Characterization of sandwich composites reinforced with glass fibres and Polyurethene Foam

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***ABSTRACT*: In this modern era , most of the engineering appliances are replaced by composite materials .Composites are widely used in automobiles, aircraft and marine applications because they are related to light weight ,high strength to weight ratio, corrosion resistance flexibility , high impact strength . In its most basic form the composite material is one which is composed of at least two elements working together. A sandwich structured composites is a special class of composite materials that is fabricated by attaching two thin but stiff skins to a light weight but thick core. The core material is Polyurethane foam, glass/ fibre panels and epoxy as a resin is used .The present paper deals the fabrication sand wich composites reinforced with glass fibres and Poly urethene foam. An attempt will be made to characterized reinforced sand wich composites in terms of compression, water absorption and chemical absorption.**

***Key Words*: Epoxy, 3- mill glass fibre, rigid polyurothene foam.**

Introduction: The use of composite sandwich structures in aerospace and civil infrastructure applications has been increasing especially due to their extremely low weight that leads to reduction in the total weight and fuel consumption, high flexural and transverse shear stiffness, and corrosion resistance (ASM Handbook 1987). In addition, these materials are capable of absorbing large amounts of energy under impact loads which results in high structural crashworthiness. In its simplest form a structural sandwich, which is a special form of laminated composites, is composed of two thin stiff face sheets and a thick lightweight core bonded between them. A sandwich structure will offer different mechanical properties with the use of different types of materials because the overall performance of sandwich structures depends on the properties of the constituents (Daniel 2008). Hence, optimum material choice is often obtained according to the design needs (Vinson 1999). Various combinations of core and face sheet materials are utilized by researchers worldwide in order to achieve improved crashworthiness (Adams 2006). In a sandwich structure generally the bending loads are carried by the force couple formed by the face sheets and the shear loads are carried by the lightweight core material (Nguyen, et al. 2005). The face sheets are strong and stiff both in tension and compression as compared to the low density core material whose primary purpose is to maintain a high moment of inertia. The low density of the core material results in low panel density, therefore under flexural loading sandwich panels have high specific mechanical properties relative to the monocoque structures. Therefore, sandwich panels are highly efficient in carrying bending loads. Under flexural loading, face sheets act together to form a force couple, where one laminate is under compression and the other under tension. On the other hand, the core resists transverse forces and stabilizes the laminates against global buckling and local buckling (Glenn and Hyer 2005). Additionally, they provide increased buckling and crippling resistance to shear panels and compression members. The critical properties of sandwich structures vary according to the application area of the structure. In automotive industry the out of plane compressive properties are more critical, whereas in wind turbines the in plane compressive properties are more important. Therefore, depending on the application area, different properties or characteristics of sandwich panels are needed to be evaluated . In order to select the correct configuration for the sandwich structures according to the design specifications, the most widely used way is numerically model them (Marques 2008). For this purpose, finite element modeling is used worldwide and the behaviour of the structures can be seen before manufacturing the real parts. The objectives of this study is to understand the mechanical behaviour and failure mechanisms of sandwich structures with polypropylene (PP) based honeycomb core and glass fibre reinforced polymer (GFRP) face sheets fabricated by hand layup technique as a function of core thickness. For this purpose, flat wise compression (FC), edgewise compression (EC), Mode I inter laminar fracture toughness and three point bending (3PB) tests were conducted on composite sandwich specimens with various core thicknesses. Constituents of the sandwich structures were also tested mechanically and the results of these tests were used as input for the finite element modeling by using ANSYS software.

Sandwich structures

A sandwich-structured composite is a special construction that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. Open and closed cell structured foam, balsa wood and syntactic foam, and composite honeycomb are commonly used core materials. Glass or carbon fiber reinforced laminates are widely used as skin materials. Sheet metal is also used as skin materials in some cases. They are commonly being used in ship construction, building, bridges, trains, car doors, panels etc. In construction new green sandwich structures are also being introduced where the core is usually made from the natural materials (wood) and the skin is made from earth (clay) instead of cement. Thus making it more environment friendly.

In general sandwich structures are symmetric; the variety of sandwich constructions basically depends on the configuration of the core. The core of a sandwich structure can be almost any material or architecture, but in general they are classified in four types; foam or solid core, honeycomb core, web core and corrugated or truss core. The adhesion of face sheets and core is another important criterion for the load transfer and for the functioning of the sandwich structure as a whole. The basic concept of a sandwich structure is that the face sheets carry the bending loads while the core carries the shear loads. The facesheets are strong and stiff in tension and compression compared to the low density core material whose primary purpose is to keep the face sheets separated in order to maintain a high section modulus (a high “moment of inertia” or “second moment of the area”) (Adams 2006).The core material has relatively low density (e.g., honeycomb or foam), which results in high specific mechanical properties, in particular, high flexural strength and stiffness properties relative to the overall panel density. Therefore, sandwich panels are efficient in carrying bending loads. Additionally they provide increased buckling resistance to shear panels and compression members. Sandwich construction results in lower lateral deformations, higher buckling resistance and higher natural frequencies than monologue constructions. A sandwich structure operates in the same way with the traditional I-beam, which has two flanges and a web connecting the flanges (Figure 2.2). The connecting web makes it possible for the flanges to act together and resist shear stresses. Sandwich structure and an I-beam differ from each other that, in a sandwich structure the core and laminates are different materials and the core provides continuous support for the laminates rather than being concentrated in a narrow web. When the structure subjected to bending the laminates act together, resisting the external bending moment so that one laminate is loaded in compression and the other in tension. The core resists transverse forces, at the same time, supports the laminates and stabilizes them
against buckling and wrinkling.

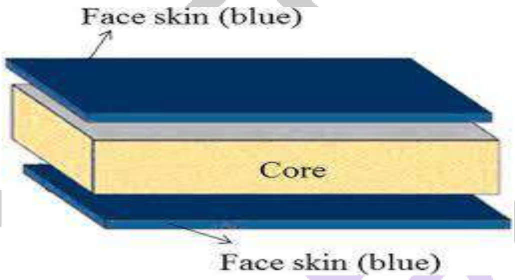

FIG : sandwich structure

Fiber composites

Composites, which contain fibers as reinforcement material, are used for many applications. A common fiber-containing composite is fibreglass, which has polyesterpolymer matrix and glass fiber fillers for reinforcement. The glass fibers strengthen the resin and make it more impact resistant. Many boat hulls are made of fibreglass that must withstand the constant beating of waves and other hard objects in water such as wood and rocks. These are the composite, which we will be studying in detail.

CONSTITUENTS OF COMPOSITES

The constituents or materials that make up the composites are resins, fillers, additives and reinforcements (e.g. fibers).

Resin system

The resin is an important constituent in composites. The two classes of resins are the thermoplastics and thermo sets. A thermoplastic resin remains a solid at room temperature. It melts when heated and solidifies when cooled. The long-chain polymers do not form strong covalent bond. That is why they do not harden permanently and are undesirable for structural application. Conversely, a thermo set resin will harden permanently by irreversible cross-linking at elevated temperatures. This characteristic makes the thermo set resin composites very desirable for structural applications. The most common resins used in composites are the unsaturated polyesters, epoxies, and vinyl esters; the least common ones are the polyurethanes and Phenolics.

Epoxies

The epoxies used in composites are mainly the glycidyl ethers and amines. The material properties and cure (hardening) rates can be formulated to meet the required performance. Epoxies are generally found in aeronautical, marine, automotive and electrical device applications. Although epoxies can be expensive, it may be worth the cost when high performance is required. It also has some disadvantages, which are its toxicity and complex processing requirements. Most of the epoxy hardeners cause various diseases.

Vinyl esters

The vinyl ester resins were developed to take advantage of both the workability of the epoxy resins and the fast curing of the polyesters. The vinyl ester has better physical properties than polyesters but costs less than epoxies. A composite product containing a vinyl ester resin can withstand high toughness demand and offer excellent corrosion resistance. Its properties are considered the best and it can adhere to reinforcements very well.

Polyurethanes

Polyurethanes are mainly used without reinforcements or in some case with fiber reinforcement. They are desired due their low cost, low viscosity and rapid hardening. They have less mechanical and less temperature tolerance as compared to the above mentioned thermo set resins. Polyurethanes are also related with resin toxicity. Most of their applications are in the car industry.

Phenolics

The Phenolic resins are made from phenols and formaldehyde, and they are divided into resole (prepared under basic conditions) and novolac resins (prepared under acidic conditions). The Phenolics are praised for their good resistance to high temperature, good thermal stability, and low smoke generation. They have a disadvantage due to their brittleness and inability to be colored until now.

Unsaturated polyesters

The unsaturated polyester amounts to about 75% of all polyester resins used in USA. The advantages of the unsaturated polyester are its dimensional stability and affordable cost as well as the ease of handling, processing, and fabricating. Some of their special properties are high corrosion resistance and fire retardants. These resins are probably of the highest value for they have a balance between performance and structural capabilities. They have low cost and have good properties such as low viscosity. One disadvantage of unsaturated polyesters it has an impact of light and UV light. In this study the LCA that has been conducted uses polyester as a resin that, forms glass reinforced composite skins of the balsawood core and PVC foam sandwich structures.

Fillers

Since resins are very expensive, it will not be cost effective to fill up the voids in a composite matrix purely with resins. Fillers are added to the resin matrix for controlling material cost and improving its mechanical and chemical properties. Some composites that are rich in resins can be subject to high shrinkage and low tensile strength. Although these properties may be undesirable for structural applications, there may be a place for their use.
The three major types of fillers used in the composite industry are the calcium carbonate, kaolin, and alumina trihydrate. Other common fillers include mica, feldspar, Wollastonite, silica, talc, and glasses. When one or more fillers are added to a properly formulated composite system, the improved performance Strength to bear stress includes fire and chemical resistance, high mechanical strength, and low shrinkage. Other improvements include toughness as well as high fatigue and creep resistance. Some fillers cause composites to have lower thermal expansion. Wollastonite filler improves the composites toughness for resistance to impact loading. Aluminium trihydrate improves on the fireresistance or flammability ratings. Some high strength formulations may not contain any filler because it increases the viscosity of the resin paste.

Additives

A variety of additives are used in the composites to improve the material properties, aesthetics, manufacturing process, and performance. The additives can be divided into three groups catalysts, promoters, and inhibitors; coloring dyes; and, releasing agents. The additives can alter the processing ability, mechanical properties, electrical properties shrinkage, environmental resistance, crystallization, fire tolerance and cost.

Reinforcements

It is the reinforcements that are the solid part of the composites, which are reinforced in to the matrix. They determine the strength and stiffness of the composites. Most common reinforcements are fibers, particles and whiskers. Fiber reinforcements are found in both natural and synthetic forms. Fiber composite was the very first form of composites, using natural fiber such as straw was reinforced in clay to make bricks that were used for building. Particle reinforcements are cheaper and are usually used to reduce the cost of isotropic material. Whiskers are pure single crystals manufactured through chemical vapour deposition and are randomly arranged in the matrix. They are also isotropic but this type Of reinforcement is very expensive. Among these reinforcements the long glass fiber (12 to 50 mm) are the ones most commonly used. There four kinds of fiber reinforcements, which are:

Carbon fibers

They were invented in 1878 by Thomas Alva Edison with cotton fiber and later on were made up of bamboo. Carbon fibers were used in high temperature missiles. They are made using rayon, Polyacrylonitrile and petroleum pitch. The carbon fiber is not organic even though they are formed from organic components. They are the strongest of all reinforcements and work is being done in order to increase their strength. They have resistance to high temperatures, and corrosive environment and lack moisture sensitivity. They also have disadvantages that they are brittle and are expensive. They are used in racing vehicles, ships, and spacecrafts and sports goods. Though the carbon fiber reinforcement is high temperature resistant it has been seen that carbon fiber reinforced in thermoplastic matrix at low temperatures collapse and fracture of the beam that is initiated by inter laminar shear and delaminating At high temperatures large scale inelastic deformation was observed by Ningyun et.al.

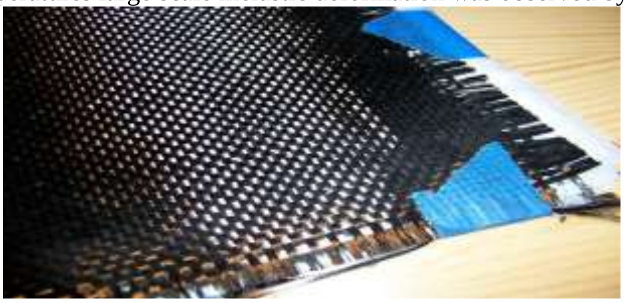

FIG : Carbon fiber

Glass fibers

Glass fiber reinforcements were produced for the first time in 1893. Now it is one of the most appealing reinforcements due to its high performance, good properties and low cost. It is made up of silicon oxide and some other oxide. Glass fibers are resistant to high temperatures and corrosive environments and they also have radar transparency.

There are two main types of glass fibers: E-glass and S-glass.

The first type is the most widely used, and takes its name from its good electrical properties but is prone to fractures in case of acoustic emissions,. The second type is very strong (S-glass), stiff, and temperature resistant. Reinforced glass fiber composite are an ideal material to make boat hulls, swimming pool linings, car bodies, roofing and furniture. Glass fiber reinforcement and polyester matrix has been used in this LCA for construction of the skin for the sandwich structures of the PVC foam and balsa wood core for the super structure of Stena Hollandaise.

FIG : Glass fibers

ADVANTAGES OF GLASS FIBRES :

1.The advantage of glass fibre is that it could be easily be moulded into any shape, it has mechanical strength that is so strong and stiff for its weight that it can out-perform most of the other materials.

2.Glass fibre last a long time, it can be coloured, shiny or dull.

3.It is low maintenance, anti-magnetic, fire resistant, ood electrical insulator and weatherproof.

Natural fibers .Natural fibers have come into use after centuries. They have been around a decade that natural fibers have started to be used again. Now they are being highly recommended because of being naturally derived from plants and due to their characteristics of being lightweight compared to glass. These reinforcements are reusable, good insulator of heat and sound, degradable and have a low cost. They also have their disadvantages as they are more prone to Force is exerted parallel to layers in the composites The layers separates as a result catching fire, their quality cannot be maintained equally, moisture causes swelling of fibers and its price may fluctuate according to the yield of the crop etc. It is being used widely for building purposes, in cars etc. The natural fibers used for composites are jute, hemp, flax, china grass etc. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin.

CORE MATERIALS

The most commonly used high quality core materials are Nomex honeycomb and PVC foam.

NomexHoneycomb : „Nomex" honeycomb (Nomex is Du Pont"s brand name for its aramid paper) is manufactured with aramid fiber paper. Nomex paper is shaped into honeycomb, a hexagonal cell structure in sheets, (like bee"s honeycomb,) that is dipped in a heat resistant phenolic resin, to improve mechanical properties and gain some stability. This structure provides an excellent combination of strength and efficiency while at the same time reduces the weight of the component. For this reason honeycomb materials are widely used where their high strength to weight ratio is valuable, in industries like aerospace, marine, military, construction, sports and automotive. Honeycomb is also manufactured with other cheaper materials, such as other aramid paper, plain paper, metal (aluminum), and plastic On the contrary, it is manufactured with more expensive materials like fiberglass and carbon fiber reinforced plastics.

PVC Foam: PVC foam is made from a polymer, polyvinyl chloride (or PVC), that is filled with air bubbles. The mix of polymer and air bubbles forms a consistent material, with increased volume many times over, while the weight remains low. It consists of 50% to 95% air resulting to a density of 55-200 kg/sqm, and thereby can contribute to save valuable weight and raw material. It may be used with most types of resin like epoxy, vinylester and others, and all types of fiber reinforcement like carbon, aramid, Kevlar, fiberglass, etc. There are two types of PVC foam: cross-linked or rigid, and linear or ductile. It is used mainly in marine construction due to the low water absorbance, but the fields of applications extend to transportation, aerospace, military, wind and industrial markets due to its excellent physical properties.

Polyurethane :

Polyurethane is a polymer composed of organic units joined by carbamate (urethane) links. While most polyurethanes are thermosetting polymers that do not melt when heated, thermoplastic polyurethanes are also available. Polyurethane polymers are traditionally and most commonly formed by reacting a di- or polyisocyanate with apolyol. Both the isocyanates and polyols used to make polyurethanes contain on average two or more functional groups per molecule. Some noteworthy recent efforts have been dedicated to minimizing the use of isocyanates to synthesize polyurethanes, because the isocyanates raise severe toxicity issues. Non-isocyanate based polyurethanes (NIPUs) haverecently been developed as a new class of polyurethane polymers to mitigate health and environmental concerns. Polyurethane products often are simply called "urethanes", but should not be confused with ethyl carbamate, which is also called urethane. Polyurethanes neither contain nor are produced from ethyl carbamate.

Advantages of polyurethane foam:
(1).Effective insulation
The thermal conductivity coefficient of the rigid polyurethane(PU) foam can be 0.018-0.024 w/(m*k), which is only the half of expanded polystyrene(EPS), if its density is 35-40kg/m³. Rigid polyurethane foam is the best organic insulating material. Since the thermal conductivity coefficient of the vesicant used is much lower than air, the insulating property of rigid polyurethane foam is better than rock wool, glass wool, expanded polystyrene and extruded polystyrene. Moreover, its insulating property can be sustainable for more than 30 years for its special closed-cell structure and resistance to gas diffusion. (2).Excellent corrosion and weather resistance the polyurethane foam performs well in corrosion and weather resistance for its closed-cell structure and its surface material. (3).Moisture proof and water proof. (4).Anti-freeze-thaw and sound absorption. The rigid polyurethane foam also performs well in antifreeze-thaw and sound absorption. (5).Energy efficiency and cost saving. Although the price is much higher than other alternatives, taking into account the excellent insulating property of the polyurethane foam, the increased costs will be offset by a substantial reduction in heating and cooling costs. Furthermore, we can reduce the thickness of external structure of the building by using thinner polyurethane foam to achieve the same insulating requirements, thereby increasing the indoor area. (6).Fireproof and high temperature resistance Rigid polyurethane foam is a flame-retardant and self-extinguishing material after. It can reach a softening point of 250 degrees Celsius and decomposes at a higher temperature. A layer of carbon will be formed if it is lighted, which will effectively prevent the spread of the flame. (7).Anti-deformation and hardly to be cracked The average life expectancy of rigid polyurethane foam can be more than 30 years under normal use and maintenance. It won‟t be destroyed by fungi and algae growth, or rodents. (8).Beautiful appearance and easy installation. The polyurethane foam can be bonded with different surface materials, such as color steel plates, cement fiberglass cloth, aluminum, stainless steel and so on. So there are a lot of beautiful appearances and structures for customers‟ choice according to their different specific requirements. It can be easily installed with fasteners because it is prefabricated in factory, which will significantly reduce the cost and shorten the schedule of construction.

Applications of polyurethane foam:
Polyurethane products have many uses. Over three quarters of the global consumption of polyurethane products is in the form of foams, with flexible and rigid types being roughly equal in market size. In both cases, the foam is usually behind other materials: flexible foams are behind upholstery fabrics in commercial and domestic furniture; rigid foams are inside the metal and plastic walls of most refrigerators and freezers, or behind paper, metals and other surface materials in the case of thermal insulation panels in the construction sector. Its use in garments is growing: for example, in lining the cups of brassieres. Polyurethane is also used for moldings which include door frames, columns, balusters, window headers, pediments, medallions and rosettes. Polyurethane formulations cover an extremely wide range of stiffness, hardness, and densities. These materials include:
 Low-density flexible foam used in upholstery, bedding, automotive and truck seating, and novel inorganic plant substrates for roof or wall gardens
 Low-density rigid foam used for thermal insulation and RTM cores
 Soft solid elastomers used for gel pads and print rollers
Low density elastomers used in footwear
 Hard solid plastics used as electronic instrument bezels and structural parts
 Flexible plastics used as straps and bands
Polyurethane foam is widely used in high resiliency flexible foam seating, rigid foam insulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires, automotive suspension bushings, electrical potting compounds, seals, gaskets, carpet underlay, and hard plastic parts (such as for electronic instruments).
MANUFACTURING METHODS

Hand lay-up technique :
Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardner (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown in figure 1. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirement is less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, diase board, deck etc.

FIG .1 : Hand lay-up technique

Materials used :
Matrix Epoxy, polyester, polyvinyl ester, phenolic resin, unsaturated polyester, polyurethane resin Reinforcement Glass fiber, carbon fiber, aramid fiber, natural plant fibers (sisal, banana, nettle, hemp, flax etc.)

Spray lay-up :
The spray lay-up technique can be said to be an extension of the hand lay-up method. In this technique, a spray gun is used to spray pressurized resin and reinforcement which is in the form of chopped fibers. Generally, glass roving is used as a reinforcement which passes through spray gun where it is chopped with a chopper gun. Matrix material and reinforcement may be sprayed simultaneously or separately one after one. Spray release gel is applied on to the mold surface to facilitate the easy removal of component from the mold. A roller is rolled over the sprayed material to remove air trapped into the lay-ups. After spraying fiber and resin to required thickness, curing of the product is done either at room temperature or at elevated temperature. After curing, mold is opened and the developed composite part is taken out and further processed further. The time of curing depends on type of polymer used for composite processing. The schematic of the spray lay-up process is shown in figure 2. Spray lay-up method is used for lower load carrying parts like small boats, bath tubs, fairing of trucks etc. This method provides high volume fraction of reinforcement in composites and virtually, there is no part size limitation in this technique.

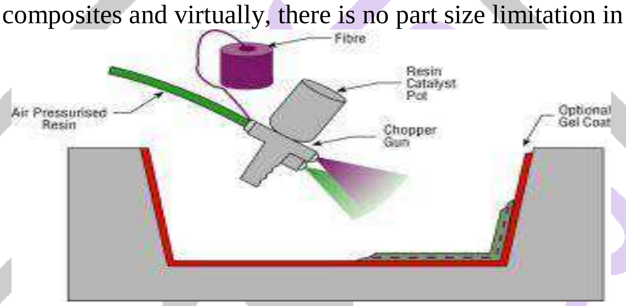

FIG .2 : Spray lay-up technique

Materials used :
Matrix Epoxy, polyester, polyvinyl ester, phenolic resin, unsaturated polyester, polyurethane resin. Reinforcement Glass fiber, carbon fiber, aramid fiber, natural plant fibers (sisal, banana, nettle, hemp, flax, coir, cotton, jute etc.) (all these fibers are in the form of chopped short fibers, flakes, particle fillers etc.)

PULTRUSION :
Pultrusion is a type of continuous automated closed molding, composite processing method. The basic mechanism of pultrusion system is same as that of the metal extrusion process. The only difference is that in extrusion process, material is pushed through the dies whereas in pultrusion, material is pulled through the dies. Reinforcement in terms of continuous rovings or fiber mats is unrolled from creel holding rolls and passes through a resin tank. In resin tank, fibers are dipped thoroughly to get completely wetted fibers. Now, these resin saturated fibers are guided to the hot die where the desired profile is given to these resin impregnated fibers with the help of dies. Curing of the composite also takes place in this section due to heating. Now, the cured composite profile is pulled with the help of gripper coming from the hot dies. Finally, pultruded profiles are cut with the help of a cutter which is inbuilt after the pulling mechanism in the pultrusion system. The schematic of pultrusion system is shown in figure. Sometimes, in the resin tank, some filler materials are added which also go with the fiber roving. Though, excess resin is removed in the hot die portion due to pressure, but in some pultrusion systems, a pre-former is used in between the resin tank and hot die. In the pre-former, excess polymer is squeezed out and uncured composite is generated which is then passed through hot die section. The pultrusion process is generally used and is suitable for thermoset polymer composites and a constant cross section profile of the composite product is produced on a continuous basis. As the cross section of product is uniform, the fiber distribution and alignment and resin impregnation is good in this process. Though rate of production is high but a large variation in area of cross-section is difficult to achieve. The expenditure requirement to start pultrusion process is low as compared to other costly and complex molding processes.

Important components of putrusion process:
There are mainly six components in the pultrusion system which govern the processing of composites. These components are: 1. Fiber Creels 2. Pre former 3. Resin impregnation systems 4. Hot dies 5. Pulling mechanism 6. Cut off saws.
The creel should be located in such a way that it should provide uniform and controlled tension to roving while transferring to the pultrusion system. For continuous and uninterrupted supply of the roving strand, a second back-up roving package is also provided besides running package. The shape and size of creel is decided on the basis of number of roving packages to be handled

and its dimension and the distance to be maintained in between the strands. Preform plates are critical component of pultrusion system as it properly aligns and feeds the reinforcement to the heated die. If pre-forming system is not properly functioning, it may lead to bad quality output and failure of pultrusion system. Resin impregnation system has a resin bath tank. The size of the tank depends upon the volume of resin to be handled. Resin impregnation system may have a heating arrangement for the resin to enhance fiber wettingbut the working life of bath is decreased due to heating system. The commonly used resin impregnation system is dip bath system which is also known as open bath. It allows the reinforcement travelling from the creels down into the bath and the resin coated fibers comes out through a guided bar

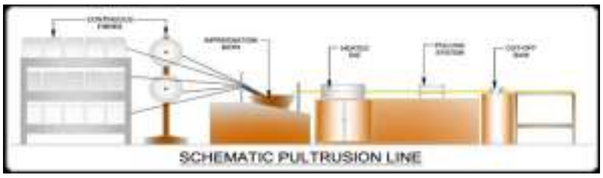

FIG : Pultrusion

located into the bath. Heating dies are the main component of any pultrusion system where part to be produced is given shape and is cured. Pulling system pulls the product from the heated dies on a continuous basis. Generally, a caterpillar belt is used in the pulling system. The last unit of pultrusion system is cut off saw which cut the pultruded product in desired size. Most commonly, a flying type of cut off saws are used in the pultrusion system. A flying cut off is movable unit which moves with the same speed as the pultruded product moves. The advantage of this movement is that the cutting edge of the component is square and straight. Sometimes, water is used as coolant and lubricant for cutting blades during cutting which is known as a wet saw. It also flushes the dust and debris generated duringcutting to the filter. A dry-cut saw uses a continuous rim diamond blade which does not require any coolant or lubrication during cutting and it gives clean cut of the product.

Resin Transfer Molding :

Resin transfer molding Resin transfer molding is a closed molding process. In this technique, as the name indicates, resin is transferred over the already placed reinforcement.inforcementin terms of either woven mat

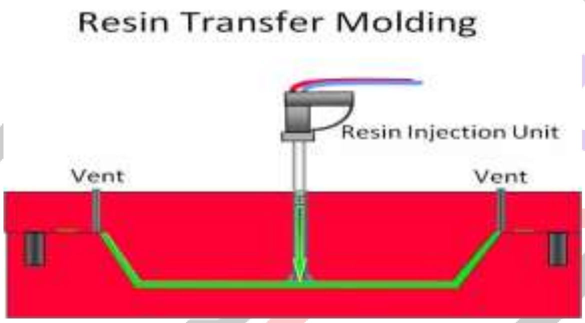

FIG : Resin transfer moulding

or strand mat form is placed on the surface of lower half mold. A release gel is applied on the mold surface for easy removal of the composite. The mold is properly closed and clamped. The clamping can be done either perimeter clamping or press clamping mechanism. The resin is pumped into the mold through ports and air is displaced through other vents. The uniformity of resin flow can be enhanced by using a catalyst as an accelerator and vacuum application. After curing, the mold is opened and composite product is taken out. The schematic of resin transfer molding process is shown in figure 1. Resin transfer molding can incorporate soft or hard mold depending upon the expected duration of run. For soft mold, thermosetting polymers like epoxy and polyester can be used for molding material. For hard mold, materials like steel and aluminium can be used. The cost of mold varies from very low to high cost mold with short to long life mold. The process can be automated to reduce cycle time. For complex shapes to be produced, preformed fiber reinforcements are used. The viscosity of the resin plays an important role in resin transfer molding process because injection time depends upon viscosity of the resin. If viscosity of resin is high, high pressure is required which may cause displacement of fibers, known as fiber wash.

Vacuum Bag Molding :

In vacuum bag molding, vacuum is created to remove entrapped air, gases and excess resin. As the lay-up of reinforcement (it may be a woven mat or other fabric form) and resin is completed then a non-adhering film of nylon or polyvinyl alcohol (PVA) is placed over the lay-up and sealed. These films forms a bag through which vacuum is createdwithin the mold and at this condition composites are cured either at room temperature or at any specific temperature. In this process, atmospheric pressure is used to suck air under vacuum bag which compacts composite layers down and produces a superior quality laminate.

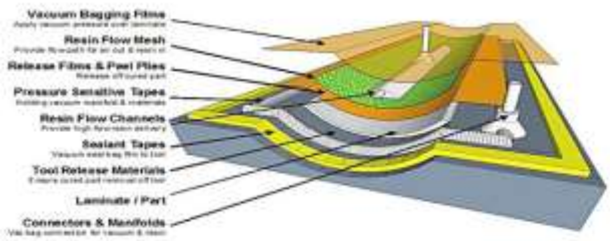

FIG .: Vacuum bagging

Fabrication of Composite Sandwich Structure:

The sandwich structures were impregnated and laminated by hand lay-up technique. In this technique, six layers of non-crimp glass fabrics were cut in 20 x 20 cm2 dimensions. Three layers of fabric were wetted by epoxy resin in order to form lower face sheet and then core material was placed on the lower face sheet, the upper face sheet was laminated with three layers of fabric on the core. Manufacturing process was made in a mould, coated with amold release agent. After the lamination procedure was completed, composites were cured at room temperature under the pressure 5k pa for 5 hours.

FIG .: Fabrication process

CHARACTERIZATION OF SANDWICH STRUCTURE

Compression test:

Compression test method according to ASTM C365 was used to measure the deflection and in-plane compressive strength of the composite face sheet panels. For this purpose, compression test specimen was cut from larger face sheet panels and test was performed by using the universal testing machine.

Before compression :

FIG : Specimen before testing

During compression :

FIG . Compression test using UTM

Max force (Fmax)	19.4 KN
Displacement at F max	37.1 mm
Max. displacement	37.2 mm
C/S Area (So)	26 mm2

Compressive strength	0.001 (KN/mm2)

After compression :

FIG.: Specimen after testing

Results Obtained :

Water absorption test:

The mass of absorbed water may also affect the behaviour of sandwich structures. It should be noted that in a sandwich panel the presence of facings bonded on two sides of the core may affect the amount of water absorbed by the core. Absorbed water affects the characteristic properties ofsandwich core materials, such as electrical properties (for example, dielectric constant, loss tangent, and electrical resistance) and mechanical properties (for example, strength and modulus). This test method provides a standard method of obtaining sandwich core moisture absorption data for design properties, material specifications, research and development applications, and quality assurance. In this a specimen of 50*50 mm is dipped in water for a time period of 24 hrs.

FIG .10 : Water absorption test

Calculations:

Weight of the sample before dipped in water = 4.67gms

Weight of the sample after dipped in water = 6gms

Percentage of weight absorbed =(6-4.67)/6*100

Weight absorbed by the sample =22.1%

Chemical absorption test:

In chemistry, absorption is a physical or chemical phenomenon or process in which atoms, molecules or ions enter some bulk phase–gas, liquid or solid material. This is a different process from adsorption, since molecules undergoing absorption are taken up by the volume, not by the surface (as in the case for adsorption). A more general term is sorption,

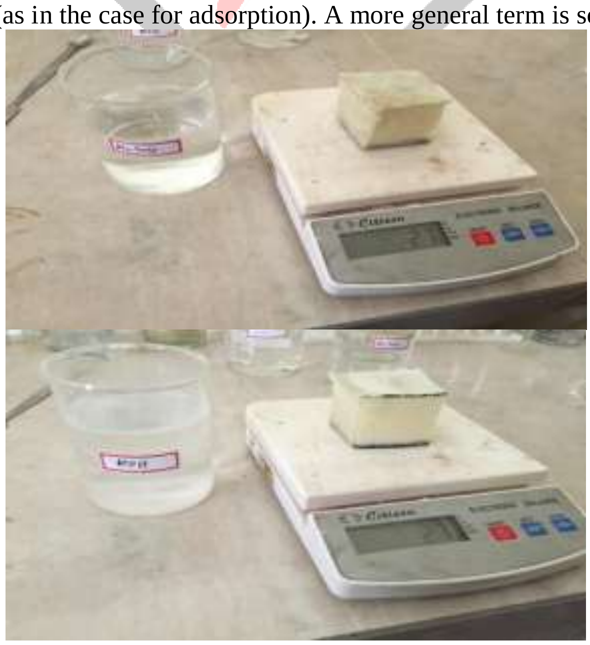

FIG 11 : a) Chemical absorption test of acid
b)Chemical absorption test of base

which covers absorption, absorption, and ion exchange. Absorption is a condition in which something takes in another substance. In many processes important in technology, the chemical absorption is used in place of the physical process, e.g.,absorption of carbon dioxide by sodium hydroxide – such acid-base processes do not follow the Nernst partition law. The process of absorption means that a substance captures and transforms energy. The absorbent distributes the material it captures throughout whole and adsorbent only distributes it through the surface. The reddish color of copper is an example of this process because it is caused due to its absorption of blue light. Chemical absorption test is performed by using H_2SO_4 as acid and KOH as base. Here, the two samples are dipped in H_2SO_4 as well as base.

Calculations:
(sulphuric acid): H_2SO_4
weight of the sample before dipped= 25.16
weight of the sample after dipped =27
percentage of weight absorbed =
Weight absorbed by the sample =6.8%
KOH(potassium hydroxide):
weight of the sample before dipped =26.51
weight of the sample after dipped =27
percentage of weight absorbed =
Weight absorbed by the sample =1.8%

RESULT AND CONCLUSION

Water absorption results :
Weight of the sample before dipped in water = 4.67gms
Weight of the sample after dipped in water = 6gms
Percentage of weight absorbed =
Weight absorbed by the sample =22.1%
Amount of water absorbed by the sandwich structure for 50 mm thickness is 22.1%.
So by reducing the thickness it can be used in marine applications.
Chemical absorption results :
(sulphuric acid):H_2SO_4
weight of the sample before dipped= 25.16
weight of the sample after dipped =27
percentage of weight absorbed =
Weight absorbed by the sample =6.8%
Amount of absorbed by the sandwich structure is 6.8%.
KOH(potassium hydroxide):
weight of the sample before dipped =26.51
weight of the sample after dipped =27
percentage of weight absorbed =
Weight absorbed by the sample =1.8%
Amount of absorbed by the sandwich structure is 1.8%.

CONCLUSION :

The primary objective of this work is to fabricate and characterize the mechanical, chemical absorption & water absorption properties of sandwich structure . Conclusions obtained from this study are as follows

In this study, the mechanical properties of composite sandwich structures fabricated with E-glass fiber/Rigid polyurethane foam were evaluated. The individual behavior of the E-glass fiber/Rigid polyurethane foam were also determined by performing related ASTM tests on these materials. Application of the flatwise compression tests to the sandwich structure showed that core material compressive strength and modulus increased with the core thickness as the sandwich structure thickness increase. In the flatwise compression test, sandwich structure walls buckled locally and densified. For the sandwich structures, based on flatwise compression test, it was observed that composite sandwich structures deformed similarly with the core material itself. It was also observed that only the core material influences the flatwise compressive properties of sandwich panel. As per practical result water absorption is very high in sandwich structure compared to other type of composite materials. As a practical result it has been observed that it is very less reactive with base when compared to acids. However, this study can be further extended in future to new types of composites using other potential synthetic fibers and the resulting experimental findings can be similarly analysed.

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