NUMERICAL INVESTIGATION AND CHARACTERIZATION FOR GLASS FIBER REINFORCED POLYMER AND CARBON FIBER REINFORCED POLYMER COMPOSITE FOR HIGH CORROSION CHEMICAL TANK

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ABSTRACT

Light weight design and construction is a major benefit for transportation tanks. In many countries, regulations impose a limit on the gross mass of road vehicles. The gross mass of the vehicle includes the tank, its cargo, the trailer, and prime mover. The transportation of liquid dangerous goods is a worldwide industry. Steel and aluminum are the main materials used to fabricate transport tankers to support this industry. These materials are used for different purposes. Aluminum is lightweight, cost effective, and competitive for use where liquid cargoes are mild to noncorrosive, such as Class 3 (flammable) dangerous goods. Steel is used where aluminum is not possible, which is mainly for transport of corrosive chemicals, classified as Class 8 dangerous goods. Generally, the use of mild steel is preferred in terms of cost, but is often not possible due to limited corrosion resistance. If higher corrosion resistance is required stainless steel may be suitable. Some Class 8 corrosive chemicals require special consideration in terms of the materials that the transport vessel is made from, as these can attack the stainless steel materials. Fiber reinforced polymers (FRPs) are emerging as an important alternative to steel materials for the transport industry, and these materials can be used with or without liner.

Keyword : - *Chemical tank analysis, fibre reinforced plastics, carbon fiber, glass fiber, Impact analysis.*

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1. INTRODCUTION

A composite is a structural material which consists of two or more constituents combined at a macroscopic level. The constituents of a composite material are a continuous phase called matrix and a discontinuous phase called reinforcement. A composite material is an oldest and good for advance technology of the world. The main advantage of composite material is light in weight and fabrication process is easy. Now composites materials are extensively used in automotive, aerospace, marine etc. industry. Since the development of composite material improves the mechanical strength. To fabricate the laminate main material is epoxy and hardener. To improve the mechanical strength epoxy is added more in aircraft and marine. There is different type of fiber is used. The strength of the composite depends on the type of the fiber and Orientation. Material is classily as isotropic and anisotropic. The isotropic material is in same direction and load with same strains, The direction with anisotropic materials is in are loads are created with strains and shear strain. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large coefficient of thermal expansion, thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide. Examples of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials tend to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with Silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. The fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcing elements and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers. The fibers carry the loads along their longitudinal directions. Sometimes, filler is added to smoothen the manufacturing process and to impact special properties to the composites. Lightweight design and construction is a major benefit for transportation tanks. In many countries, regulations impose a limit on the gross mass of road vehicles. The gross mass of the vehicle includes the tank, its cargo, the trailer, and prime mover. These regulations also impose a limit on the forces that individual axles can exert on the road through the contact wheels, with the sum of all axles adding to the gross mass of the complete vehicle. If the mass of the tank, trailer or prime mover can be reduced, then additional cargo can be transported, whilst keeping the complete vehicle at or below the gross mass limit, provided that the mass reduction is accompanied by an increase in the volume of the tank. The required volume of the tank to achieve the maximum gross mass of the vehicle is a function of the density of the liquid being transported. Tare mass reduction and consequent payload increase allows transport operators to reduce the number of transport vehicles that are required to perform their operations when moving large annual volumes of product. Lower vehicle tare mass also results in lower fuel consumption per unit volume of cargo transported. Trucking is the dominant mode of domestic freight and offers a substantial opportunity to improve transportation energy efficiency and reduce the emission of criteria pollutants and greenhouse gases (GHGs). In response, the Environmental Protection Agency (EPA) is proposing the voluntary Ground Freight Transportation Initiative, which will work with all industry sectors associated with freight movement as well as local governments to improve efficiency and reduce emissions through a range of voluntary actions. These actions may include best management practices, operational improvements, and advanced technologies. Strategies that EPA and partners will investigate as potential measures that could improve the environmental performance and energy efficiency of one subsector of ground freight, the trucking sector, are explored. Eight trucking strategies are assessed, including technological innovations and human factor (operations) strategies. All are commercially available (or, for operations, feasible) today, but most have achieved little market penetration. Each strategy is briefly described, and each strategy’s impact on the fuel economy of a typical freight truck is assessed. Then estimations of the current and potential maximum market penetration of each strategy as well as the potential reductions of U.S [1]. Fiber metal laminates are good candidates for advanced aerospace structural applications due to their high specific mechanical properties especially fatigue resistance. The most important factor in manufacturing of these laminates is the adhesive bonding between aluminum and FRP layers. In this study several glass fiber reinforced laminates and glass-fiber reinforced with aluminum were manufactured. Mechanical Tests like Tensile, Compression and Impact tests were carried out based on ASTM standard were then conducted to study the strength of both the laminates under specific conditions and their resistance towards loads and impact behavior of these laminates are observed. In addition, FMLS of with good adhesion bonding show better resistance under low velocity impact and their corresponding contact forces are about 25% higher than that of specimens with a weak bonding. In this experiment we find that the tensile and impact strength of the glass fiber with Al is higher than the glass fiber alone. This result will produce the more fusible and dynamic properties in the composite structure [2]. Fiber metal laminates are good candidates for advanced aerospace structural applications due to their high specific mechanical properties especially fatigue resistance. The most important factor in manufacturing of these laminates is the adhesive bonding between aluminium and FRP layers. In this study several glass-fiber reinforced aluminium laminates with different bonding adhesion were manufactured. Mechanical Tests like Tensile, Compression and Impact tests were carried out based on ASTM standard were then conducted to study the effects of interfacial adhesive bonding on impact behaviour of these laminates. It was observed that the damage size is greater in laminates with poor interfacial adhesion compared to that of laminates with strong adhesion between aluminium and glass layers [3]. High performance lightweight foamed concrete has the same mechanical properties of normal weight concrete (conventional concrete). The main applications are void filling, bridge abutments, bridge decks, marine structures, frame buildings, roads, sewer systems, roofing, walls, and floors. However, concrete is extensive brittleness and considered weak material in tension. Glass fibers are used as additive to the lightweight foamed concrete to increase the energy absorption capacity. The work was prepared to investigate the effect of glass fibers on tensile properties of lightweight foamed concrete with different volume fraction of glass fibers (0.06, 0.2, 0.4 and 0.6%) by the testing fresh density, dry density, flow ability, compressive strength, direct tensile strength and splitting tensile strength. The results showed that a reduction in flow ability was obtained with increased glass fibers content. Besides, the fresh and dry densities increased with the addition of glass fibers. Also, significant enhancements in compressive strength, direct tensile strength and splitting tensile strength were got by glass fibers inclusion. Thus, the increase of compressive strength, direct tensile strength and splitting tensile strength were up to the 56.6%, 50% and 46%, respectively, due to 0.6% glass fibers [4]. The effects of seawater exposure on the mechanical properties of unidirectional T700 carbon fiber/vinyl ester (510A) composites have been examined. Carbon fibers with two different types of sizings (F and G) were studied. Dynamic mechanical analysis testing of the neat resin and a carbon/vinyl ester composite revealed similar viscoelastic responses and glass transition temperatures indicating same type of cured resin for both cases. An analysis of moisture absorption dynamics of the composites revealed Fickian behavior. The composites absorbed more moisture than the resin. The moisture up-take in the composites is dominated by the fiber/matrix region. A comprehensive mechanical test program involving tension, compression, and shear tests was conducted on the composites at dry and saturated conditions. Composites with F-sized carbon fibers displayed overall higher strengths than those with G-sized fibers at both dry and moisture saturated conditions [5]. A comprehensive review is conducted on the performed investigations in the field of mechanical behaviour of glass-fibre reinforced thermosetting-resin (GFRP) pipes. Classified into six categories of stress/strain analysis, failure evaluation, environmental issues, viscoelastic behaviour and creep analysis, fatigue analysis and impact analysis, the main streamline of the performed and on-going studies in current years have been outlined. The recent trend and challenges in conducted researches are highlighted and discussed. Performing a gap analysis, new perspectives which are still required to be developed more deeply for their industrial applications or have not been addressed in literature are nominated [6]. Now a day's composites are important class of materials which are available to mankind. So studies of these composites are played a very important role in engineering, material science, metallurgy and solid mechanics applications. The fiber reinforced polymer composites are more widely used in the automotive industry, aeronautical industry and finds many other industrial applications due to their benefits like low cost, noise control, low weight and ease of processing. The objective of this research is to prepare E-glass fiber based composite with percentage variation of glass fibre content like 1%. and 2% with using a bisphenol A as matrix material and conducting flexural test on the composite.[7]The present study describes the processing and mechanical characterization of two different fibers (glass and carbon) and two different fabric architectures (woven roving and stitch bonded) made into composites with Dow Chemical's Derakane 510A-40, a brominated vinyl ester (VE) resin. Both E-glass and T700 carbon fibers are coated with VE compatible sizing. The composite panels are fabricated by the vacuum assisted resin transfer molding (VARTM), the specimens are machined, and the mechanical tests are conducted as per the accepted test standards. Tension, compression, in-plane shear, and interlaminar shear properties are measured and their associated failure modes are compared with each other. The specific properties of the composites are compared with that of the marine steel. The carbon composites have superior properties, higher specific strength, and specific modulus than the marine steel. The glass composites have higher specific strength but lower specific modulus than marine steel [8]. Experimental results are presented for the direct effect of an acidic stress environment on the stress intensity factor of woven E-glass fibre-reinforced bisphenol–vinylester resin (E–VE), woven E-glass fibre-reinforced bisphenol–epoxy resin (E–ER) and woven C-glass fibre-reinforced bisphenol–vinylester resin (C–VE) composites. Compact type specimens were exposed in hydrochloric acid of various concentrations and temperatures during constant tensile loading conditions. The constant tensile loading tests determined the rate of crack propagation and stress intensity factors for stress-corrosion cracking. The results indicated that the crack propagation behaviour depended on the concentration of acid, temperature, stress-intensity factor and time [9]. Polymer matrix composite tanks offer major advantages to the transport industry in terms of increased payload and corrosion resistance compared to conventional steel tanks. Chemical resistance and versatility can be enhanced through the addition of a thermoplastic liner. This paper presents the results of chemical conditioning, testing and analysis of a linear low-density polyethylene liner, on its own and supported by carbon fiber reinforced polymer. Results are compared to ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road) requirements [10].

2. PROBLEM IDENTIFICATION

In many countries, regulations impose a limit on the gross mass of road vehicles. The gross mass of the vehicle includes the tank, its cargo, the trailer, and prime mover. These regulations also impose a limit on the forces that individual axles can exert on the road through the contact wheels, with the sum of all axles adding to the gross mass of the complete vehicle. If the mass of the tank, trailer or prime mover can be reduced, then additional cargo can be transported, whilst keeping the complete vehicle at or below the gross mass limit. provided that the mass reduction is accompanied by an increase in the volume of the tank. The transportation of liquid dangerous goods is a worldwide industry. These materials are used for different purposes. Steel is used where aluminum is not possible, which is mainly for transport of corrosive chemicals, classified as Class 8 dangerous goods. Generally, the use of mild steel is preferred in terms of cost but is often not possible due to limited corrosion resistance. If higher corrosion resistance is required stainless steel may be suitable. For highly corrosive chemicals that cause major corrosion problems for stainless steel, a liner can be used to protect the steel tank from the chemical cargo. This liner is generally made from rubber. A high degree of care must be taken in the fabrication and service of rubber liners, as failure of the liner can result in severe corrosion effects to the tank wall and rapid loss of containment. Fibber reinforced polymers (FRPs) are emerging as an important alternative to steel materials for the transport industry, and these materials can be used with or without liner.

3. MATERIAL SELECTION

The materials are generally selected based on the requirement of the application. The materials used are bi directional woven fabrics of glass fiber and carbon fiber. The resin used is epoxy resin.

3.1 Carbon fibre

Carbon fiber is made of thin, strong crystalline filaments of carbon that is used to strengthen material. Carbon fiber can be thinner than a strand of human hair and gets its strength when twisted together like yarn. Then it can be woven together to form cloth and if needed to take a permanent shape, carbon fiber can be laid over a mould and coated in resin or plastic.

3.2 Glass fibre

Glass fibers are formed from melts and manufactured in various compositions by changing the amount of raw materials like sand for silica, clay for alumina, calcite for calcium oxide, and colemanite for boron oxide. Glass fiber products are classified according to the type of composite at which they are utilized. Moreover, chopped strands, direct draw rovings, assembled rovings, and mats are the most important products that are used in the injection molding, filament winding, pultrusion, sheet molding, and hand layup processes to form glass fiber-reinforced composites. Protection of the glass fiber filaments from breakage or disintegration is an important issue either during manufacturing of glass fiber or during composite production. The resultant interphase layer can either increase or decrease the performance of the composite considering harmony between sizing components and matrix polymer. Compatibility between sizing and matrix polymer enhances high mechanical properties and on the contrary incompatible sizing results in poor mechanical properties.

4. FABRICATION OF TEST SPECIMENS

The fabrication process is carried out by the hand lay up method. The resin used for the fabrication process is epoxy resin. The glass fiber laminates and carbon fiber laminates are prepared. The test coupons were fabricated by the size of 300 x 300 mm. The fiber and matrix ratio was maintained as 1:1 ratio. The Mylar sheet was used as platform for fabrication to obtain the proper finishing. The individual laminates were dried up for 24 hours as the curing time.

4.1 Laminate preparation

The data sheet supplied with the product has been read to determine the ratio of Epoxy resin LY 556 . Although usually given on a volume basis (e.g. 5:2 parts resin to hardener respectively), some systems also give a weight ratio, which is nearly always different. For instance, a system of 5:2 mix ratio by volume may be 3:1 by weight.

4.2 Handlay up technique

Hand lay-up is the simplest and oldest open molding method for fabricating composites. At first, dry fibers in the form of woven, knitted, stitched, or bond fabrics are manually placed in the mold, and a brush is used to apply the resin matrix on the reinforcing material. Subsequently, hand rollers are used to roll the wet composite to ensure an enhanced interaction between the reinforcement and the matrix, to facilitate a uniform resin distribution, and to obtain the required thickness. Finally, the laminates are left to cure under standard atmospheric conditions. Generally, this process is divided into four steps: mold preparation, gel coating, lay-up, and curing. Curing is the process of hardening the fiber-reinforced resin composite without external heat. A pigmented gel coat is first applied to the mold surface to obtain a high-quality product surface. There are several disadvantages of this method. The skills to laminate the reinforcement and matrix, such as resin mixing, laminate resin contents, and the quality of the laminate, are crucial. The laminate is usually achieved with the incorporation of excessive quantities of voids. The lower molecular weights of the hand lay-up resins mean that they have the potential to be more harmful than higher molecular weight products. The lower viscosity of the resins also implies that they have an increased tendency to penetrate clothing. Resins need to be low in viscosity to be workable by hand. This usually compromises their mechanical/thermal properties, due to the need for high diluent/styrene levels. Moreover, the amount of fiber loading relies heavily on the processing method. This is also influenced by the anatomical features of the fibers, which have intra-fiber voids called lumen. The hand lay-up fabrication process is mainly used in marine and aerospace structures

Fig-1 : Mould preparation

Fig – 2 : Applying resin on mould

Fig – 3 : Removing air using roller

Fig – 4 : CFRP laminate

Fig – 5 : GFRP laminate

5. MECHANICAL CHARACTERIZATION

The mechanical characterization in fiber reinforced laminates is used for determining the mechanical properties of the fiber laminated plastics. The tests generally conducted are tensile test, flexural test, water absorption test and impact test. The test coupons are prepared based on the ASTM standards.

5.1 Tensile test

Tensile Testing is a form of tension testing and is a destructive engineering and materials science test whereby controlled tension is applied to a sample until it fully fails. This is one of the most common mechanical testing techniques. It is used to find out how strong a material is and also how much it can be stretched before it breaks. This test method is used to determine yield strength, ultimate tensile strength, ductility, strain hardening characteristics, Young's modulus and Poisson's ratio.

5.2 Flexural test

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique.

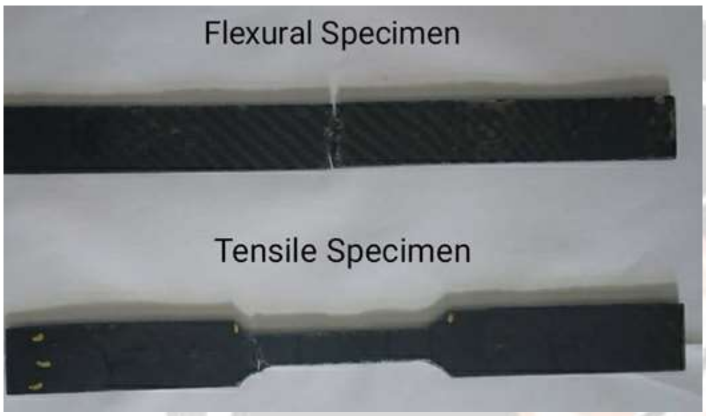

Fig – 6 : CFRP tension and flexural specimen

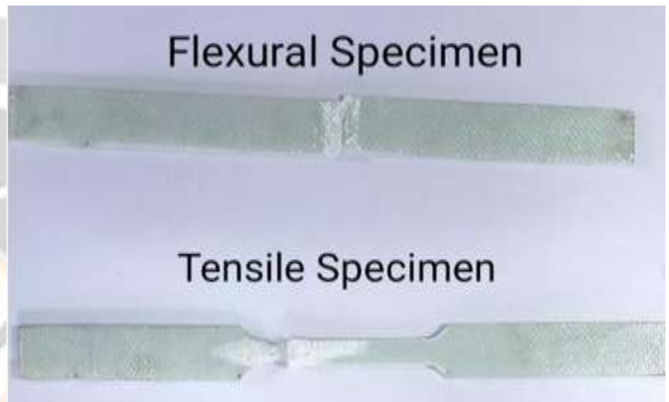

Fig – 7 : GFRP tension and flexural specimen

Table – 1 : Comparison of flexural strength, tensile strength and impact strength among the laminates

S.No	FRP laminate	Thickness (mm)	Flexural strength (MPa)	Tensile strength (MPa)	Impact strength (J)
1	Carbon	3.27	366.38	376.56	5.5
2	Glass	3.38	277.89	338.39	3
3	Carbon-Glass	3.5	403.68	412.47	7

6. NUMERICAL SIMULATION

ANSYS Workbench is a project-management tool. It can be considered as the top-level interface linking all our software tools. Workbench handles the passing of data between ANSYS Geometry / Mesh / Solver / Post Processing tools. This greatly helps project management. You do not need to worry about the individual files on disk (geometry, mesh etc). Graphically, you can see at-a-glance how a project has been built. Because Workbench can manage the individual applications AND pass data between them, it is easy to automatically perform design studies (parametric analyses) for design optimization.

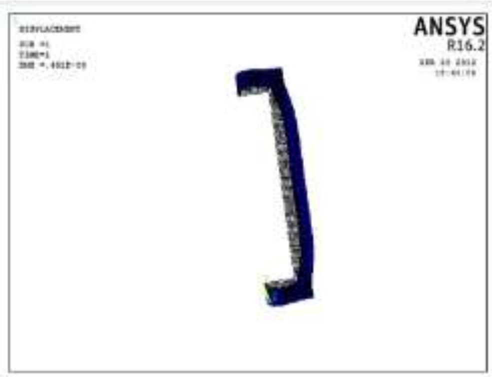

Fig – 8 : Deformation of tank due to pressure

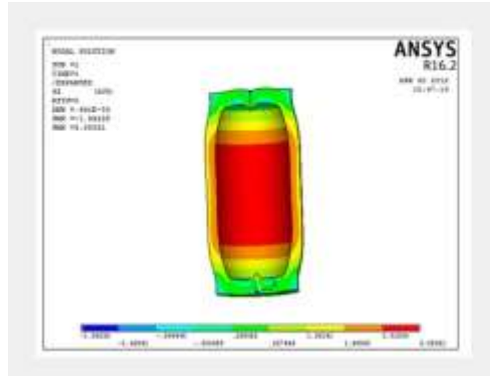

Fig-9 : pressure acting inside the cylinder

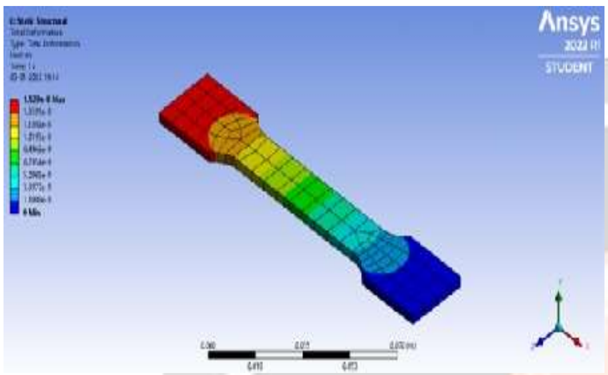

Fig – 10 : Tensile test on CFRP

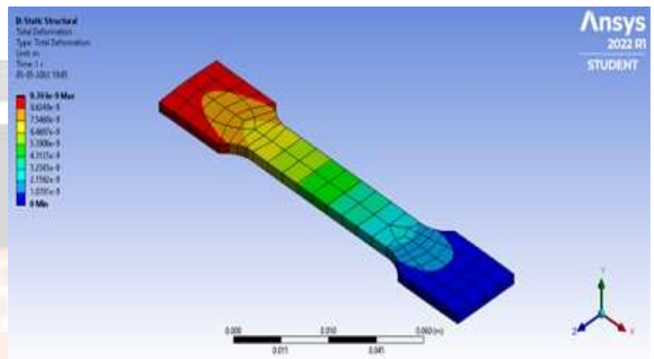

Fig – 11 : Tensile test on GFRP

6. CONCLUSION

Tanks used in the chemical transport and storage industry, particularly for Class 8 corrosive chemicals, suffer from major corrosion problems. There are existing methods for corrosion protection of steel and stainless-steel tanks. FRP tanks are an alternative to steel tanks. FRP tanks have good chemical resistance, through the inclusion of a corrosion barrier and can be further improved using thermoplastic liners. Such tanks and corrosion protection methods have been in service for many years, and there is an expectation that these will be in service for years to come with increasing demand on such infrastructure. Increase in demand for tanks can be linked to many different requirements, including population growth, climate change, and service contracts. It is observed that Carbon-Glass combined fiber with lowest thickness shows high flexural strength. Similarly, Glass fiber with height thickness shows lowest flexural strength and the carbon fiber shows increased high flexural strength Compared to the other fibers. It is observed that Carbon fiber with lowest thickness shows high tensile strength. Similarly, Glass fiber with height thickness shows increased high tensile strength and the combination of glass-carbon fiber shows increased high tensile strength. It is observed that Carbon fiber with thickness shows high compression strength. Similarly, Glass fiber with height thickness shows increased high compression strength and the combination of glass-carbon fiber shows increased high compression strength with low thickness.

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