saturate the reinforcement with the activated resin. The resin is held in the container and the pump is connected with the roller head. Roller/saturator is ideally used for large molding for example building panels. All methods in contact molding are cold cure. So laminates can take several hours to mature. This can be accelerating by applying heat. For gel-coat the temperature rise up to $30-35^{0}c$ it is necessary to cool the gel-coat before applying backing laminate. Once the laminating is complete then rise temperature up to 35^0c before gelation. After gelation the temperature is increased up to 60^0c and keeps under this temperature for 1 hour and then cool down under ambient temperature before removing from the mold.

Closed mold processes

Contact molding process remains dominant in composite manufacturing industry for long period of time, but they have many environmental and quality issues. Closed mold processes cover large area of these issues. Now a day closed mold processes cover wide range of production and have many advantages over the contact molding

Vacuum infusion

In this process open mold is used with little or no modification. In which dry reinforcement is placed between the rigid air tight mold and flexible vacuum bag. Then sealed the edges of the mold with the tape and placed this cavity under the vacuum in order to compact the reinforcement.

Then catalyzed resin is introduced into the mold through injection at the edge of the equipment as shown in the figure 1.4. When the resin is injected it follows through the parameters and at the end in the center. When the part is cured. Then remove the bag and the component from the mold. The resin used in this process is of low viscosity [7].

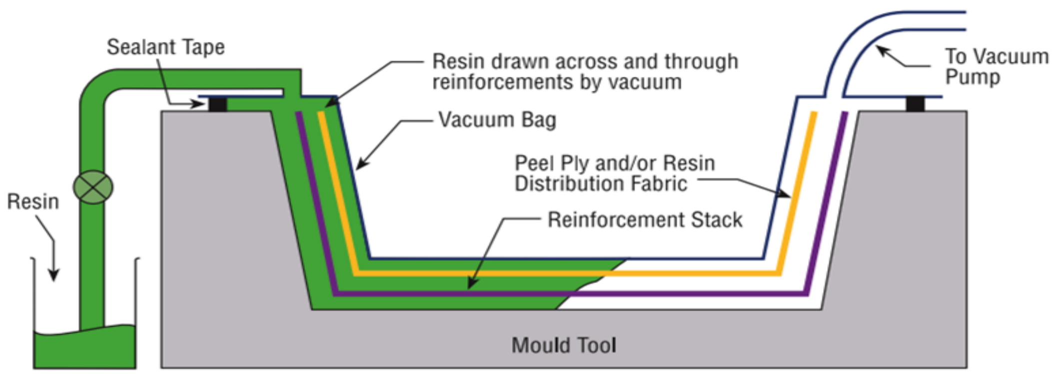


Figure1.4 Schematic diagram of vacuum infusion

Resin transfer molding: RTM

The basic of resin transfer molding is to spread the dry continuous reinforcement into the mold and then closed the mold boundaries and injected the catalyzed resin. When the resin is spread completely then allow for curing.

Continuous processes

They are used to produce to the composites component such as sheeting and pipes; they are suitable for the long continuous production. Some of the processes are describe below.

Pultrusion

This process is used to produce the components of uniform cross-section with exceptional properties. Earlier on this process is used to produce simple items but after lots of developments now this method is used to produce the items of complex dimensions [8],[9]. Pultrusion is some extent similar to the metal extrusion process. In the composite pulltrusion process, continuous fiber reinforcements in structural sections can be manufactured by pulling the resin coated filaments by a die not just like the metal extrusion process, where hot metallic bars and rods are pushed through a die to manufacture extruded parts. Continuous fiber strands taken from a number of spools and consecutively pulled through a resin bath and a shaping guide/hot die as shown in the figure. The fibers are treated in the resin bath and the surplus resin is pressed out. When passing through squeezing rollers. The die guide delivers a gradual change from a simpler to a more complex pre-formed shape near to that of the pultruded part. Constant component mats and woven fabrics can also be drawn along with filament strands to provide better transverse properties to the pultruded segments. The die is a very hazardous part in the fabrication process. It is typically made of chromium plated steel and should have an extremely flat surface. A smooth surface prevents sticking of the resin at the entrance segment, where only the gelation of resin, but not curing has been started.

Thermosets like epoxies and polyesters are normally used in the pultrusion process.

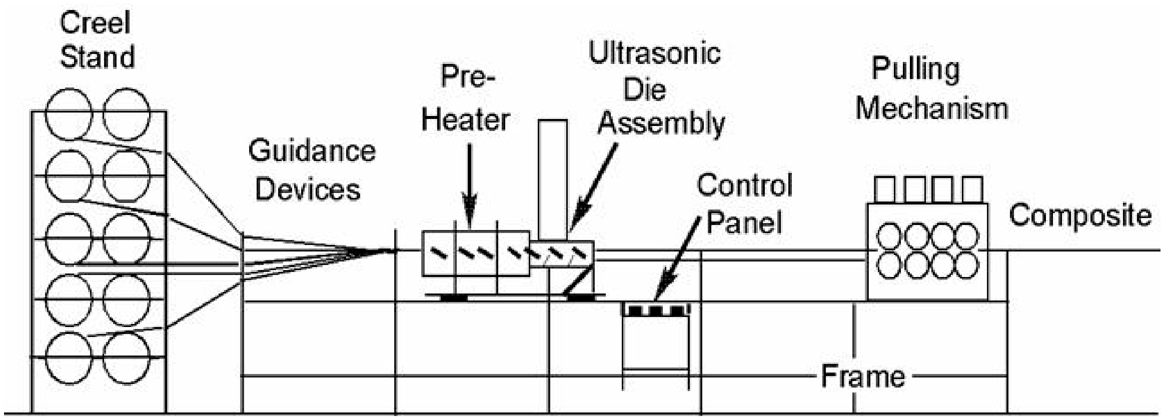


Figure 1.5 Schematic diagram of pultrusion

Filament winding

The filament winding process is active for fabrication of a continuous fiber reinforced composite structure having circular shape. Common examples are hoses, pipes, cylindrical tanks, pressure vessels, speed motor cases, etc. Continuous fiber strands or roving's are first coated with resin in a resin bath and then passed through rollers to squeeze out excess resin and finally wound, under constant tension, around a portable mandrel. The mandrel is typically prepared of steel. However, other materials like plastic foam and rubber are also used in fabrication of some mandrels. A steel mandrel can be so designed that it can be pull to pieces mechanically and removed part by part without damaging the filament wound composite part.

There are two types of filament winding patterns like helical winding and biaxial winding. In the method of helical winding, a constant angle, which is also known as helical angle, is maintained by controlling the rotational and axial motions of the manderal. By reversing both axial and rotational motions, the filements are wound with a minus helical angle.

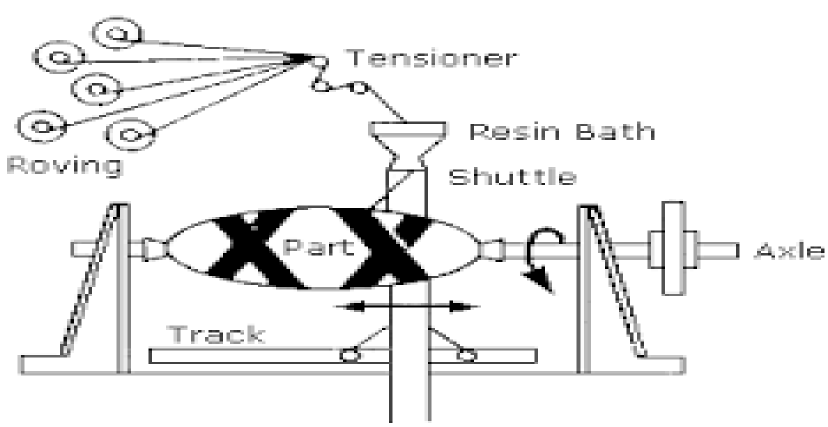


Figure 1.6 Schematic diagram of filament winding

Green composites

The fully green composites of natural fibers and biodegradables resin has attract many researcher to-ward this topic because of their low cost renewable resource usage and biodegradability. These composites have application in blended textiles, carpets; conveyer belt etc. green composites are made from flex, jute, hemp, pineapple leaf, sisal, ramie, banana fibers, corn stalk etc.

Advantages of Green Composite over traditional composites

- Less expensive.
- Reduced weight.
- Increased flexibility.
- Renewable resource.
- Sound insulation.
- Thermal recycling is possible where glass poses problems.
- Friendly processing and no skin irritation.

Fully biodegradable high strength composites or 'advanced green composites' were composing by using recycle protein base resin and high strength cellulose base fibers. For their comparison they use E-glass and aramid fibers and use recycled protein resins and then compare mechanical properties such as tensile strength and flexural rigidity etc. there comparison give the idea that they are used in primary structural based applications. That in future they will be replaced with petroleum based fibers and resins and at the end of their life they are easily dispose with-out harming the environment. To build advanced green composites, three things are essential: high strength fibers, resins with improved properties and good fiber/resin interfacial bonding [10].

Green composite were manufactured by using soy based bio plastic and pineapple leaf fibers using injection molding and compare their thermal properties, mechanical properties the improvement in the properties of the composites is just because of their combine effect i.e. resin and reinforcement [11].

As the environmental awareness and environmental risk are increases. Green composites have attained much more research consideration, as they have the potential to be attractive than the outdated petroleum-based composites which are poisonous and non-biodegradable. Just because of their lightweight, pleasant processing and acoustic protection. Green composites extensively used from aerospace applications to household use product. The green composites are not only replacing the traditional materials i.e. steel and wood but also replaceable with certain non-biodegradable polymer composites. This research has been conducted to classify the several types of green composites on the basis of their physical, chemical, and mechanical properties [12].

Mechanical behaviors of staple Kevlar fiber-reinforced thermoplastic polyurethane (TPU) have been studied with respect to fiber orientation. The strength of the composite is enhanced at higher fiber content with a minimum at 10 (PHR) pounds of the ingredient would be added to 100 pounds of resin. Anisotropic property in strength is obviously observed beyond 15 PHR fibers packing. Impact strength is reduced sufficiently at all fiber filling irrespective of fiber orientation [13].

A composite based on natural flax fiber and recycled high density polyethylene was made by a hand lay-up and compression molding technique. The mechanical properties of the composites were measured under tensile and impact loading. It is observed experimentally the changes in stress–strain characteristics, yield stress, tensile strength, and tensile (Young's) modulus, ductility and toughness, all as a function of fiber content. A substantial improvement of toughness of the composite can be qualitatively described in expressions of the principal distortion and failure mechanisms recognized. These mechanisms were controlled by delamination cracking, by crack linking processes, and by widespread plastic flow of polymer-rich layers and matrix distortion around fibers. Developments in strength and stiffness with high toughness can be accomplished by varying the fiber volume fraction and governing the bonding between layers of the composite [14].

Much academic research and industrial improvement discovers new ways to create greener and environmentally friendlier chemicals and materials for a variety of applications. A significant part of this work focuses on the development, processing, manufacturing, recycling and dumping of green plastics, adhesives, polymer composites, amalgams and many other industrial products from renewable resources.

Natural fibers offer the prospective to deliver greater added value, sustainability, renewability and lower costs especially in the automotive industry.

Further research includes the fiber crop production. The ever-increasing volume of scientific literature refers with passion to the potential of natural fibers in technological, financial and environmental relationships. This keenness tends to enlarge the areas of human life and socio-economic development for the fiber crop farmers and their societies.

However, there is very little discussion or indication to support declarations about the assumed benefits for the affected population in rural areas. We claim that despite the projected new successful demand of natural fibers, it is doubtful that this will represent an actual development in the quality of life of crop fiber farmers and their communities.

The improvement of tough, high strength, high modulus fibers has controlled the use of fabrics and yielding composite laminates for a number of impact associated applications, such as turbine blade, fuselage safety and body shield. Plentiful studies have been accompanied to recognize material properties and system instruments that are significant to the performance of these ballistic textiles [15].

The stress–strain curves of kevlar49 aramid fiber packages under both quasi-static filling and high rate packing were attained. The strain rate ranges from 10^{-4}/s to 10^{3}/s. Based on a bimodal Weibull scattering statistical model of strain-rate requirement of fibers and a test technique of defining mechanical properties and Weibull constraints of fibers from fiber bundle test, the rate dependence of kevlar49 fiber strength is planned. Experimental results displays that kevlar49 fiber has sensitivity to strain rate. Consistence of simulated and experimental results shows that the model is effective to clarify the mechanical behavior of kevlar49 fiber and the test method is possible and dependable [16].

Carbon fiber, Kevlar 49 fiber and carbon-Kevlar 49 hybrid reinforced epoxy laminates, containing 0°, 90° and 45° layers, were exposed to drop load and ball rifle impact at incident energies up to 18 J. Remaining tensile, flexural and shear strengths were measured after impact. It was revealed that a hybrid composite can have meaningfully better overall impact properties than laminates reinforced with only one type of fiber. Tests on one directional laminates presented that the stagnant mechanical properties of hybrid composites were not as good as all-carbon fiber reinforced composites; for multidirectional laminates the variance was less [17].

2. Objectives of Green Composites

- Ecological results have caused in renewed attention in natural materials.
- Recyclability and environment friendly are becoming sufficiently important to the introduction of products.
- The resins and fibers used in green composite are degradable and decomposed when subjected to microorganisms.
- They are decomposed into water and carbon di oxide and absorbed by the plant system.
- To improve mechanical properties.
- To improve moisture resistance.
- To improve thermal properties.

- To improve process ability.

3. Materials and methods

Material

There are two types of materials are used.

i. Virgin Kevlar fabric
ii. Regenerated Kevlar fabric
iii. epoxy

Virgin Kevlar fabric

Composites consist of two materials one behaves as a reinforcement and other behave as a resin. We used virgin Kevlar fabric as reinforcement. The fabric is made up of the warp and weft yarns having the count of 12 Ne. The fabric is made on the projectile loom. The G.S.M of the fabric is 104g/m^2. The construction of the fabric is… the fresh Kevlar fabric is used as reinforcement in the composites. We cut the fabric pieces of 200×200mm for these composites samples. We made four composites samples from the fresh Kevlar fabric each having different numbers of fabric layers and different stacking sequence

Regenerated Kevlar fabric

The regenerated yarn is made from regenerated Kevlar bobbin in yarn manufacturing department, National Textile University, Faisalabad. Fabric manufacturing is done on sample loom at Sapphire Textile Mills, unit # 06, Sheikhupura. The warp and weft having the count of 20 Ne. The G.S.M of the fabric is 102g/m^2. We use plan weave 1/1 for fabric manufacturing. The regenerated Kevlar fabric is used as reinforcement in the composites. We cut the fabric pieces of 200×200mm for the composites samples. We made four composites samples from the regenerated Kevlar fabric each having different numbers of fabric layers and different stacking sequence of these layers.

Epoxy

Epoxy is used as a resin. It is in the form of yellowish liquid having mild odor. Its flash point is greater than 250c^0. It is partially insoluble in water. At 20c^0 its relative density is about 1.16 g/cm^3. We add 50% resin by weight to the weight of the total layers of the fabric to whom we are going to make the composite sample. We use epoxy because of its resistant to environmental degradation, resistant to water degradation, low viscosity and easily process able. That is why it is uses in automobiles, air crafts, boats hulls etc.

Equipment

The equipment includes all the instruments and machines used for preparation and production of samples, testing of samples and confirmation of results.

Production of samples

Fabric samples were prepared on sample loom. That made the fabric from single cone using 1/1 plan weave. It uses a solid picking media like rapier for pick insertion. The specifications of sample loom and the process flow chat is given below.

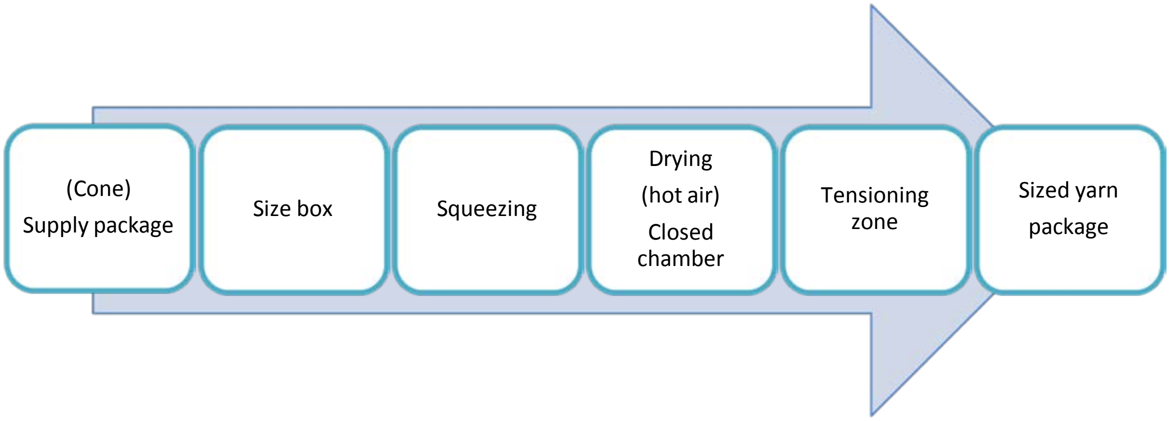


Figure 3.7 Process flow of sample sizing

Figure 3.8 Sample loom

Table 3.2 Sample loom specification

Part name	Specification
Working Width of warping	500 mm/ 20 inches
Warping Length	3.6m
Weaving Width	20 inches
Speed of loom	45 ppm maximum
Weft Selector	8 colors electronic weft selection device

Fabric Take-up	Electronically controlled. Weft density can be changed freely within the same weave
Warp Let-off	Positive electronically controlled. Digital display of warp, optional Second beam assembly is available.
Shedding	Computerized controller. 20 healed frames Driven pneumatically by air (1st & 2nd healed frames are for leno and selvedges)
Drawing-in	Healed frames can be separated from the loom for healeds and reeds drawing-in
Design	Built-in SEdit2 design and editing software. It could be installed separately on other PC for design works
Air Consumption	880L/min. (500 mm Width) / 1400 L/min. (900 mm width), Air pressure 5-7 kgf/cm2
Power	220V Single phase, 50-60Hz

Vacuum bagging for fabrication of composite

The fabrications of the samples were done on the vacuum bagging apparatus. The different parts of the vacuum bagging were:

Vacuum pump

The objective to use the vacuum pump to evacuated the air from bagging film. The suction pressure of about -30bar were applied. It removed the voids and helped to ensure an even distribution of the resin on the fabric reinforcement layers.

Bagging film

Bagging film was placed around the laid-up composite material and covered the fabric reinforcement layers. The material of bagging film was nylon.

Bagging tape

It binds the bagging film with the surface and provides good adhesion for suction. Bagging tape is a butyl-based vacuum bag sealant giving high elasticity and tenacity.

Peel ply

The first sheet that goes against the uncured laminate is a release film or a peel ply that is used as an obstacle between the laminate and the subsequent bleeder or breather layers. This layer can be non-porous or spongy material depending on whether or not resin drain is necessary. Often a perforated release film is used for a well-ordered resin bleed. The diameter and the spacing of the holes can differ depending on the amount of resin flow anticipated. It allows free passage of volatiles and excess matrix during the cure. It can be removed easily after cure of composite sample.

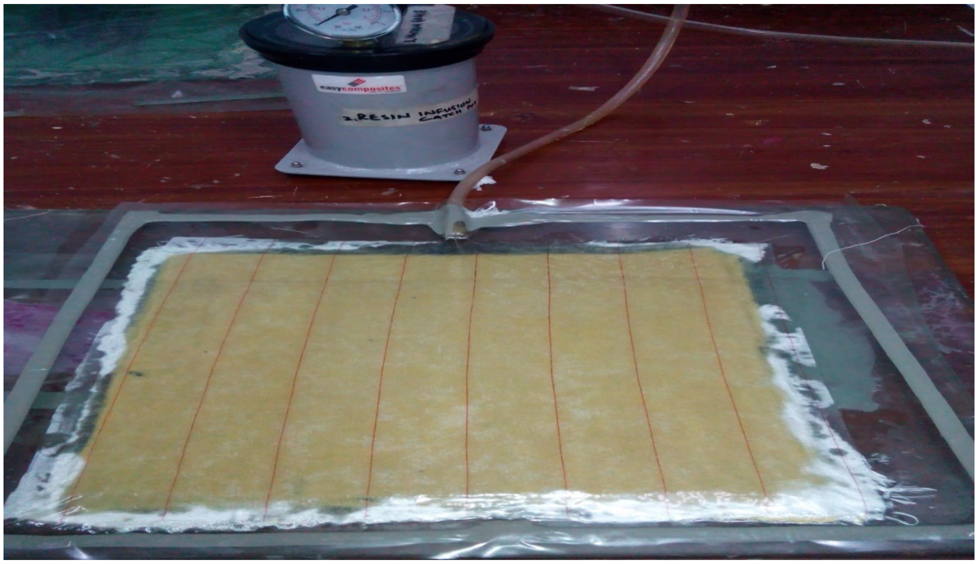


Figure 3.9 Vacuum bag molding technique

1.1 Production methods of composites

This section is used to describe the method for the fabrication of composites and the test that we perform on these samples.

1.1.1 Fabrication of composites

After it the samples were cut in to 200×200mm square shape. Eight and four layers were used for composite sample fabrication. Eighteen layers were cut at 0^0 and90^0. Six layers were cut at 45^0.The layers were placed according to the below pattern.

1.2 Stacking sequence in composites samples

Stacking sequence in composite samples is given in the table

Table 3.3 Stacking sequences in composites samples

Sample ID	**Stacking sequence**	**No of layers**	**Material**
1	0/+90/-90/0	4	Fresh Kevlar fabric
2	0/+45/-45/0	4	Fresh Kevlar fabric
3	0/+90/-90/0	8	Fresh Kevlar fabric
4	0/+45/-45/0	8	Fresh Kevlar fabric
5	0/+90/-90/0	4	Regenerated Kevlar fabric
6	0/+45/-45/0	4	Regenerated Kevlar fabric
7	0/+90/-90/0	8	Regenerated Kevlar fabric
8	0/+45/-45/0	8	Regenerated Kevlar fabric

1.3 Laboratory and testing equipment

Two types of the composite testing were done:

1.4 Impact strength tester

Impact strength test was done in Steam Power Station Faisalabad. All the samples were cut in the 50×10mm dimensions. Manually bring the two sides on to the top as shown in the figure 2.3 and then set the reading at zero. Then insert the sample vertically in to the notch by pushing the notch. Then release the lever that automatically unclamps the two jaws and they cross each other and sample get strike and break and note the reading from the meter. The unit of the impact strength is foot pounds. One by one the samples were placed in balanced impact tester and readings were noted.

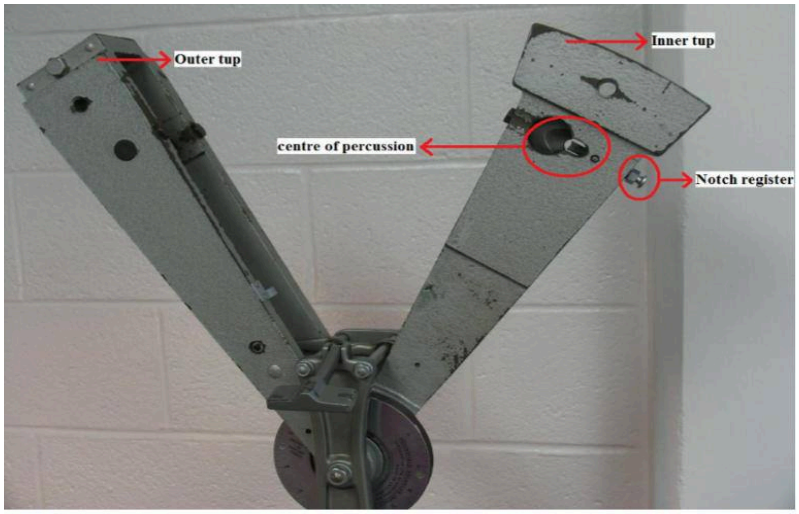
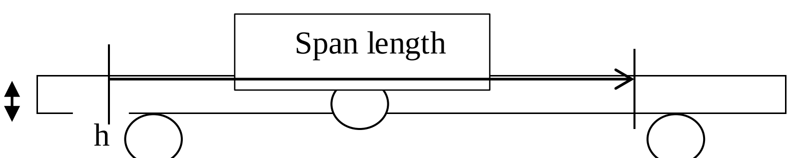


Figure 3.10 Impact strength tester

1.5 Bending strength tester

Bending strength test was done in NTRC of National Textile University Faisalabad. Bending strength the span to thickness ratio was done but commonly 32:1 used. This was three point bending strength while four point bending strength also used. The width of the sample was noted. It was 13mm. The thickness value was noted. Than multiply it with the 32 which give the gauge length of each sample. The five hundred Newton (N) load cell and hundred seconds per millimeter extension were noted. After it the corresponding maximum load force (N) value was noted. The bending strength was noted according to following formula. The samples are placed on the two jaws and start the machine. The machine start pushing the sample downward and automatically note the amount of load that is needed to bend the sample as shown in the figure 3.4



$$Bending\ strength = \sigma = \frac{3PL}{2bh^2}$$

Where L=gauge length

b=width of composite samples

P=maximum force applied (N)

h=thickness of composite samples

Figure 3.11 Bending strength tester

4. Materials and Methods

Testing of composite samples

The composite consist of two parts mainly one is in the form of continuous phase known as matrix and the other is in the form of discontinuous phase known as reinforcement. In this project we two types of fabric for reinforcement i.e. virgin Kevlar fabric and regenerated Kevlar fabric and using epoxy as a matrix. We have done two types of testing on these composites i.e. bending strength and impact strength there results are discuss below.

Bending strength of 4 layers composites

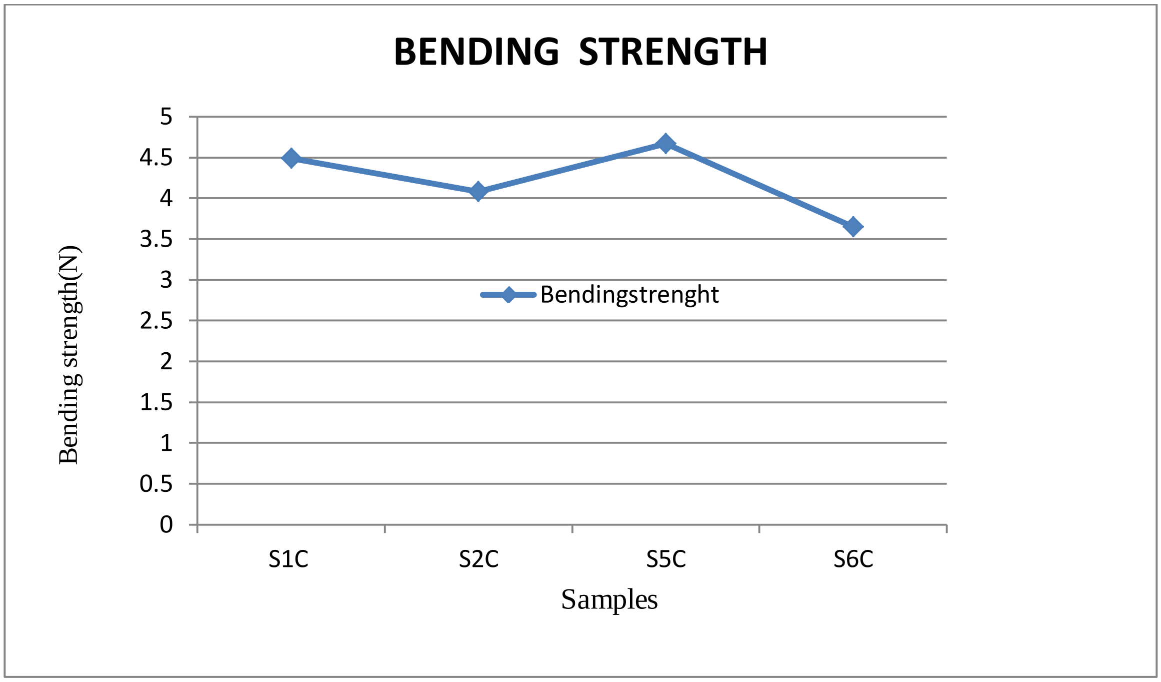


Figure 4.12 Bending strength of 4 layer composites

The figure represents the bending strength of the 4 layers composite samples. The sample S1C and S2C are made up of fresh Kevlar and S5C and S6C are made from the regenerated Kevlar fabric. Sample S1C and S5C have the stacking sequence of 0±90. The sample S2C and S6C having stacking sequence of 0±45. The bending strength of S5C is highest and S6C have lowest value. When force is applied on composite having stacking sequence of 0±90 the force is distributed in two directions (x and y coordinate). The empty spaces are there between weft and warp yarns lie on x and y coordinates respectively and load is not distributed equally in all directions. While in 0±45, the force is distributed along xy-plane and also in diagonal which is due to stacking sequence at 45^0.There are warp and weft at perpendicular to each other and due to 45 angles there are no spaces between the fabric layers. So, when bending load is applied, the load is distributed to the whole structure of the fabrics so these composites are somehow flexible and bend easily so it has less values for bending load but 0±90 have somehow rigid structure that's why it has greater values for bending load. If we talk about the material type used for the fabrication, we have used two types of materials i.e. fresh Kevlar and regenerated Kevlar.so if we check the results of bending test we will come to know that there are no such differences based on material types as values are much closer to each other and depends upon only on the stacking sequence we used.

Bending strength of 8 layers fabric

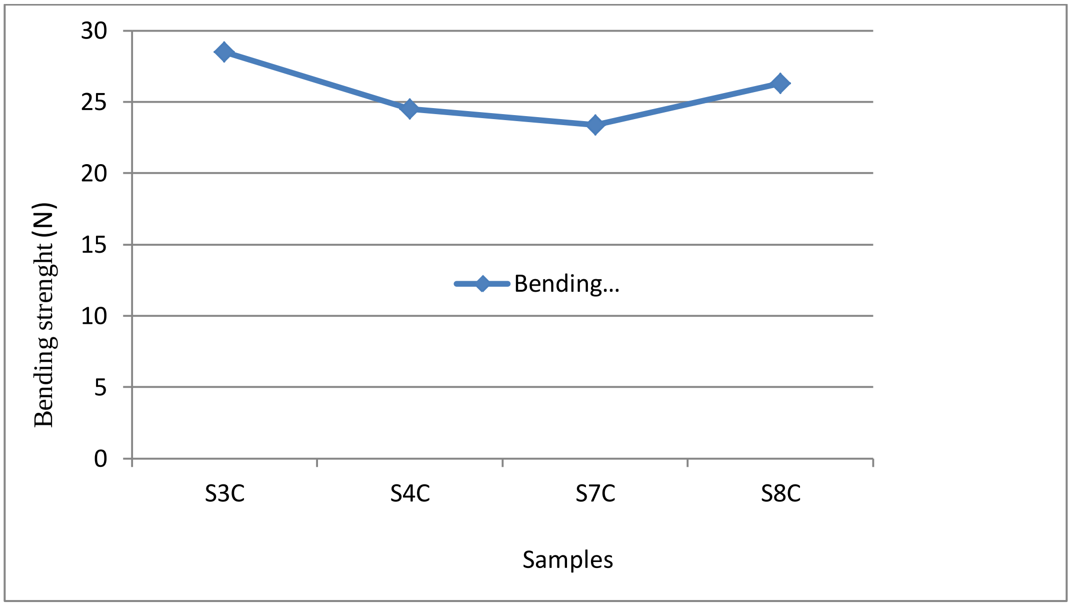


Figure 4.13 Bending strength of 8 layer composite

The figure represents the bending strength of 8 layers composites.S3C and S4C are made of fresh Kevlar fibers.S7C and S8C are composites made of regenerated Kevlar fibers. The stacking sequence of S3C and S8C is 0±90 and for the composites S4C and S7C is 0±45.when load is applied on the composites having stacking sequence of 0±90, the force is distributed in two dimensions, show stiffness to bending and have higher values of bending strength as compared to the composites having stacking sequence of 0±45. The composites of 0±45 have warp and weft along xy plane and having yarns at 45 angle which are in the diagonal of composites so, here applied load is distributed along three directions so it shows flexibility to the bending load and bent easily that's why these composites have lower values of bending strength as compared to composites having stacking sequence of 0±90.S3C has highest value and S7C has lowest value for impact strength as shown in figure 3.2

Impact strength of 4 layers composites

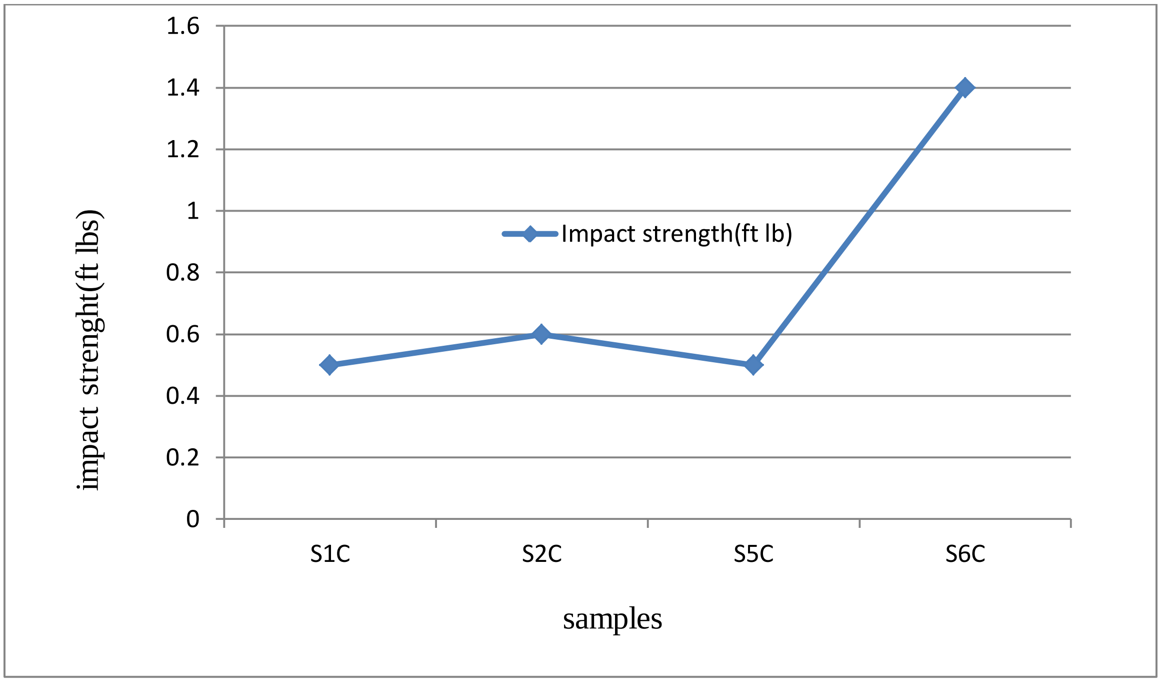


Figure 4.14 Impact strength of 4 layer composites

When we are dealing with impact strength, actually we have to study the behavior of the distribution of the impact force on entire structure. So we have to choose the materials which have greater force distribution properties, so we chose Kevlar fiber for its ballistic applications. The graph shows the 4 layers composite's impact strength values.S1C and S2C are made of fresh Kevlar.S5C and S6C composites are made of regenerated Kevlar.S1C and S5C have the stacking sequence of 0±90 but the composites S2C and S6C have the stacking sequence of 0±45.S6C has the highest and S1C has the lowest value for impact strength as shown in figure.S2C and S6C has higher values as compared to S1C and S5C.The reason is that When impact force is applied on the composites having stacking sequence of 0±45,The force is distributed along xy-plane and also in diagonal which is due to stacking sequence at 45^0.There are warp and weft at perpendicular to each other and due to 45 angle there are no spaces between the fabric layers. So, when impact load is applied, the load is distributed to the whole structure of the composites. In case of the composites having stacking sequence of 0±90, the applied force is distributed only in two dimensions so that it has less value of impact strength as compared to 0±45.It also shows some rigidity as compared to 0±45 which is more flexible than 0±90 composites.

Impact strength of 8 layers composites

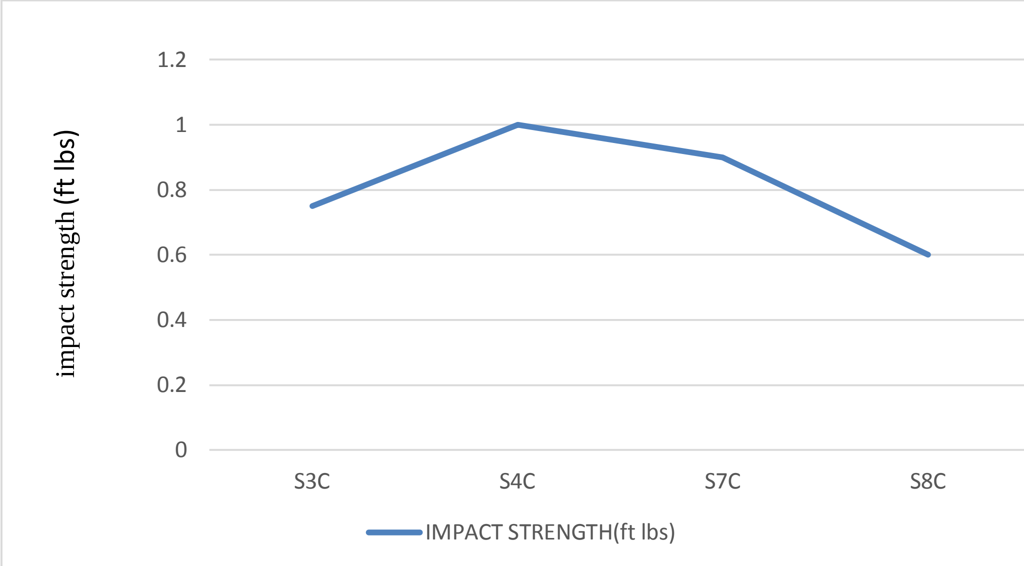


Figure 4.15 Impact strength of 8 layers composites

The figure shows the 8 layers composite's impact strength values.S3C and S4C are made of fresh Kevlar.S7C and S8C composites are made of regenerated Kevlar.S3C and S8C have the stacking sequence of 0±90 but the composites S4C and S7C have the stacking sequence of 0±45.S4C has the highest and S8C has the lowest value for impact strength as shown in figure.S3C and S7C has higher values as compared to S4C and S8C.Actually When impact force is applied on the composites having stacking sequence of 0±45,The force is distributed along xy-plane and also in diagonal which is due to stacking sequence of 45^0.There are warp and weft at perpendicular to each other and due to 45 angle there are no spaces between the fabric layers. So, when impact force is applied, the load is distributed to the whole structure of the composites. In case of the composites having stacking sequence of 0±90, the applied force is distributed only in two dimensions so that's why it has less value of impact strength as compared to 0±45.

5. CONCLUSION

It is concluded that the bending strength in 4 layers and 8 layers composites having stacking sequence 0±90 is high this is just because when force is applied on composite having stacking sequence of 0±90 the force is distributed in two directions (x and y coordinate). The empty spaces are there between weft and warp yarns lie on x and y coordinates respectively and load is not distributed equally in all directions. While in 0±45, the force is distributed along xy-plane and also in diagonal which is due to stacking sequence at 45^0.There are warp and weft at perpendicular to each other and due to 45 angles there are no spaces between the fabric layers. So, when bending load is applied, the load is distributed to the whole structure of the fabrics so these composites are somehow flexible and bend easily so it has less values for bending load but 0±90 have somehow rigid structure that's why it has greater values for bending load. If we talk about the material type used for the fabrication, we have used two types of materials i.e. fresh Kevlar and regenerated Kevlar.so if we check the results of bending test we will come to know that there are no such differences based on material types as values are much closer to each other and depends upon only on the stacking sequence we used.

The impact strength of the composites having stacking sequence 0±45 is higher then those composites having stacking sequence of 0±90 in both types of the composites having 4 layers and 8 layers. The reason is that the force is distributed along xy-plane and also in diagonal which is due to stacking sequence at 45^0.There are warp and weft at perpendicular to each other and due to 45 angle there are no spaces between the fabric layers. So, when impact load is applied, the load is distributed to the whole structure of the composites. In case of the composites having stacking sequence of 0±90, the applied force is distributed only in two dimensions so that it has less value of impact strength as compared to 0±45.It also shows some rigidity as compared to 0±45 which is more flexible than 0±90 composites.

6. FUTURE PERSPECTIVE

In future, the weave design of the fabric samples, made from regenerated Kevlar and virgin Kevlar could be changed from 1\1 plain weave to 3/1 twill and 4/1 satin and use as a reinforcement and phenol as a resin then compare their mechanical properties. Then find out the difference between their properties and conclude that how we can get results close to the virgin Kevlar composites for ballistic applications and auto mobile industries.

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