EXPERIMENTAL ANALYSIS OF HYBRID COMPOSITES FOR AUTOMOTIVE APPLICATION

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this Design project titled **"EXPERIMENTAL ANALYSIS OF HYBRID COMPOSITES FOR AUTOMOTIVE APPLICATION (BUMPER)"** is the bonafide work of **THIRUMARAN T (18104016), DINESH KUMAR S (18104019), B ABHISHEK (18104021) and HARISH S (18104041)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other project report on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The automotive industry is growing faster than any other industry, and the demand for lightweight components is growing with it. Automobile design is influenced by two main factors: weight and safety. Even though conventional materials used in automobile manufacturing, such as plastics, are lighter than steel, there is still potential for weight reduction. Hybrid Composites are being explored for use in production of lighter, safer, and more fuel-efficient vehicles. Due to its better strength and lower weight ratios, the research focuses on combining synthetic and natural fibers in polymer matrix composites. The combination of natural fibers such as coconut coir and glass fiber composites has expanded growing claims in various engineering and technological fields. The bumper of Suzuki Alto was designed using both conventional plastic and hybrid composites. The impact resistance of these Hybrid composite materials are then compared to those of conventional car bumper materials. This analysis indicated weight, cost, and environmental impact reductions, as well as drawbacks such as mass production difficulty and complexity of the manufacturing process. Static and Dynamic Analysis were conducted on the bumper, and the results were compared.

Keywords: Crash, Hybrid Composite Materials, Comparison, Bumper.

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CHAPTER 1
INTRODUCTION

A bumper is a steel, aluminium, rubber, or plastic component which is mounted on the front and rear of a vehicle. When a low-speed collision occurs, the bumper system absorbs the impact and helps to prevent or minimise vehicle damage. Weight reduction has been the primary focus of automotive manufacturers in recent years. Automobile makers are currently focusing on reducing fuel consumption, weight, and maximising the use of natural resources. Better design concepts, better materials, and a more efficient manufacturing process can all help achieve the goals listed above. Companies in the manufacturing industry were looking for new composite materials with good mechanical, chemical, and dynamic qualities. Hybrid composites are composites that comprise two or more fillers in the same matrix. Glass fibre reinforcing in a polyester matrix result in composites that have impact strength comparable to reinforced thermoplastics . There has recently been a surge in interest in combining diverse natural fibres to create high-performance composite materials. In attempt to discover a new material, researchers combined coconut fibre (also known as coir fibre) with composite material in a study. Coir is a thick, coarse, and long-lasting natural fibre found in the coconut husk. It is relatively water resistant and resistant to microbial deterioration and salt water damage. Because of its mechanical qualities, low cost, processing advantages, and low density, natural fibre reinforced composites are fast gaining popularity. Natural fibres such as coconut coir and jute are more readily available in Asia, and they have some cost, density, renewability, recyclability, abrasiveness, and biodegradability advantages over standard reinforcement materials . The performance of fibre reinforced composites is determined by the fibre matrix and its capacity to transfer load from the matrix to the fibre. Polymeric materials reinforced with synthetic fibres such as glass, carbon, and aramid provide advantages of high stiffness and strength to weight ratio when compared to traditional construction materials such as wood, concrete, and steel.

1.1 POLYMER COMPOSITES:

Polymer composites are a combination of polymers (i.e., thermosets or thermoplastics) with various continuous and noncontinuous reinforcements/fillers, principally added to polymers to improve the material performance. Polymer composites are increasingly being used in various engineering fields.

1.2 CLASSIFICATION OF POLYMER COMPOSITES

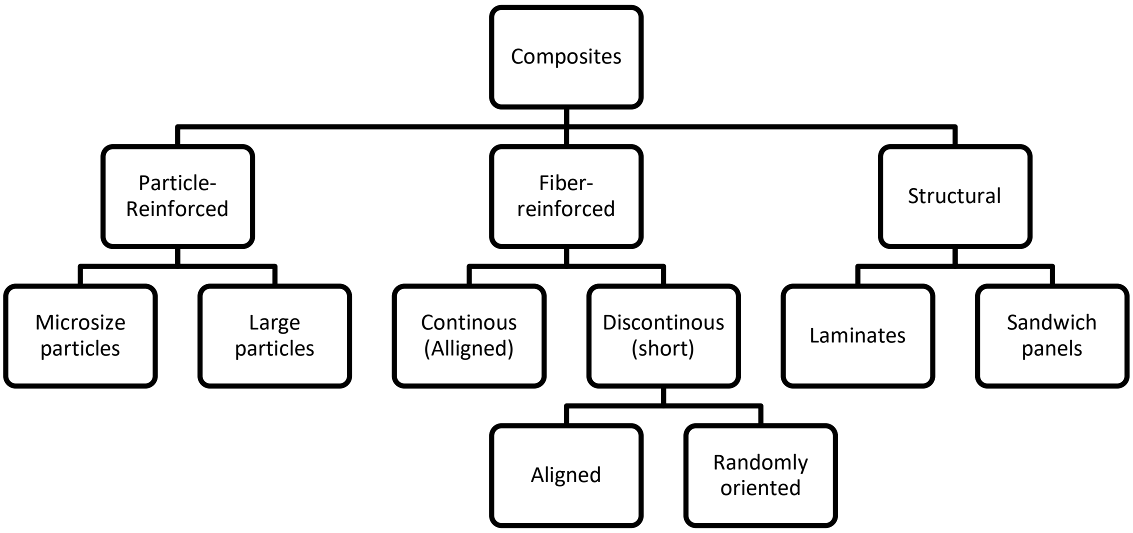


Figure 1.1 Classification of polymer composites

Polymer composites can be classified into three groups on the basis of reinforcing material. They are:

1.2.1 Fiber reinforced polymer (FRP)

1.2.2 Particle reinforced polymer (PRP)

1.2.3 Structural polymer composites (SPC)

1.2.1 Fiber Reinforced Polymer (FRP)

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. These also reduces the production cost. Most commonly used agents include asbestos, carbon/graphite fibers, beryllium, beryllium carbide, beryllium oxide, molybdenum, aluminum oxide, glass fibers, polyamide, natural fibers etc. Similarly common matrix materials include epoxy, phenolic resin, polyester, polyurethane, vinyl ester etc. Among these materials, resin and polyester are most widely used. Epoxy, which has higher adhesion and less shrinkage than polyesters, comes in second for its high cost.

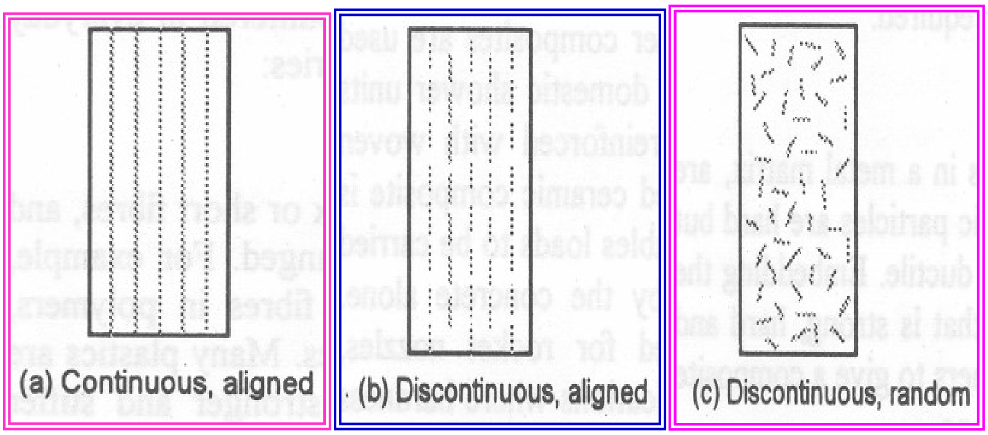


Figure 1.2 types of fiber reinforced polymer

To measure the relative mechanical advantage of composites, two parameters are widely used, namely, the specific modulus and the specific strength. These two parameter ratios are high in composites.

The building block of a laminate is a single lamina. Therefore, the mechanical analysis of a lamina precedes that of a laminate. A lamina is an anisotropic and non-homogeneous material. But for approximate macro-mechanical analysis, a lamina is assumed to be homogeneous where the calculation of the average properties is based on individual mechanical properties of fiber and matrix, as well as content, packing geometry and shape of fibers. The lamina is considered as orthotropic, so it can be characterized by nine independent elastic constants: three young's moduli along each material axis, three Poisson's ratio for each plane and three shear moduli for each plane. Once the properties for each lamina are obtained, properties of a laminate, made of those laminae can be calculated using those individual properties.

In the highly competitive airline market, using composites is more efficient. Though the material cost may be higher, the reduction in the number of parts in an assembly and the savings in the fuel cost makes more profit. It also lowers the overall mass of the aircraft without reducing the strength and stiffness of its components.

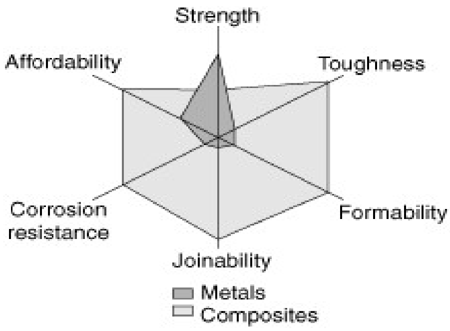


Fig.1.3 comparative characteristics of metals and composites

1.2.2 Particle Reinforced Polymer (PRP)

Particles which are used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminum and amorphous materials, including polymers and carbon black. Particles are used to enhance the modulus and to decrease the ductility of the matrix. Some of the useful properties of ceramics and glasses include high melting temp., low density, high strength, stiffness; wear resistance, and corrosion resistance etc. Many ceramics are good electrical and thermal insulators. Some ceramics have special properties; some have magnetic properties; some are piezoelectric materials; and a few special ceramics are even superconductors at very low temperatures. One major drawback of ceramics and glass is their brittleness. An example of particle – reinforced composites is an automobile tire, which has carbon black particles in a matrix of poly-isobutylene elastomeric polymer.

1.2.3 Structural Polymer Composites (SPC)

These are laminar composites which are composed of layers of materials held together by matrix. This category also includes sandwich structures. Over the past few decades, we find that polymers have replaced many of the conventional materials in various applications. The most important advantages of using polymers are the ease of processing, productivity and cost reduction. The properties of polymers are modified using fillers and fibers to suit the high strength and high modulus requirements. Fiber reinforced polymers offer advantages over other conventional materials when specific properties are compared. That's the reason for these composites finding applications in diverse fields from appliances to spacecrafts.

1.3 RESIN MATRIX

The resins that are used in fibre reinforced composites are sometimes referred to as 'polymers. All polymers exhibit an important common property in that they are composed of long chain-like molecules consisting of many simple repeating units. Man-made polymers are generally called 'synthetic resins' or simply 'resins. Polymers can be classified under two types, 'thermoplastic' and 'thermosetting', according to the effect of heat on their properties.

Although there are many different types of resin in use in the composite industry, the majority of structural parts are made with three main types, namely polyester, vinyl-ester and epoxy.

1.3.1 Polyester Resins

Polyester resins are the most widely used resin systems, particularly in the marine industry. By far the majority of dinghies, yachts and work-boats built in composites make use of this resin system.

Polyester resins such as these are of the 'unsaturated' type. Unsaturated polyester resin is a thermoset, capable of being cured from a liquid or solid state when subject to the right conditions. Unsaturated polyester differs from saturated polyester such as Terylene™ which cannot be cured in this way. It is usual, however, to refer to unsaturated polyester resins as 'polyester resins', or simply as 'polyesters.

1.3.2 Vinylester Resins

Vinyl-ester resins are similar in their molecular structure to polyesters, but differ primarily in the location of their reactive sites, these being positioned only at the ends of the molecular chains. As the whole length of the molecular chain is available to absorb shock loadings this makes Vinyl-ester resins tougher and more resilient than polyesters.

The vinyl-ester molecule also features fewer ester groups. These ester groups are susceptible to water degradation by hydrolysis which means that vinyl-esters exhibit better resistance to water and many other chemicals than their polyester counterparts, and are frequently found in applications such as pipelines and chemical storage tanks.

1.3.3 Epoxy Resins

The large family of epoxy resins represents some of the highest performance resins of those available at this time. Epoxies generally out-perform most other resin types in terms of mechanical properties and resistance to environmental degradation, which leads to their almost exclusive use in aircraft components. As a laminating resin their increased adhesive properties and resistance to water degradation make these resins ideal for use in applications such as boat building. Here epoxies are widely used as a primary construction material for high-performance boats or as a secondary application to sheath a hull or replace water-degraded polyester resins and gel coats.

The term 'epoxy' refers to a chemical group consisting of an oxygen atom bonded to two carbon atoms that are already bonded in some way. The simplest epoxy is a three-member ring structure known by the term 'alpha-epoxy' or '1,2-epoxy'. The idealized chemical structure is shown in the figure below and is the most easily identified characteristic of any more complex epoxy molecule.

Comparison of resin properties

The choice of a resin system for use in any component depends on a number of its characteristics, with the following probably being the most important for most composite structures:

- Adhesive Properties
- Mechanical Properties
- Degradation from Water Ingress.

Adhesive properties:

It has already been discussed how the adhesive properties of the resin system are important in realizing the full mechanical properties of a composite. The adhesions of the resin matrix to the fibre reinforcement or to a core material in a sandwich construction are important. Polyester resins generally have the lowest adhesive properties of the three systems described here. Vinyl-ester resin shows improved adhesive properties over polyester but epoxy systems offer the best performance of all, and are therefore frequently found in many high-strength adhesives. This is due to their chemical composition and the presence of polar hydroxyl and ether groups. As epoxies cure with GTC-4-0111–21 low shrinkage the various surface contacts set up between the liquid resin and the adherents are not disturbed during the cure. The adhesive properties of epoxy are especially useful in the construction of honeycomb-cored laminates where the small bonding surface area means that maximum adhesion is required.

The strength of the bond between resin and fibre is not solely dependent on the adhesive properties of the resin system but is also affected by the surface coating on the reinforcement fibres.

Mechanical properties:

Two important mechanical properties of any resin system are its tensile strength and stiffness.

Degradation from water ingress:

An important property of any resin, particularly in a marine environment, is its ability to withstand degradation from water ingress. All resins will absorb some moisture, adding to a laminate's weight, but what is more significant is how the absorbed water affects the resin and resin/fibre bond in a laminate, leading to a gradual and long term loss in mechanical properties. Both polyester and vinyl-ester resins are prone to water degradation due to the presence of hydrolysable ester groups in their molecular structures. As a result, a thin polyester laminate can be expected to retain only 65% of its inter-laminar shear strength after immersion in water for a period of one year, whereas an epoxy laminate immersed for the same period will retain around 90%.

1.4 SYNTHETIC FIBRES

The mechanical properties of most reinforcing fibres are considerably higher than those of un-reinforced resin systems. The mechanical properties of the fibre/resin composite are therefore dominated by the contribution of the fibre to the composite.

1.5 TYPES OF SYNTHETIC FIBRE

1.5.1 Glass

By blending quarry products (sand, kaolin, limestone, colemanite) at 1,600°C, liquid glass is formed. The liquid is passed through micro-fine bushings and simultaneously cooled to produce glass fibre filaments from 5-24µm in diameter. The filaments are drawn together into a strand (closely associated) or roving (loosely associated), and coated with a "size" to provide filament cohesion and protect the glass from abrasion. By variation of the "recipe", different types of glass can be produced. The types used for structural reinforcements are as follows:

a. E-glass (electrical) - lower alkali content and stronger than A glass (alkali). Good tensile and compressive strength and stiffness, good electrical properties and relatively low cost, but impact resistance relatively poor. Depending on the type of E glass the price ranges from about £1-2/kg. E-glass is the most common form of reinforcing fibre used in polymer matrix composites.

b. C-glass (chemical) - best resistance to chemical attack. Mainly used in the form of surface tissue in the outer layer of laminates used in chemical and water pipes and tanks.

c. R, S or T-glass – manufacturer's trade names for equivalent fibres having higher tensile strength and modulus than E glass, with better wet strength retention. Higher ILSS and wet out properties are achieved through smaller filament diameter. S-glass is produced in the USA by OCF, R-glass in Europe by Vetrotex and T-glass by Nittobo in Japan. Developed for aerospace and defence industries, and used in some hard ballistic armour applications. This factor, and low production volumes mean relatively high price. Depending on the type of R or S glass the price ranges from about £12-20/kg.

E Glass fibre is available in the following forms:

a. strand - a compactly associated bundle of filaments. Strands are rarely seen commercially and are usually twisted together to give yarns.

b. yarns - a closely associated bundle of twisted filaments or strands. Each filament diameter in a yarn is the same, and is usually between 4-13µm. Yarns have varying weights described by their ‘tex’ (the weight in grammes of 1000 linear metres) or denier (the weight in lbs of 10,000 yards), with the typical tex range usually being between 5 and 400.

c. rovings - a loosely associated bundle of untwisted filaments or strands. Each filament diameter in a roving is the same, and is usually between 13-24μm. Rovings also have varying weights and the tex range is usually between 300 and 4800. Where filaments are gathered together directly after the melting process, the resultant fibre bundle is known as a direct roving. Several strands can also be brought together separately after manufacture of the glass, to give what is known as an assembled roving.

Assembled rovings usually have smaller filament diameters than direct rovings, giving better wet-out and mechanical properties, but they can suffer from catenary problems (unequal strand tension), and are usually higher in cost because of the more involved manufacturing processes.

It is also possible to obtain long fibres of glass from short fibres by spinning them. These spun yarn fibres have higher surface areas and are more able to absorb resin, but they have lower structural properties than the equivalent continuously drawn fibres.

1.5.2 Aramid

Aramid fibre is a man-made organic polymer (an aromatic polyamide) produced by spinning a solid fibre from a liquid chemical blend. The bright golden yellow filaments produced can have a range of properties, but all have high strength and low density giving very high specific strength. All grades have good resistance to impact, and lower modulus grades are used extensively in ballistic applications. Compressive strength, however, is only similar to that of E glass.Although most commonly known under its Dupont trade name ‘Kevlar’, there are now a number of suppliers of the fibre, most notably Akzo Nobel with ‘Twaron’. Each supplier offers several grades of aramid with various combinations of modulus and surface finish to suit various applications. As well as the high strength properties, the fibres also offer good resistance to abrasion, and chemical and thermal degradation. However, the fibre
can degrade slowly when exposed to ultraviolet light.

1.5.3 Carbon

Carbon fibre is produced by the controlled oxidation, carbonisation and graphitisation of carbon-rich organic precursors which are already in fibre form. The most common precursor is polyacrylonitrile (PAN), because it gives the best carbon fibre properties, but fibres can also be made from pitch or cellulose. Variation of the graphitization process produces either high strength fibres (@ ~2,600°C) or high modulus fibres (@ ~3,000°C) with other types in between. Once formed, the carbon fibre has a surface treatment applied to improve matrix bonding and chemical sizing which serves to protect it during handling.

1.6 NATURAL FIBRE:

Natural fibre, any hair like raw material directly obtainable from an animal, vegetable, or mineral source and convertible into nonwoven fabrics such as felt or paper or, after spinning into yarns, into woven cloth. A natural fibre may be further defined as an agglomeration of cells in which the diameter is negligible in comparison with the length. Although nature abounds in fibrous materials, especially cellulosic types such as cotton, wood, grains, and straw, only a small number can be used for textile products or other industrial purposes. Apart from economic considerations, the usefulness of a fibre for commercial purposes is determined by such properties as length, strength, pliability, elasticity, abrasion resistance, absorbency, and various surface properties.

Natural fibres are broadly classified into two categories – Plant fibres and animal fibres. Examples for both plant fibres and animal fibres have been provided in this subsection.

1.6.1 Plant Fibres

- Seed fibres – the fibres obtained from the seeds of different types of plants.
- Leaf fibres – the natural fibres that can be collected from the leaves of certain plants. Examples include pineapple and banana leaf fibres.
- Fruit fibres – the natural fibres that are obtained from the fruit of a plant (coconut fibre, for example).

- Stalk fibres – the natural fibres that are obtained from the stalks of certain kinds of plants. Examples include the wheat straws, bamboo fibres, fibres obtained from the stalk of rice and barley plants, and straw.
- Bast fibres – the natural fibres that are obtained from the cells belonging to the outer layer of the stem. Examples of bast fibres include jute fibres, flax fibres, vine fibres, industrial hemp fibres, kenaf fibres, rattan fibres, and ramie fibres. It can be noted that these fibres are widely used in fabric and packaging due to their durable nature.

1.6.2 Animal Fibres

Animal fibres are natural fibres which usually contain proteins like fibroin, keratin, and collagen. Common examples on animal fibres are listed below.

- Silk – animal fibres that are obtained from silkworms (different species produce different types of silk).
- Sinew – animal fibre that connects the muscles of certain animals to their bones.
- Wool – animal fibre that is obtained by shearing off the fur of certain breeds of sheep.
- Mohair – animal fibre crafted from the hair of the Angora goat.

1.7 APPLICATIONS OF NATURAL FIBRES

Natural fibers, including certain glass fibres, are widely used in the construction industry in certain construction materials. Such composites (can also be referred to as biocomposites), even when placed in a matrix of synthetic polymers, can still be considered as natural fibres. Cellulose fibre has a wide range of applications spanning over several industries such as the automobile and electronics industry. These natural fibres can be used for insulation and for noise-absorbing panels.

When it comes to industrial value, the four most prominent animal fibres are silk, wool, angora, and camel hair. Many plant fibres also have vital industrial applications. For example, cotton fibre is an integral raw material for the textile industry. Other important plant fibres in industry include hemp fibre, jute fibre, and flax fibre.

Furthermore, natural fibres may have applications in medicine since they can help in the manufacture of biomaterials. For example, the natural fibre Chitin can be used to remove certain toxic pollutants from industrial water discharge.

1.8 PROCESSING ROUTE

Taking composite materials as a whole, there are many different material options to choose from in the areas of resins, fibres and cores, all with their own unique set of properties such as strength, stiffness, toughness, heat resistance, cost, production rate etc.. However, the end properties of a composite part produced from these different materials is not only a function of the individual properties of the resin matrix and fibre (and in sandwich structures, the core as well), but is also a function of the way in which the materials themselves are designed into the part and also the way in which they are processed. This section compares a few of the commonly used composite production methods and presents some of the factors to be borne in mind with each different process, including the influence of each process on materials selection.

1.8.1 SPRAY LAY-UP

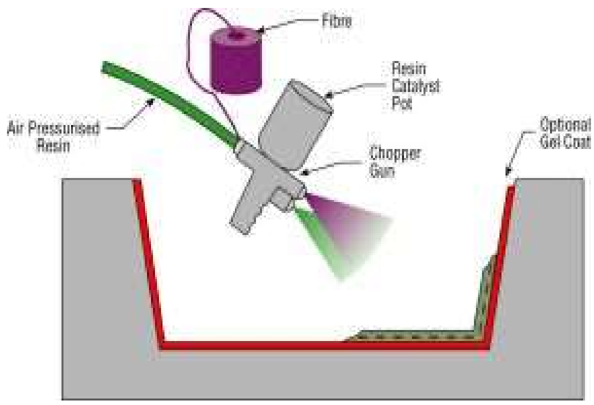


Figure1.4 Spray lay-up process

Description

Fibre is chopped in a hand-held gun and fed into a spray of catalysed resin directed at the mould. The deposited materials are left to cure under standard atmospheric conditions.

Materials options

Resins: Primarily polyester.

Fibres: Glass roving only.

Cores: None. These have to be incorporated separately.

Main advantages

i) Widely used for many years.

ii) Low-cost way of quickly depositing fibre and resin.

iii) Low-cost tooling.

Main disadvantages

i) Laminates tend to be very resin-rich and therefore excessively heavy.

ii) Only short fibres are incorporated which severely limits the mechanical properties of the laminate.

iii) Resins need to be low in viscosity to be sprayable. This generally compromises their mechanical/thermal properties.

iv) The high styrene contents of spray lay-up resins generally means that they have the potential to be more harmful and their lower viscosity means that they have an increased tendency to penetrate clothing etc.

(v) Limiting airborne styrene concentrations to legislated levels is becoming increasingly difficult.

Typical applications

Simple enclosures, lightly loaded structural panels, e.g. caravan bodies, truck fairings, bathtubs, shower trays, some small dinghies.

1.8.2 HAND LAY-UP

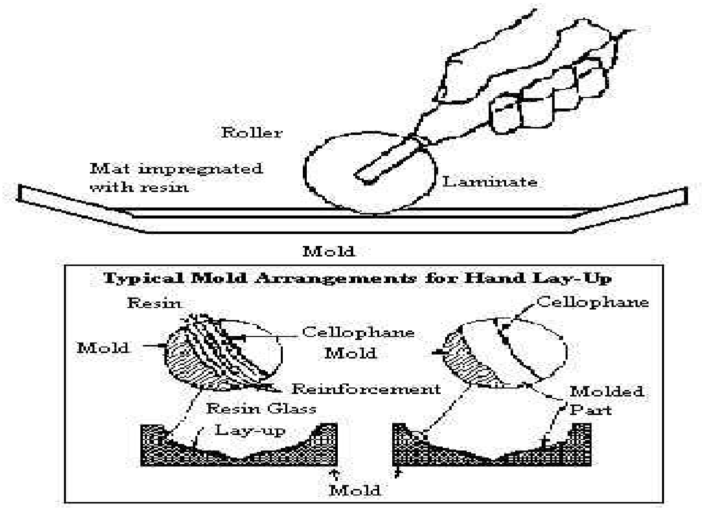


Figure 1.5 Hand lay-up process

Description

Resins are impregnated by hand into fibres which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions.

Materials options

Resins: Any, e.g., epoxy, polyester, vinylester, phenolic.
Fibres: Any, although heavy aramid fabrics can be hard to wet-out by hand.
Cores: Any.

Main advantages

i) Widely used for many years.
ii) Simple principles to teach.
iii) Low cost tooling, if room-temperature cure resins are used.
iv) Wide choice of suppliers and material types.
v) Higher fibre contents, and longer fibres than with spray lay-up.

Main disadvantages

i) Resin mixing, laminate resin contents, and laminate quality are very dependent on the skills of laminators. Low resin content laminates cannot usually be achieved without the incorporation of excessive quantities of voids.

ii) Health and safety considerations of resins. The lower molecular weights of hand lay-up resins generally means that they have the potential to be more harmful than higher molecular weight products. The lower viscosity of the resins also means that they have an increased tendency to penetrate clothing etc.

iii) Limiting airborne styrene concentrations to legislated levels from polyesters and vinylesters is becoming increasingly hard without expensive extraction systems.

iv) Resins need to be low in viscosity to be workable by hand. This generally compromises their mechanical/thermal properties due to the need for high diluent/styrene levels.

Typical applications

Standard wind-turbine blades, production boats, architectural mouldings.

1.8.3 VACUUM BAGGING

Description

This is basically an extension of the wet lay-up process described above where pressure is applied to the laminate once laid-up in order to improve its consolidation. This is achieved by sealing a plastic film over the wet laid-up laminate and onto the tool. The air under the bag is extracted by a vacuum pump and thus up to one atmosphere of pressure can be applied to the laminate to consolidate it.

Materials options

Resins: Primarily epoxy and phenolic. Polyesters and vinylesters may have problems due to excessive extraction of styrene from the resin by the vacuum pump.

Fibres: The consolidation pressures mean that a variety of heavy fabrics can be wet-out.

Cores: Any.

Main advantages

i) Higher fibre content laminates can usually be achieved than with standard wet lay-up techniques.

ii) Lower void contents are achieved than with wet lay-up.

iii) Better fibre wet-out due to pressure and resin flow throughout structural fibres, with excess into bagging materials.

iv) Health and safety: The vacuum bag reduces the amount of volatiles emitted during cure.

Main disadvantages:

i) The extra process adds cost both in labour and in disposable bagging materials

ii) A higher level of skill is required by the operators

iii) Mixing and control of resin content still largely determined by operator skill

iv) Although vacuum bags reduce volatiles, exposure is still higher than infusion or prepreg processing techniques.

Typical Applications:

Large, one-off cruising boats, racecar components, core-bonding in production boats.

Other some important methods are

- Filament Winding
- Pultrusion
- Resin Transfer Moulding (RTM)
- Other Infusion Processes - SCRIMP, RIFT, VARTM etc.
- Autoclave
- Oven
- Resin Film Infusion (RFI)

A lot of work has been carried out on various aspects of polymer composites, but a few researchers have reported on the in-force concept. In view of this, the present work is to investigate the mechanical properties like Tensile, Flexural (compression*) and Impact Strength of glass fiber epoxy laminate with and without Aluminum alloy.

CHAPTER 2
LITERATURE REVIEW

Dipen Kumar Rajak et al (2019) carried out a research on Fiber-Reinforced Polymer Composites. Composites are the most promising and discerning material accessible in this century, according to his studies. Fiber-reinforced polymer composites have outstanding qualities such as high durability, stiffness, damping property, flexural strength, and resistance to corrosion, wear, impact, and fire, in addition to high strength to weight ratio. Composite materials have found uses in mechanical, construction, aerospace, car, biomedical, marine, and many other production industries due to their vast variety of different properties. This study shows that the performance of composite materials is largely determined by their constituent elements and manufacturing techniques. As a result, the functional properties of various fibres available worldwide, their classifications, and the manufacturing techniques used to fabricate composite materials must be investigated in order to determine the material's optimal characteristic for the desired application. This study illustrates why fiber-reinforced composite materials are a promising alternative to solo metals or alloys due to their remarkable performance in a wide range of applications.

Yefa Hu et al (2015) conducted a research on carbon fiber–reinforced plastic bumper beam subjected to low-velocity frontal impact. In this research paper lightweight and safety performance of automobiles are two important factors for automobile designs. In this article, a research on lightweight and crashworthiness of automotive bumper has been conducted. The carbon fiber-reinforced plastic bumper beam is considered to replace the traditional high-strength steel one. The low-velocity impact finite element simulations for the above two bumper beams are performed via LS-DYNA. Furthermore, the energy absorption capabilities and dynamic response characteristics of the carbon fiber-reinforced plastic bumper beam are investigated and compared with the steel one. The results show that the carbon fiber-reinforced plastic bumper beam is of the better energy absorption capabilities and dynamic response characteristics than those of the steel one; the weight has decreased remarkably close to 50%. Meanwhile, the effect of lay-up and wall thickness on the crashworthiness of the carbon fiber-reinforced plastic bumper beam under low-velocity impact is also studied in this article to select appropriate design schemes.

E. S. Roopesh et al (2015) conducted a research on Design and Analysis of an Automotive Frontal Bumper Beam for Low-Speed Crashes. In this research paper**,** low-velocity impact test, the main parameters like material, shape, thickness and impact conditions are considered generally for modeling and analysis of an automobile bumper for better crashworthiness. Analysis of bumper beam under the conditions of impact is considered to the respective low-velocity standards of automotive. The crash analysis is performed on bumper by considering aluminum and composite materials in order to compare the deflection and Von-mises stresses in order to know the behavior of impact. In maximum deflection situation, under the elastic mode the strength is investigated with impact force and energy absorption. This research gives us designing a bumper beam of automotive should be good enough in order to provide the safety of passengers, which should also be of low weight to improve the efficiency of the passenger car. Apart from the safety factor, gas emission and fuel efficiency regulations are also considered importantly which gives the advantage to the manufacturer in weight reduction of automotive.

R. Szlosarek et al (2016) performed a research on Development of carbon fibre-reinforced plastic (CFRP) crash absorbers with stable crushing behavior considering the connection to the bumper system. In this research crash absorbers made of fiber-reinforced plastics becoming more and more popular to reduce the mass in the front section of cars. Various research projects analyzed the high specific energy absorption and the stable crushing behavior of this material, however without examining the connection to other car body components. This paper focuses on the connection of the crash absorbers to the bumper system, particularly regarding to the crushing behavior. An initial step focused on the development of a crash absorber made of carbon-fiber-reinforced plastic, which shows similar energy absorption compared to absorbers made of aluminum. This research studies on the crash absorbers made of carbon fiber reinforced plastic are becoming increasingly popular to reduce the mass in the front end of automobiles. For this reason, various research projects dealt with the high specific energy absorption and the stable compression behavior of this material, but neglecting the connection to other vehicle components. This article deals with the connection to the bumper system, especially with regard to the compression behavior.

Beesu Supriya et al (2021) carried out a research on static, modal and impact analysis of car bumper using varied parameters. In this research car bumpers can absorb the impact energy with deformation. A Benz car bumper was utilized for static and modal analysis. The different bumper materials used for this analysis were Polypropylene (PP), Polyurethane (PUR) and Poly-Vinyl-Chloride (PVC). 3-D modeling was carried out with the help of CATIA software. Static and impact analysis were performed to calculate the deformation and stress induced in the car bumper at different vehicle speeds (45, 60 & 75 km/hr). Modal evaluation was carried out to estimate the frequency and deformation for mode shapes. In this research the finite element analysis of car bumper was carried out by means of Solid Works software. It was inferred from the static analysis that both the deformation and stresses increase with an increase in the car speed from 45 km/hr to 75 km/hr. The deformation and stress in the car bumper for all the materials were maximum at a car speed of 75 km/hr. From the static analysis, it was observed that the stress values for PP material were less when compared to PVC and PUR material at all vehicle speeds. It was concluded that PP is the optimum material for manufacturing the car bumper based on the static, modal and impact analysis.

Roham Rafiee et al (2019) administered a research on Theoretical and numerical analyses of composite cylinders subjected to the low velocity impact. The main objective of this research is to develop a theoretical solution for predicting the low-velocity impact induced failure in composite cylinders. Observing both in-plane and out-of-plane impact induced failure modes in composite cylinders is demanded of determining all components of the stress and strain fields. Thus, it is necessary to exploit the appropriate theory for this purpose. Layer-wise theory is employed to develop a theoretical solution for extracting stress/strain components in a composite cylinder subjected to low-velocity. Then, proper failure criteria are employed to predict the failure caused by impact. Finally, finite element modeling is performed to analyze the low-velocity impact in composite cylinders. Comparing the results, it is revealed that developed theoretical solution is more accurate than finite element modeling.

S.Jayavani et al (2015) directed a research on recent development and future trends in coir fiber-reinforced green polymer composites. In this research the development of natural fiber composites with thermoplastics and thermosets finds applications in various fields, from agriculture to automotive. It can reduce the dependency on petroleum resources which causes several environmental problems. Natural fibers are renewable and biodegradable that reduces carbon footprint to the environment. Coir fibers are natural fibers used in the development of composites offers comparable properties with other mineral fillers. This article reviews different methods of coir fiber modification include alkali treatment, silane treatment, hydrogen peroxide treatment, sodium hypochlorite treatment, sodium periodate treatment coupled with *p*-aminophenol and urea, treatment with benzene diazonium salt and maleated coupling agent. It also reviews composites of coir fiber with thermoplastic, rubber and thermoset plastics. In this research paper hybrid composites based on coir fiber are also being discussed. Thermoplastic composites such as biodegradable (PLA, PBS) and petroleum-based polymers (PE, PP) and thermoset polymers include polyurethane, epoxy and polyester-based composites also reviewed. Degradation and biodegradation studies were reviewed in the case of biodegradable polymers. Hybrid fibers of coir with other natural and mineral fibers have recently been used in composite industry has also been reviewed. All these composites show better properties. It can be used in different applications in the field of automobile, building and construction, consumer products and furniture.

Dr.M.Athimoolam et al (2020) carried out a research Potentiality of Nano Filler/Natural Fiber Filled Polymer Hybrid Composites. In this research, the increasing demand for greener and biodegradable materials leading to the satisfaction of society requires a compelling towards the advancement of nano-materials science. The polymeric matrix materials with suitable and proper filler, better filler/matrix interaction together with advanced and new methods or approaches are able to develop polymeric composites which show great prospective applications in constructions and buildings, automotive, aerospace and packaging industries. This research gives us the biodegradability of the natural fibers is considered as the most important and interesting aspects of their utilization in polymeric materials. Nanocomposite shows considerable applications in different fields because of larger surface area, and greater aspect ratio, with fascinating properties. Being environmentally friendly, applications of nanocomposites offer new technology and business opportunities for several sectors, such as aerospace, automotive, electronics, and biotechnology industries. This research article intended to present information about diverse classes of natural fibers, nanofiller, cellulosic fiber based composite, nanocomposite, and natural fiber/nanofiller-based hybrid composite with specific concern to their applications. It will also provide summary of the emerging new aspects of nanotechnology for development of hybrid composites for the sustainable and greener environment.

Adesina et al (2019) conducted a research on Analysis of alternate Hybrid Natural fibre composites for Automobile Bumper Applications. In this research paper the conservation of natural resources, reducing the usage of energy and weight reduction has become the main aim of the automobile industries nowadays. In this research paper Industries invested in Research and development for replacing conventional high weight steel material with alternate materials. So the objective is to fabricate Epoxy resin based Kevlar-Jute hybrid composites and to determine the properties of these composites. The analysis results showed that the developed composite material properties improved by the reinforcement of Kevlar and jute fibers in the resulting hybrid composites. Results indicate that increase in the percentage of Kevlar reinforcement lowers the percentage of epoxy, which leads to cost reduction in the developed composites.

Zahra Dashtizadeh et al (2019) coordinated a research on Mechanical evaluation of hybrid natural fibre–reinforced polymeric composites for automotive bumper beam. In this research paper the use of lightweight materials in the automobile is one of the possible ways to achieve fuel efficiency demand and reduce the environmental pollution from greenhouse gases created *via* the automotive industry. The numerous advantages of natural fibre, such as low density, recyclability, biodegradability, relative ease of availability and low cost have brought it to spotlight for a variety of automotive applications. This article expounds the use of natural fibres and its hybrid as reinforcement in a synthetic polymer matrix for automotive polymer bumper beam material. The various attempts by researchers in their consideration and selection of high-performing materials for the development of automotive composite bumper beam were presented. Possible modifications employed to improve the relevance of natural fibre for this application over synthetic fibre were also considered. Lower impact properties were deduced from the mechanical evaluation of the various researches using hybrid natural fibre as a major limitation when compared with the conventional glass mat thermoplastics and the long fibre–reinforced thermoplastics used as typical bumper beam material.

Do-HyoungKim et al (2015) performed a research on Mechanical and Thermal Properties of Natural Fibre Based Hybrid Composites. This research paper explains Environmental issues that motivated researchers to replace synthetic fibres with natural fibres in the fabrication of polymer composites. However, natural fibres demonstrate weak mechanical or thermal properties which limit their different applications. Researchers have suggested fabrication of hybrid composites in order to improve the mechanical and thermal properties of natural fibre-based composites. Hybrid composites are made up by two or more fibres in one matrix or two polymer blends and with one natural fibre reinforcement. By hybridising one natural fibre with another natural fibre/synthetic fibre in one matrix, the resulting composite is a unique product (hybrid composites) that displays better mechanical and thermal properties in comparison with individual fibre-reinforced polymer composites. The advantages of developing hybrid composites are that they are more reliable for different applications and more environmental friendly. In this review paper, we present some recently published works related to mechanical and thermal properties of natural/natural fibres, and natural/synthetic fibre-based hybrid composites.

M.M.Davoodi et al (2010) carried out a research on Design optimization and manufacture of hybrid glass/carbon fiber reinforced composite bumper beam for automobile vehicle. In this study, the hybrid glass/carbon composite bumper beam was designed and manufactured via the design optimization process combined with the impact analysis. The glass/carbon mat thermoplastic (GCMT) composite was devised to substitute for the conventional glass mat thermoplastic (GMT) for reducing the weight of bumper beam. For the design optimization, the mechanical properties of GCMT were predicted and the optimal design of bumper beam was performed with the impact simulation. Based on the final design, the real bumper beam was manufactured and its impact performances were measured. It was found that the optimally designed GCMT bumper beam had 33% less weight compared to the conventional GMT bumper beam while having the improved impact performances.

S.M.Sapuan et al (2011) performed a research on Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam. In this research paper it is estimated that the annual world car production rate will reach 76 million vehicles per year by 2020. New regulations such as the EU End of Life Vehicles (ELV) regulations are forcing car manufacturers to consider the environmental impact of their production and possibly shift from the use of synthetic materials to the use of agro-based materials. Poor mechanical properties and certain manufacturing limitations currently limit the use of agro-based materials to non-structural and semi-structural automotive components. The hybridization of natural fiber with glass fiber provides a method to improve the mechanical properties over natural fibers alone. This research is focused on a hybrid of kenaf/glass fiber to enhance the desired mechanical properties for car bumper beams as automotive structural components with modified sheet molding compound (SMC). A specimen without any modifier is tested and compared with a typical bumper beam material called glass mat thermoplastic (GMT). The results indicate that some mechanical properties such as tensile strength, Young's modulus, flexural strength and flexural modulus are similar to GMT, but impact strength is still low, and shows the potential for utilization of hybrid natural fiber in some car structural components such as bumper beams.

J. O. Agunsoye et al (2019) conducted a research on concept selection of car bumper beam with developed hybrid bio-composite material. In this research paper the application of natural fibre composites is going to increase in different areas caused by environmental, technical and economic advantages. However, their low mechanical properties have limited their particular application in automotive structural components. Hybridizations with other reinforcements or matrices can improve mechanical properties of natural fibre composite. Moreover, geometric optimizations have a significant role in structural strength improvement. This study focused on selecting the best geometrical bumper beam concept to fulfill the safety parameters of the defined product design specification (PDS). The mechanical properties of developed hybrid composite material were considered in different bumper beam concepts with the same frontal curvature, thickness, and overall dimensions. Topsis method was employed to select the best concept. It is concluded that double hat profile (DHP) with defined material model can be used for bumper beam of a small car. In addition, selected concept can be strengthened by adding reinforced ribs or increasing the thickness of the bumper beam to comply with the defined PDS.

Akinlabi O. David et al (2021) administered a research of Novel epoxy-carbonized coconut shell nanoparticles composites for car bumper application. In this research paper the structure and mechanical properties of carbonized coconut shell nanoparticles (CSnp) reinforced epoxy composite have been evaluated to establish the possibility of using the composite as a new material for automobile car bumper application. Epoxy resin of the type LY556 was blended together with CSnp at 5–25 wt%. Scanning electron microscopy (SEM), mechanical test, and thermogravimetric analysis (TGA) were examined. SEM morphology reveals adhesion between CSnp and polymer matrix at low wt%CSnp while at higher weight percent of CSnp agglomeration of CSnp was observed. The addition of CSnp at 25 wt% produced the optimal hardness values of 26.35 VHN, tensile stress of 338.75 MPa, and flexural strength of 156 MPa, while at 10 wt% CSnp produced optimal impact energy value of 5.71 J. The developed epoxy composite when compared with two existing Toyota models showed improved impact energy at break of 10.5% over Big Daddy Model and 37.45% over Carina model under the same testing conditions.

Mohd Nizam Suddin et al (2004) carried out a research on Development and characterization of hybrid coconut/glass fibers reinforced low density polyethylene composites for bumper application. The EU's End of Life Vehicles (ELV) regulations are forcing car manufacturers to consider the environmental impact of their production and possibly shift from the use of synthetic materials to the use of agro-based materials. However, poor mechanical properties and certain manufacturing limitations currently limit the use of agro-based materials to non-structural and semi-structural automotive components. This research is focused on a composite of hybrid coconut/glass fiber as reinforcement in recycled low density polyethylene matrix alone to enhance the desired mechanical properties for car bumper as automotive structural components. X-ray fluorescence analysis conducted on coconut fiber showed the presence of silica and alumina materials make coconut fibre a choice one. Morphology analysis was performed using scanning electron microscopy (SEM), which reveals that there are small discontinuities and reasonably uniform distribution of the reinforcement fibers and the reinforced low density polyethylene (RLDPE) binder resulting to better mechanical properties. The study shows the successful development of composites of coconut fiber (CF) hybridized with glass fiber (GF) and reinforced low density polyethylene (RLDPE) binder using a simple molding technique.

Hybridized samples (CF-GF/RLDPE) showed higher strength when compared to un-hybridized (CF/RLDPE) composites. Better microstructural bonding exists with 25% and 30% wt CF-GF composite resulting in good mechanical properties for the hybridized composites. The grades of composites obtained in the course of this study are applicable in the production of low strength car bumpers.

Mohd Sapuan Salit et al (2005) administered a research on total design of polymer composite automotive bumper fascia. In this research paper an automobile bumper fascia is a component, which contributes to vehicle crashworthiness during front or rear collisions. In the past, the fascia was made of plastic materials. In this paper, the bumper fascia made of polymeric based composite material was designed with solid modeling software. The polymeric based composite material was selected because of low weight, high specific stiffness, high specific strength, high-energy absorption and easy to produce in complex shapes. Four conceptual designs of a bumper fascia were developed with a 3-D solid model. The weight of the bumper fascia was obtained through weight analysis that had been carried out using Pro/Engineer software. The fascia was successfully designed with less weight compared to the current fascia.

Adesina, O. T et al (2019) coordinated a research on Application of Glass Fibre Reinforced Composite in the Production of Light Weight Car Bumper**.** In this research paper the use of lightweight materials in the automobile is one of the possible ways to achieve fuel efficiency demand and reduce the environmental pollution from greenhouse gases created via the automotive industry. The numerous advantages of natural fibre, such as low density, recyclability, biodegradability, relative ease of availability and low cost have brought it to spotlight for a variety of automotive applications. This article expounds the use of natural fibres and its hybrid as reinforcement in a synthetic polymer matrix for automotive polymer bumper beam material. The various attempts by researchers in their consideration and selection of high-performing materials for the development of automotive composite bumper beam were presented. Possible modifications employed to improve the relevance of natural fibre for this application over synthetic fibre were also considered. Lower impact properties were deduced from the mechanical evaluation of the various researches using hybrid natural fibre as a major limitation when compared with the conventional glass mat thermoplastics and the long fibre–reinforced thermoplastics used as typical bumper beam material. The use of various modifiers as tougheners has not been able to achieve comparable strength with GMT and LFRT. However, the need for nanobiocomposite should be explored for possible improvement on the impact properties in this area of application.

Hussain Ahmad Ural et al (2020) conducted a research on carbon fiber materials in automotive industry. In this research light weighting becomes a main issue for energy efficiency in automotive industry. The emission of gases and fuel efficiency of vehicles are two important issues. The best way to improve the fuel efficiency is to decrease the weight of vehicle parts. Research and development played an important role in lightweight materials for decreasing cost, increasing ability to be recycled, enabling their integration into vehicles, and maximizing their fuel economy efficacy. There arises a need for developing a novel generation of materials that will combine both weight reduction and safety issues. The application of carbon fibre reinforced plastic material offers the best lightweight potential to realize lightweight concepts. Carbon fibre reinforced plastic has outstanding specific stiffness, specific strength, and fatigue properties compared to commonly used metals. In automotive industry, the advantages of carbon fibre reinforced plastic are reduction in weight, part integration and reduction, crashworthiness, durability, toughness, and aesthetic appealing. Carbon fibre reinforced plastic is a composite material that has been used extensively in various applications such as aerospace industry, sports equipment, oil and gas industry, and automotive industry. Keeping in view the aforementioned advantages of carbon fibre reinforced plastic, the authors have presented a brief review on carbon fibre for automotive industrial applications.

Hai Nguyen et al (2017) carried out a research on Hybrid polymer composites for structural applications. In this research paper the Hybrid composites have unique features that can be used to meet specified design requirements in a more cost-effective way than nonhybrid composites. They offer many advantages over conventional composites including balanced strength and stiffness, enhanced bending and membrane mechanical properties, balanced thermal distortion stability, improved fatigue/impact resistance, improved fracture toughness and/or crack arresting properties, reduced weight and/or cost, and reduced notch sensitivity. “Synergistic” effect of hybrid composites has attracted the interest of researchers worldwide. This chapter reviews recent structural applications of hybrid composites for various sectors such as aerospace, automobile, civil engineering, energy, marine, sport, and telecommunication. The development and applications of innovative hybrid FRP–concrete composite structural system for civil infrastructure (e.g., highway bridge decks, girders, columns, and piles) are emphasized.

Christopher D. Eamon et al (2018) administered a research on Design and Construction Guidelines for Strengthening Bridges using Fiber Reinforced Polymers (FRP). This research concerns the development of guidelines for the design and use of externally-bonded FRP strengthening systems on bridges in Michigan. Six representative international FRP-related guidelines were analyzed and compared for applicability and effectiveness to MDOT needs. An experimental program involving natural and accelerated laboratory weathering was conducted to determine acceleration factors appropriate for the climate of Michigan. Bond pull-off and other specimen tests were used to establish rates of strength degradation, and an environmental reduction factor was estimated from these results. From the review of the existing guidelines as well as the test results, recommendations for design as well as installation, quality control, inspection, maintenance and repair were proposed that are based on modifications to as well as a synthesis of existing provisions.

2.1 FINDINGS OF LITERATURE REVIEW

The above-mentioned literature can be summarized in the following way: -

a. There are few studies reporting about the work done related to improvement in the design of front bumper of passenger car.

b. The applicability of these studies for passenger cars (India) is not validated

c. Present studies have not identified the effect of shape, size and or material

d. The safety of the passenger needs to be increased.

The literature does not address the impact analysis of the passenger cars considering the shape, material and size for the Indian cars.

CHAPTER 3
RESEARCH GAP

Car manufacturers use steel and variety of plastics to make bumpers. The most common include polycarbonates, polypropylene, polyamides, polyesters, polyurethanes, and thermoplastic olefins or TPOs. Manufacturers mix these plastics with glass fibers or other materials to strengthen the bumper. Carbon fibers have been extensively used research and in racing to reduce weight and increase performance of the vehicle.

Incorporation of carbon fiber in daily use vehicles is very expensive and practically impossible; therefore, other alternatives to carbon fiber have to test for their effectiveness. This design and analysis project mainly focuses on pedestrian safety and also reducing the overall cost of the bumpers. Polyester which has been proven to be effective in transferring the load and reducing the impact time was chosen as the matrix.

Coconut coir, cheap to obtain and also environmentally green to produce and procure was chosen as the reinforcement to receive the transferred load and withstand the load during impact or crash to reduce the fatality. To increase the efficiency of the reinforcement, E-glass fiber was chosen as the addition to the reinforcement, due to ease of attainment, high load withstanding capacity and high impact strength properties. The combination of E-Glass Fiber and Coconut Coir was selected as the hybrid composite to enhance the efficiency and to supplement the plastic matrix.

CHAPTER 4
OBJECTIVES

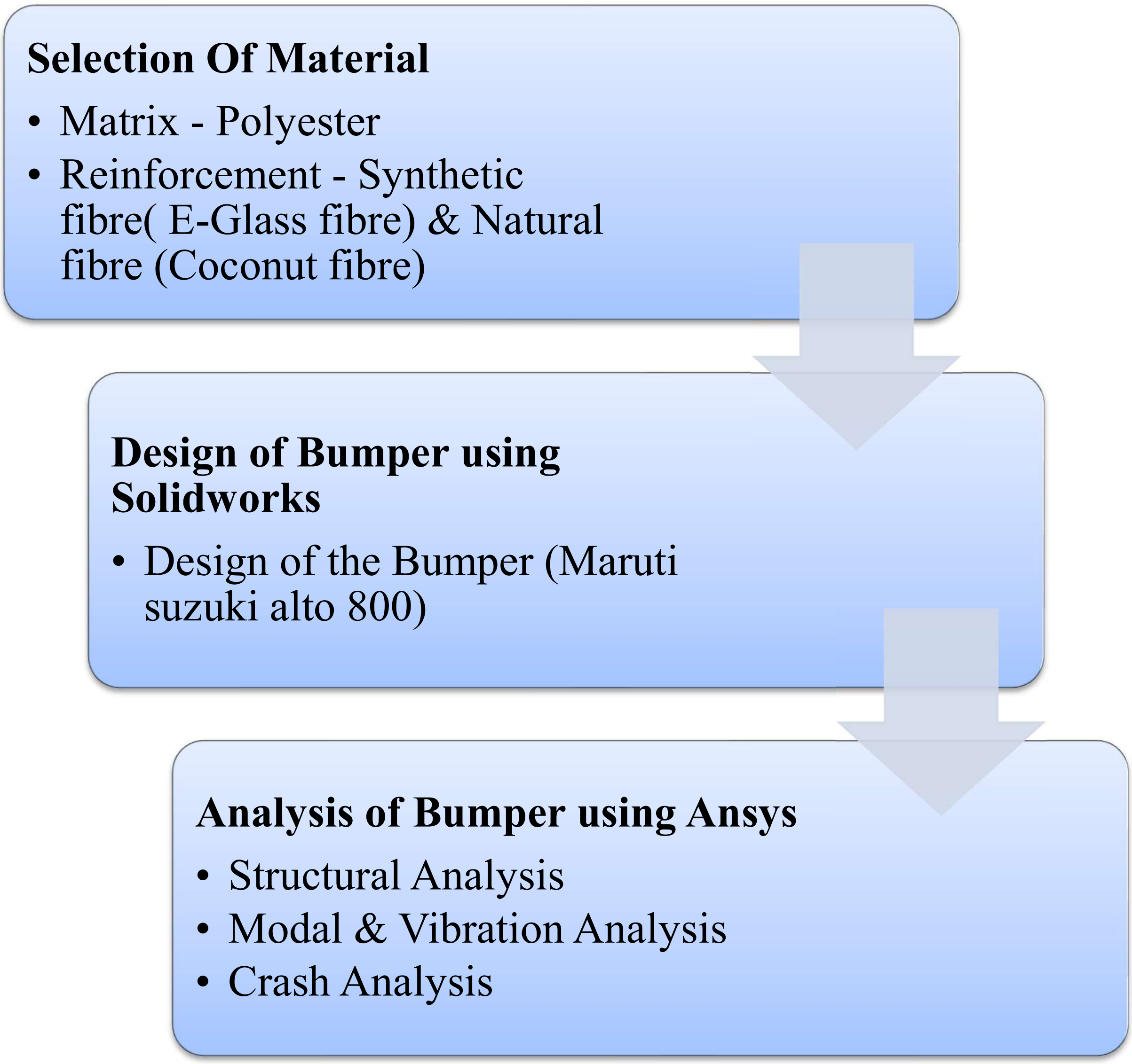
To investigate Maruti Suzuki Alto 800 bumper made of hybrid composites, using Polyester as the matrix and E-Glass Fibre and Coconut Coir as the reinforcements.

To design the bumper using SolidWorks.

To perform structural, modal and crash analyses on the hybrid composite material bumper and compare the results with the existing bumper.

CHAPTER 5

METHODOLOGY



CHAPTER 6
MATERIALS AND METHODS

This chapter describes the materials and methods used for the processing of the composites under this investigation. It presents the details of the characterization and tests which the composite samples are subjected to.

6.1 BUMPER

The bumper is a safety system is used to observe the low-speed collision. It is placed in car body. The car bumper is designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles in low-speed collisions. Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars. Bumpers are designed to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low-speed collisions. The national highway traffic safety administration (NHTSA) produces some bumper standard to the light passenger vehicle. The bumper standard, prescribes performance requirements for passenger cars in low-speed front and rear collisions. It applies to front and rear bumpers on passenger cars to prevent the damage to the car body and safety related equipment. The bumper standards are,

- The front and rear bumpers on passenger cars should prevent the damage to the car body.
- Bumper should withstand at a speed of 2 mph across the full width and 1 mph on the corners.
- Bumper should also withstand 5 mph crash into a parked vehicle.
- Placement of the bumper is 16 to 20 inches above the road surface.

So, all bumpers should satisfy the above standards.

Requirements of Bumper Material

- It should absorb more energy while collision.
- It should have good rust resistance.
- It should have high strength.
- Light in weight.
- Easy to manufacture in large quantity.
- Low cost.

6.2 COMPOSITE MATERIAL

In recent days, various materials like composites are experimented in almost all parts of the automobiles and it has also ventured into bumper. Due to reduction in weight, composite materials are preferred over conventional steel bumper. Composite bumper absorbs more collusion energy than steel bumper.

Advantages of Composite Material:

One of the most advantageous reasons for considering their use over steel is their reduced weight.

- Absorb more collision energy.
- Excellent corrosion resistance.
- High impact strength.
- Material properties of composite bumper allow rapid response to induced or release stress.

6.3 POLYMER MATRIX SELECTION:

The Polymer matrix that has been chosen for the design and experimental analysis of hybrid composites for automotive application is Polyester.

Polyester is often used for pipes, tanks and high-performance components in the marine and automotive industries. Although it is the most commonly used resin due to the ease of manufacture which matches that of Vinyl ester resin, it is very cheap, but with limited structural properties it is not suitable for use when high structural properties are required, or when use is required in extreme temperature conditions. Due to the unsaturated nature (lots of double bonds, specifically ester groups) of this composite the tensile strength of it is greatly reduced when compared with Vinyl ester or Epoxy resins. Polyester also bonds with water throughout its lifetime, gaining weight within the first few days from manufacture, which is from absorption of water reacting with the double bonds on the backbone chain structure of the resin, and then losing weight slowly as the polymer is broken down, leached out of the composite, which is in turn replaced with water. This decreases the strength of the material. Even with Polyester resin reacting to water in this way, for non-structural work such as coating a boat hull, many marinas use Polyester instead of Vinyl ester resins due to the cheap cost and a faster curing time leading to quick turnover makes Polyester much more favorable.

6.4 SYNTHETIC FIBRE:

The Synthetic fibre composite that has been chosen for the design and experimental analysis of hybrid composites for automotive application is E-glass fibre. **E-glass fibre** has been in use since 1930, in large-scale industrial applications, as a high-temperature insulator for electrical conductors this high-quality fibre is distinguished by its resistance to high temperatures and its excellent electrical insulating properties. This fibre is rot-proof, resistant to the most common chemical agents and dimensionally stable, even if substantial variations in humidity and temperature.

E-glass fibre products are particularly resistant to abrasion and vibration and have excellent flexibility. The glass thread has a higher specific resistance (tensile strength/volumetric mass) than that of steel. This feature makes it possible to develop glass threads that reinforce high-performance composites.

E-glass fibre has low **thermal conductivity**. For felt, for example, conductivity is 0.03 $W.m^{-1}.K^{-1}$. The fibre can withstand temperatures of over 600 °C and is non-combustible. Fibrous E-glass products are resistant to oils, solvents and most chemical agents. They are also rot-proof. It has excellent **electrical insulation properties**, even at low thickness. Glass thread E-Fibers are inorganic, have good resistance to abrasion and are incombustible. In addition, they have excellent dielectric strength and are compatible with organic dyes.

Figure 6.1.E-Glass Fibre

E-Glass Fibers have seen various applications in varied industries in the past decade; E-Glass Fibers have seen abundant application in electrical insulation, thermal insulation and also various reinforcements. They are actively being used for door seals, protection of cables, sheaths and pipes and insulation of the same.

Glass Fibers have seen increase in the usage for automotive and aeronautical applications; these fibers are used in interior of cars, moldings for fabrication of door seals, front and rear panels of cars and commercial vehicles. E-Glass fibers can be designed in various forms like threads, packing, ropes, braided ropes, felts and sleeves which are then laminated.

6.5. NATURAL FIBRE SELECTION

The Natural fiber chosen with E-Glass Synthetic Fiber was Coconut Coir. Coconut Coir, a natural fiber, strong and lightweight, abundantly available in India and South-East Asian countries, is the choice to produce polymer composites. Due to higher specific modulus and durability, these composites find usage in almost all industries. Various mechanical properties such as tensile, flexural, compressive and impact strength can be tested to compare and contrast the characteristics of this chosen reinforcement with other reinforcements for hybrid composites. Coconut coir shows good matrix binding and less fiber pull out compared to other reinforcements available.

Hybrid composites have better robust properties than independent matrix form or reinforcement. This makes hybrid composites better choices of usage for bumpers as they are cost effective, have base materials easily available and easy to replace and manufacture as well.

Figure.6.2. Coconut coir

In general, bumpers are made of conventional materials such as mild steel, plastic, cast iron, and stainless steel. Hybrid Composite materials and alloys are employed to make the bumper lightweight. These have a high strength-to-weight ratio, are rigid, and are corrosive-free. In this work, to analyze the bumper model, the existing bumper material (PP+EPM-TD15) and hybrid Composite material (Polyester, E glass-fibre and Coconut coir) are used. In this work, the ratio of hybrid composite material is taken as Polyester-70%, E glass fiber-15% and Coconut coir-15%. Table 2 provides the data of mechanical properties of Existing Material (PP+EPM-TD15) and Hybrid Composite material (Polyester, E glass-fibre and Coconut coir).

Table 6.1. Description for Existing and Hybrid Composite Bumper

DESCRIPTION	PP+EPM-TD15	Polyester	E glass-Fibre	Coconut coir
Density (kg/m^3)	1050	1100	1450	1250
Youngs Modulus (N/mm^2)	2250	920	72000	633
Poissons Ratio	0.36	0.36	0.38	0.375

CHAPTER 7
DESIGN

7.1 AUTOMOTIVE BUMPER MEASUREMENTS

The geometrical and structural parameters of the Maruti Suzuki Alto 800 bumper are as follows: the bumper's length is 1394 mm, thickness is 4 mm, and the total breath is 431 mm. The mechanical parameters of PP+EPM-TD15, the existing bumper material employed in this study, include density of 1050 kg/m3, Poisson ratio of 0.36, and finally young's modulus of 2.25 GPa. The weight of the Existing material bumper is determined using known geometrical and mechanical qualities, and it is 1.5 kg.

Figure 7.1 Side view

Figure 7.2 Front view

7.2. BUMPER'S CONCEPTUAL DESIGN

For designing the composite bumper an already existing Maruti Suzuki Alto 800 bumper is used as mould. Dimensions are assumed as same as that of Maruti Suzuki Alto 800 bumper for fabrication. Figures 7.3 and 7.4 depict the fundamental viewpoints of the three-dimensional bumper. With the help of Solidworks, the Maruti Suzuki Alto 800's bumper design is completely modelled.

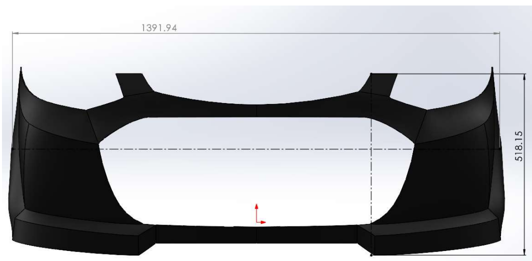


Figure 7.3 Front View

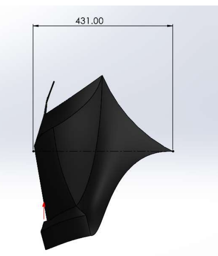


Figure 7.4 Side View

The 3d modelling of the bumper was designed using solidworks, the dimensions were taken from the existing bumper, and with the help of “spline” command we could replicate the model. The model was split into entities to develop as whole and for each entity “surface” command was used to define the surface of the model. After completion of sketch, we used the “thicken” command to give thickness to the model. all entities were then merged into one and “mirror” command was used to mirror the model.

7.3. MESHING

A mesh is a representation of a larger geometric domain by smaller discrete cells. Meshes are commonly used to compute solutions of partial differential equations and render computer graphics, and to analyze geographical and cartographic data. A mesh partitions space into *elements* (or *cells* or *zones*) over which the equations can be solved, which then approximates the solution over the larger domain. Element boundaries may be constrained to lie on internal or external boundaries within a model. Higher-quality (better-shaped) elements have better numerical properties, where what constitutes a "better" element depends on the general governing equations and the particular solution to the model instance.

7.3.1 Three-dimensional

Basic three-dimensional cell shapes

The basic 3-dimensional element are the tetrahedron, quadrilateral pyramid, triangular prism, and hexahedron. They all have triangular and quadrilateral faces. Extruded 2-dimensional models may be represented entirely by the prisms and hexahedra as extruded triangles and quadrilaterals.

In general, quadrilateral faces in 3-dimensions may not be perfectly planar. A nonplanar quadrilateral face can be considered a thin tetrahedral volume that is shared by two neighboring elements.

Tetrahedron

A tetrahedron has 4 vertices, 6 edges, and is bounded by 4 triangular faces. In most cases a tetrahedral volume mesh can be generated automatically.

Pyramid

A quadrilateral-based pyramid has 5 vertices, 8 edges, bounded by 4 triangular and 1 quadrilateral face. These are effectively used as transition elements between square and triangular faced elements and other in hybrid meshes and grids.

Triangular prism

A triangular prism has 6 vertices, 9 edges, bounded by 2 triangular and 3 quadrilateral faces. The advantage with this type of layer is that it resolves boundary layer efficiently.

Hexahedron

A hexahedron, a topological cube, has 8 vertices, 12 edges, bounded by 6 quadrilateral faces. It is also called a hex or a brick. For the same cell amount, the accuracy of solutions in hexahedral meshes is the highest.

7.3.2 Mesh Quality

A mesh is considered to have higher quality if a more accurate solution is calculated more quickly. Accuracy and speed are in tension. Decreasing the mesh size always increases the accuracy but also increases computational cost.

Accuracy depends on both discretization error and solution error. For discretization error, a given mesh is a discrete approximation of the space, and so can only provide an approximate solution, even when equations are solved exactly. (In computer graphics ray tracing, the number of rays fired is another source of discretization error.) For solution error, for PDEs many iterations over the entire mesh are required. The calculation is terminated early, before the equations are solved exactly. The choice of mesh element type affects both discretization and solution error.

Accuracy depends on both the total number of elements, and the shape of individual elements. The speed of each iteration grows (linearly) with the number of elements, and the number of iterations needed depends on the local solution value and gradient compared to the shape and size of local elements.

7.4 Mesh of the car bumper

The fine uniform tetra mesh was constructed with the help of proximity and curvature set-up in the discretized model of the bumper shown in figure 7.5. Table 7.1 lists and checks the details of the sub components of the mesh model.

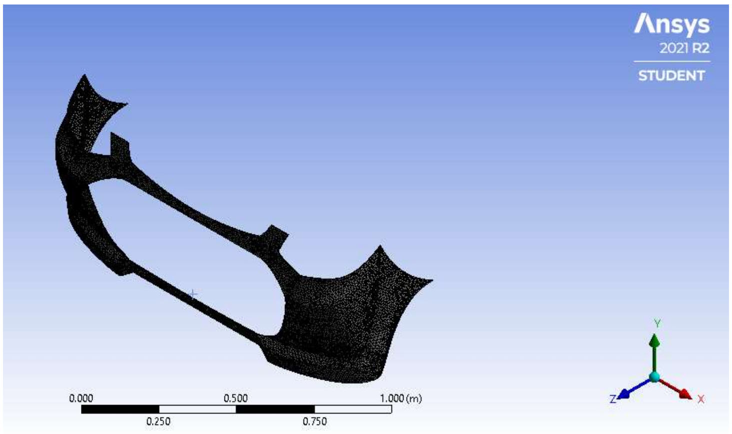


Figure 7.5. Mesh of Car Bumper

Table 7.1. Mesh details

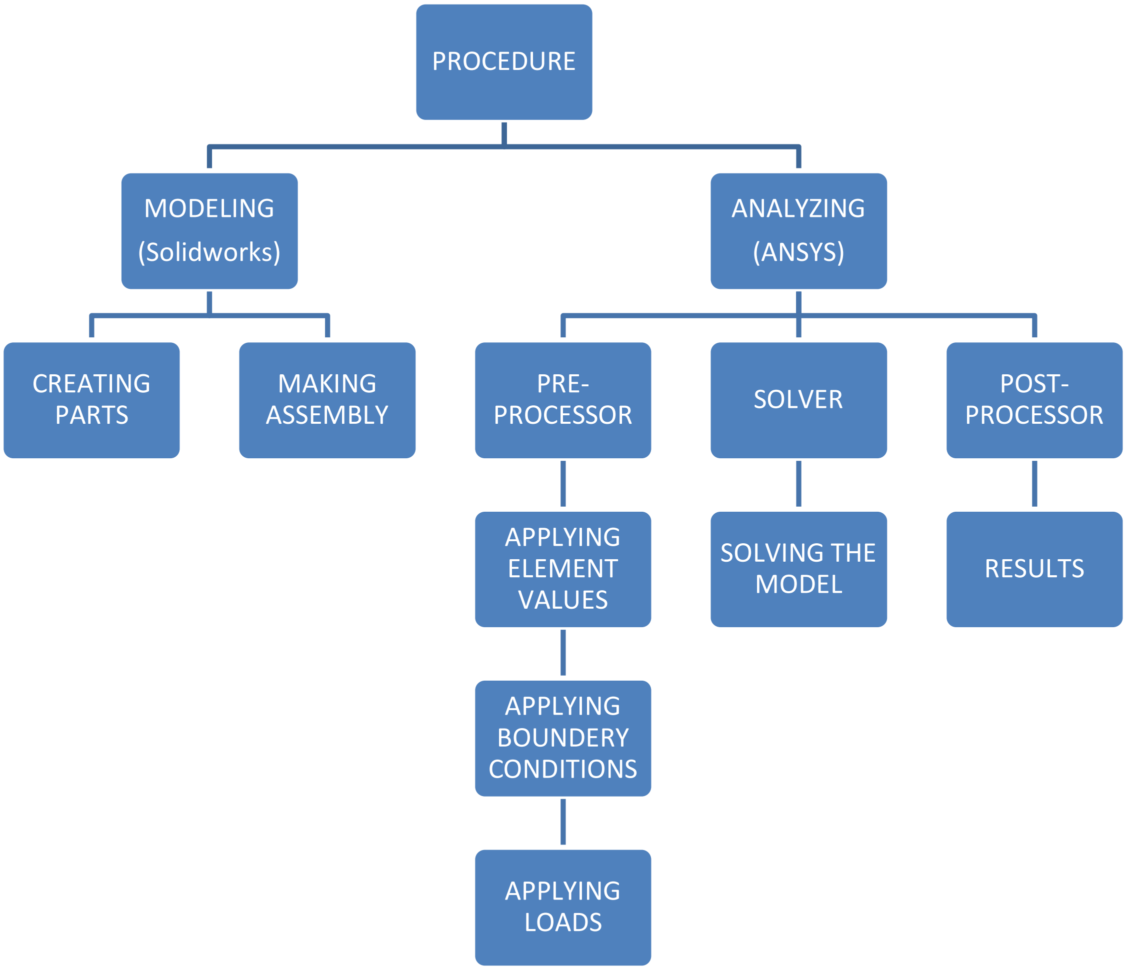
Mesh Type	**Fine Mesh**
Nodes	16031
Elements	45466
Mesh Quality	0.54

CHAPTER 8

ANALYSIS

8.1 ANSYS: AN OVERVIEW

ANSYS is a finite element analysis (FEA) software that can be used for a wide range of applications. Finite Element Analysis (FEA) is a numerical approach for breaking down a large system into small (user-defined) parts called elements. The software creates a thorough explanation of how the system functions as a whole by implementing equations that regulate the behavior of various elements and solving them altogether. These findings can subsequently be presented in tabular or graphical format.



8.2 ANSYS EVALUATION

ANSYS is a complete FEA simulation software package developed by ANSYS Inc – USA. It is used by engineers worldwide in virtually all fields of engineering.

- Structural
- Thermal
- Fluid (CFD, Acoustics, and other fluid analyses)
- Low-and High-Frequency Electromagnetic.

STATIC ANALYSIS--Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

MODAL ANALYSIS**--**Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.

HARMONIC ANALYSIS--Used to determine the response of a structure to harmonically time-varying loads.

TRANSIENT DYNAMIC ANALYSIS--Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static Analysis above are allowed.

SPECTRUM ANALYSIS**--**An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

BUCKLING ANALYSIS--Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.

EXPLICIT DYNAMIC ANALYSIS**--**This type of structural analysis is only available in the ANSYS LS-DYNA program. ANSYS LS-DYNA provides an interface to the LS-DYNA explicit finite element program. Explicit dynamic analysis is used to calculate fast solutions for large deformation dynamics and complex contact problems.

In addition to the above analysis types, several special-purpose features are available:

- Fracture mechanics
- Composites
- Fatigue
- p-Method
- Beam Analyses

Procedure:

Every analysis involves three main steps:

- Pre-processor
- Solver
- post processor

8.3 STRUCTURAL ANALYSIS

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

Types of structural analysis

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Structural analyses are available in the ANSYS Multiphysics, ANSYS Mechanical, ANSYS Structural, and ANSYS Professional programs only.

Elements used in structural analyses

Most ANSYS element types are structural elements, ranging from simple spars and beams to more complex layered shells and large strain solids. Most types of structural analyses can use any of these elements.

Table 8.1 Elements used in Structural Analysis

Category	Element Name(s)
Spars	LINK1, LINK8, LINK10, LINK180
Beams	BEAM3, BEAM4, BEAM23, BEAM24, BEAM44, BEAM54, BEAM188, BEAM189
Pipes	PIPE16, PIPE17, PIPE18, PIPE20, PIPE59, PIPE60
2-D Solids	PLANE2, PLANE25, PLANE42, HYPER56, HYPER74, PLANE82, PLANE83, HYPER84, VISCO88, VISCO106, VISCO108, PLANE145, PLANE146, PLANE182, PLANE183
3-D Solids	SOLID45, SOLID46, HYPER58, SOLID64, SOLID65, HYPER86, VISCO89, SOLID92, SOLID95, VISCO107, SOLID147, SOLID148, HYPER158, SOLID185, SOLID186, SOLID187, SOLID191
Shells	SHELL28, SHELL41, SHELL43, SHELL51, SHELL61, SHELL63, SHELL91, SHELL93, SHELL99, SHELL150, SHELL181
Interface	INTER192, INTER193, INTER194, INTER195
Contact	CONTAC12, CONTAC52, TARGE169, TARGE170, CONTA171, CONTA172, CONTA173, CON-TA174, CONTA175
Coupled-Field	SOLID5, PLANE13, FLUID29, FLUID30, FLUID38, SOLID62, FLUID79, FLUID80, FLUID81, SOLID98, FLUID129, INFIN110, INFIN111, FLUID116, FLUID130
Specialty	COMBIN7, LINK11, COMBIN14, MASS21, MATRIX27, COMBIN37, COMBIN39, COMBIN40, MATRIX50, SURF153, SURF154
Explicit Dynamics	LINK160, BEAM161, PLANE162, SHELL163, SOLID164, COMBI165, MASS166, LINK167, SOLID168

Material model interface

If we are using the GUI, we must specify the material we will be simulating using an intuitive material model interface. This interface uses a hierarchical tree structure of material categories, which is intended to assist in us choosing the appropriate model for our analysis.

Types of solution methods

Two solution methods are available for solving structural problems in the ANSYS family of products: the h-method and the p-method. The h-method can be used for any type of analysis, but the p-method can be used only for linear structural static analyses. Depending on the problem to be solved, the h-method usually requires a finer mesh than the p-method. The p-method provides an excellent way to solve a problem to a desired level of accuracy while using a coarse mesh. In general, the discussions in this manual focus on the procedures required for the h-method of solution.

Structural static analysis

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)
- Fluences (for nuclear swelling)

Performing a static analysis

The procedure for a static analysis consists of these tasks:

- Build the Model
- Set Solution Controls
- Set Additional Solution Options
- Apply the Loads
- Solve the Analysis
- Review the Results

Load types

All of the following load types are applicable in a static analysis.

Displacements (ux, uy, uz, rotx, roty, rotz)

These are DOF constraints usually specified at model boundaries to define rigid support points. They can also indicate symmetry boundary conditions and points of known motion. The directions implied by the labels are in the nodal coordinate system.

Forces (fx, fy, fz) and moments (mx, my, mz)

These are concentrated loads usually specified on the model exterior. The directions implied by the labels are in the nodal coordinate system.

Pressures (pres)

These are surface loads, also usually applied on the model exterior. Positive values of pressure act towards the element face (resulting in a compressive effect).

Temperatures (temp)

These are applied to study the effects of thermal expansion or contraction (that is, thermal stresses). The coefficient of thermal expansion must be defined if thermal strains are to be calculated. We can read in temperatures from a thermal analysis [LDREAD], or we can specify temperatures directly, using the BF family of commands.

Fluences (flue)

These are applied to study the effects of swelling (material enlargement due to neutron bombardment or other causes) or creep.

Gravity, spinning, etc.

These are inertia loads that affect the entire structure. Density (or mass in some form) must be defined if inertia effects are to be included.

Apply loads to the model

Except for inertia loads, which are independent of the model, we can define loads either on the solid model (key points, lines, and areas) or on the finite element model (nodes and elements). We can also apply boundary conditions via TABLE type array parameters. Applying Loads Using TABLE Type Array Parameters) or as function boundary conditions

Applying loads using function boundary conditions

"Loads Applicable in a Static Analysis" summarizes the loads applicable to a static analysis. In an analysis, loads can be applied, removed, operated on, or listed.

Table 8.2 Applying load using boundary condition

Load Type	Category	For details on commands and menu paths for defining these loads
Displacement (UX,UY,UZ,ROTX,ROTY,ROTZ)	Constraints	DOF Constraints in the ANSYS Basic Analysis Guide
Force,Moment (FX,FY,FZ,MX,MY,MZ)	Forces	Forces(concentrated loads) in the ANSYS Basic Analysis Guide
Pressures(PRES)	Surface loads	Surface loads in the ANSYS basic Analysis Guide
Temperature(TEMP),Fluence (FLUE)	Body loads	Body Loads in the ANSYS Basic Analysis Guide
Gravity,Spinning,and so on	Inertia loads	Inertia Loads in the ANSYS Basic Analysis Guide

8.4 COMPOSITES IN ANSYS

Composite materials have been used in structures for a long time. In recent times composite parts have been used extensively in aircraft structures, automobiles, sporting goods, and many consumer products.

Composite materials are those containing more than one bonded material, each with different structural properties.

The main advantage of composite materials is the potential for a high ratio of stiffness to weight. Composites used for typical engineering applications are advanced fiber or laminated composites, such as fiberglass, glass epoxy, graphite epoxy, and boron epoxy.

ANSYS allows us to model composite materials with specialized elements called layered elements. Once we build our model using these elements, we can do any structural analysis (including nonlinearities such as large deflection and stress stiffening).

8.5 MODELING COMPOSITES

Composites are somewhat more difficult to model than an isotropic material such as iron or steel. We need to take special care in defining the properties and orientations of the various layers since each layer may have different orthotropic material properties. In this section, we will concentrate on the following aspects of building a composite model:

- Choosing the proper element type
- Defining the layered configuration
- Specifying failure criteria
- Following modeling and post-processing guidelines

Choosing the proper element type

The following element types are available to model layered composite materials: SHELL99, SHELL91, SHELL181, SOLID46, and SOLID191. Which element we choose depends on the application, the type of results that need to be calculated, and so on. Check the individual element descriptions to determine if a specific element can be used in our ANSYS product. All layered elements allow failure criterion calculations.

- **SHELL99- Linear Layered Structural Shell Element**

SHELL99 is an 8-node, 3-D shell element with six degrees of freedom at each node. It is designed to model thin to moderately thick plate and shell structures with a side-to-thickness ratio of roughly 10 or greater. For structures with smaller ratios, we may consider using SOLID46. The SHELL99 element allows a total of 250 uniform-thickness layers. Alternately, the element allows 125 layers with thicknesses that may vary bilinearly over the area of the layer. If more than 250 layers are required, we can input our own material matrix. It also has an option to offset the nodes to the top or bottom surface.

- **SHELL91- Nonlinear Layered Structural Shell Element**

SHELL91 is similar to SHELL99 except that it allows only up to 100 layers and does not allow us to input a material property matrix. However, SHELL91 supports plasticity, large-strain behavior and a special sandwich option, whereas SHELL99 does not. SHELL91 is also more robust for large deflection behavior.

- **SHELL181 - Finite Strain Shell**

SHELL181 is a 4-node 3-D shell element with 6 degrees of freedom at each node. The element has full nonlinear capabilities including large strain and allows 255 layers. The layer information is input using the section commands rather than real constants. Failure criteria are available using the FC commands.

- **SOLID46 - 3-D Layered Structural Solid Element**

SOLID46 is a layered version of the 8-node, 3-D solid element, SOLID45, with three degrees of freedom per node (UX, UY, UZ). It is designed to model thick layered shells or layered solids and allows up to 250 uniform-thickness layers per element. Alternately, the element allows 125 layers with thicknesses that may vary bilinearly over the area of the layer. An advantage with this element type is that you can stack several elements to model more than 250 layers to allow through-the-thickness deformation slope discontinuities. The user-input constitutive matrix option is also available. SOLID46 adjusts the material properties in the transverse direction permitting constant stresses in the transverse direction. In comparison to the 8-node shells, SOLID46 is a lower order element and finer meshes may be required for shell applications to provide the same accuracy as SHELL91 or SHELL99.

❖ **SOLID191 - Layered Structural Solid Element**

SOLID191 is a layered version of the 20-node 3-D solid element SOLID95, with three degrees of freedom per node (UX, UY, UZ). It is designed to model thick layered shells or layered solids and allows up to 100 layers per element. As with SOLID46, SOLID191 can be stacked to model through-the-thickness discontinuities. SOLID191 has an option to adjust the material properties in the transverse direction permitting constant stresses in the transverse direction. In spite of its name, the element does not support nonlinear materials or large deflections.

In addition to the layered elements mentioned above, other composite element capabilities exist in ANSYS, but will not be considered further in the chapter:

✓ **SOLID95,** the 20-node structural solid element, with KEYOPT (1) = 1 functions similarly to a single layered

✓ **SOLID191** including the use of an orientation angle and failure criterion. It allows nonlinear materials and large deflections.

✓ **SHELL63,** the 4-node shell element, can be used for rough, approximate studies of sandwich shell models.

A typical application would be a polymer between two metal plates, where the bending stiffness of the polymer would be small relative to the bending stiffness of the metal plates. The bending stiffness can be adjusted by the real constant RMI to represent the bending stiffness due to the metal plates, and distances from the middle surface to extreme fibers (real constants CTOP, CBOT) can be used to obtain output stress estimates on the outer surfaces of the sandwich shell. It is not used as frequently as SHELL91, SHELL99, or SHELL181, and will not be considered for anything other than sandwich structures in this section.

✓ **SOLID65,** the 3–D Reinforced Concrete Solid Element, models an isotropic medium with optional reinforcing in 3 different user-defined orientations.

✓ **BEAM188** and **BEAM189,** the 3–D finite strain beam elements, can have their sections built up with multiple materials.

8.5.1 Element type used in the project

SOLID45 Element Description

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

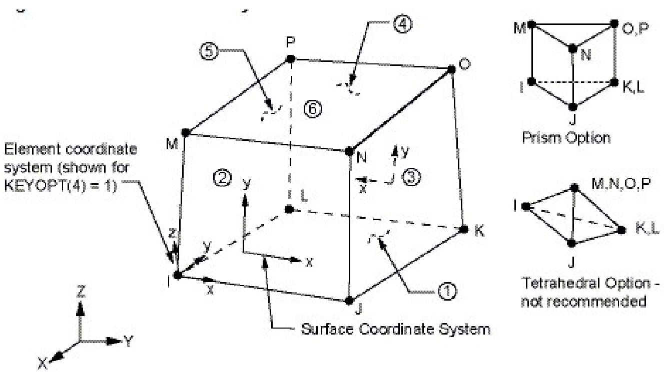


Figure 8.1 SOLID45 Geometry

TARGE170 Element Description

TARGE170 is used to represent various 3-D "target" surfaces for the associated contact elements (CONTA173, CONTA174, CONTA175, CONTA176 & CONTA177). The contact elements themselves overlay the solid, shell, or line elements describing the boundary of a deformable body and are potentially in contact with the target surface, defined by TARGE170. This target surface is discretized by a set of target segment elements (TARGE170) and is paired with its associated contact surface via a shared real constant set. We can impose any translational or rotational displacement, temperature, voltage, and magnetic potential on the target segment element. we can also impose forces and moments on target elements.

For rigid target surfaces, these elements can easily model complex target shapes. For flexible targets, these elements will overlay the solid, shell, or line elements describing the boundary of the deformable target body.

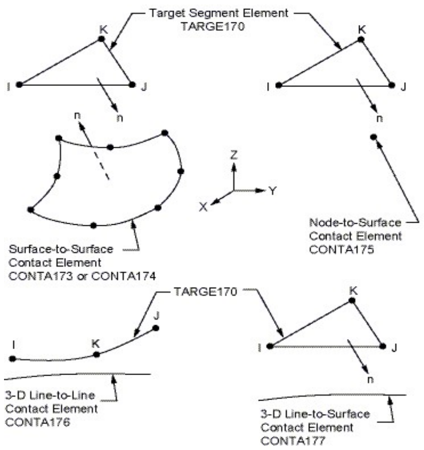


Figure 8.2 TARGE170 Geometry

8.6 STRUCTURAL ANALYSIS PERFORMED ON BUMPER

The structural analysis was performed using existing materials (PP+EPM-TD15) and hybrid composite materials (Polyester, E glass-fibre, and coconut coir) under a constant load of 10N.

8.6.1. Existing Material Bumper

Figures 8.3, 8.4 and 8.5 show the total deformation, Equivalent elastic strain and equivalent stress of the model respectively. The structural analysis on the model with existing material, that is, PP+EPM-TD15, was carried out with a uniform constant load of 5 KN.

(i) Total Deformation

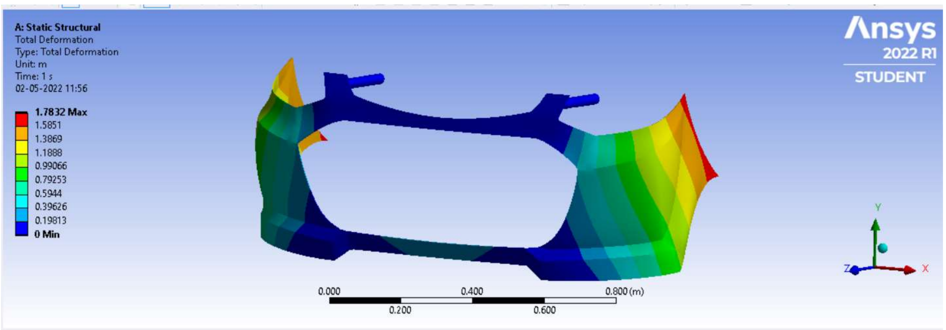


Figure 8.3 Total Deformation of Existing Material Bumper

(ii) Equivalent elastic strain

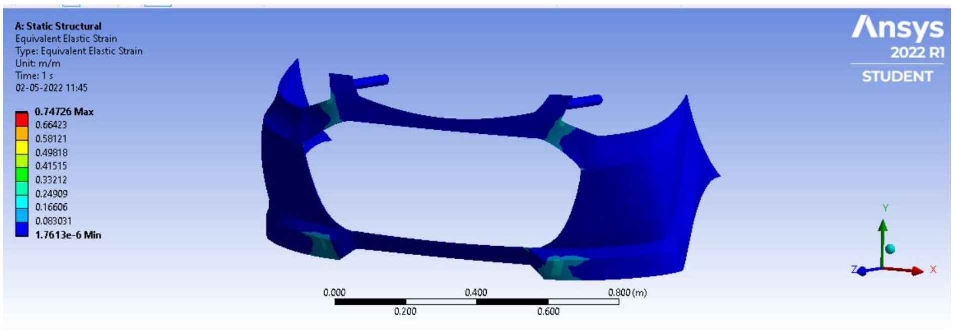


Figure 8.4 Equivalent elastic strain of Existing Material Bumper

(iii) Equivalent stress

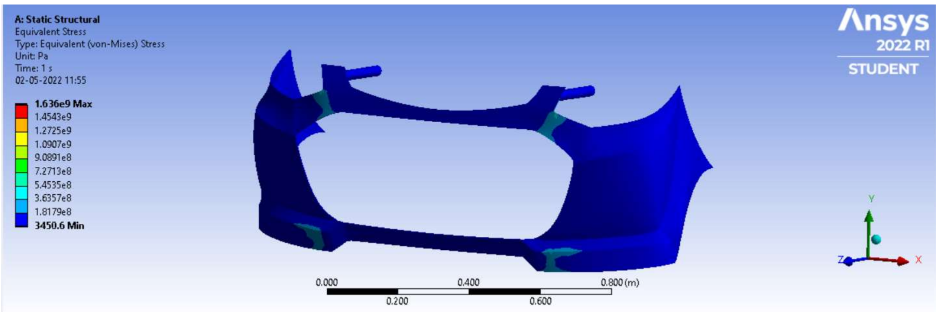


Figure 8.5 Equivalent stress of Existing Material Bumper

8.6.2 Hybrid Composite Material Bumper

Figures 8.6, 8.7 and 8.8 show the total deformation, Equivalent elastic strain and equivalent stress of the model respectively. The structural analysis on the model with new material, that is, combination of Polyester with E-Glass Fibre and Coconut Coir, was carried out with a uniform constant load of 5 KN.

(i) Total Deformation

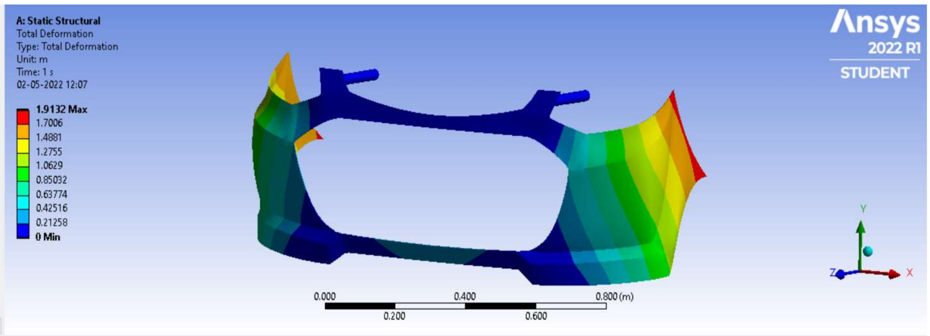


Figure 8.6 Total deformation of Hybrid Composite material bumper

(ii) Equivalent elastic strain

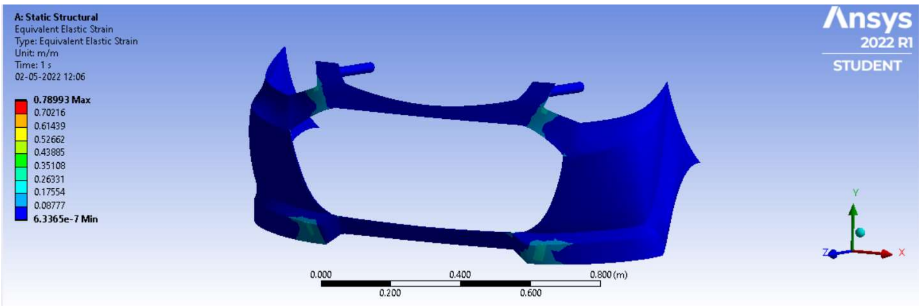


Figure 8.7 Equivalent elastic strain of Hybrid Composite material bumper

(iii) Equivalent stress

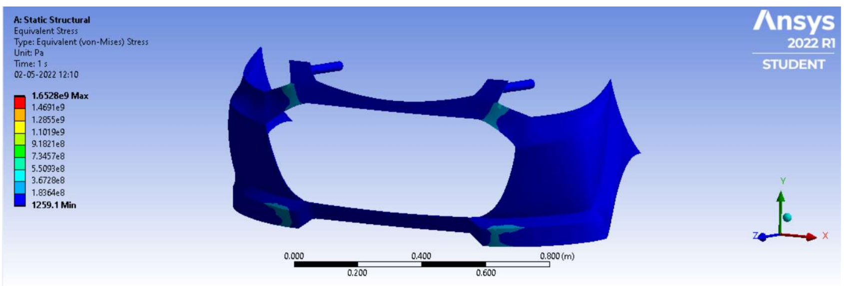


Figure 8.8 Equivalent stress of Hybrid Composite material bumper

Table 8.3. Comparison of Structural Analysis Results for Existing Material Bumper with Hybrid Composite Material Bumper

DESCRIPTION	Existing Material	Hybrid Composite
Total Deformation (m)	0.59794	0.64085
Equivalent elastic strain	2.7982e-2	3.0005e-2
Equivalent stress (Pa)	4.8777e7	4.979e7

8.7 MODAL ANALYSIS:

Modal analysis is the fundamental dynamic analysis type, providing the natural frequencies at which a structure will resonate. These natural frequencies are of paramount importance in various engineering fields. Suspensions are usually tuned to have different natural frequencies for passenger cars and race cars.

8.7.1 Modal Analysis performed on Existing Material Bumper

Figures 8.9 and 8.10 show the natural frequency and directional deformation of the model respectively. The modal analysis on the model with existing material, that is, PP+EPM-TD15, was carried out.

(i) Total deformation (Natural Frequency)

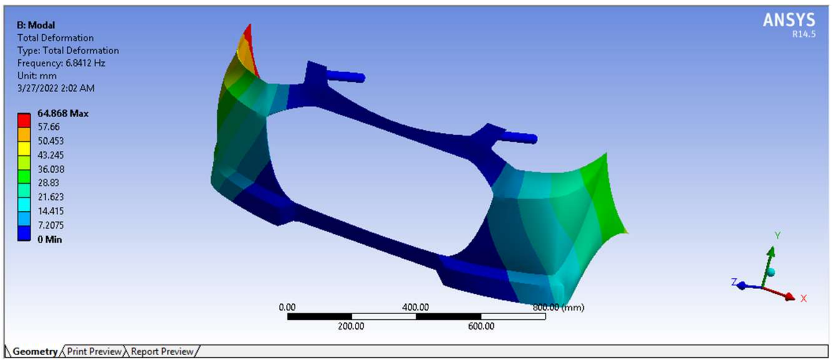


Figure 8.9 Total deformation (Natural Frequency) of existing material bumper

(ii) Random Vibration

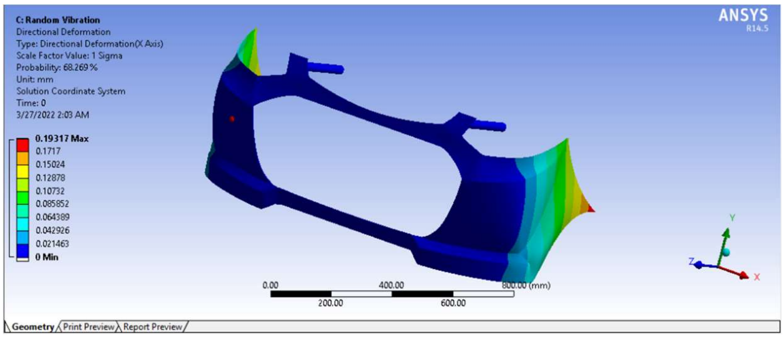


Figure 8.10 Random vibration of existing material bumper

8.7.2 Modal Analysis performed on Hybrid composite Material Bumper

Figures 8.11 and 8.12 show the natural frequency and directional deformation of the model respectively. The modal analysis on the model with new material, that is, combination of Polyester with E-Glass Fibre and Coconut Coir, was carried out.

(i) Total deformation (Natural frequency)

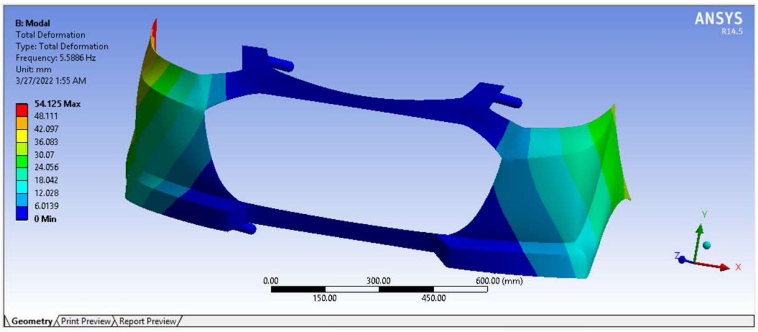


Figure 8.11 Total deformation of Hybrid Composite material bumper

(ii) Random Vibration

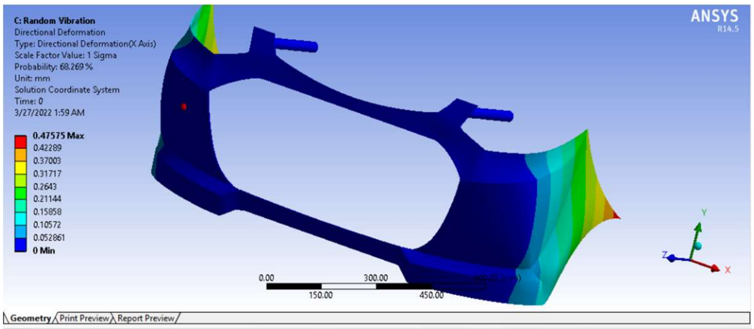


Figure 8.12 Random Vibration of Hybrid Composite material bumper

Table 8.4. Comparison of Modal Analysis Results for Existing Material Bumper with Hybrid Composite Material Bumper

DESCRIPTION	Existing material	Composite material
Directional deformation (mm)	**0.19317**	**0.47575**
Natural Frequency(Hz)	**6.8412**	**5.5886**

8.8 EXPLICIT DYNAMIC ANALYSIS:

"Implicit" and "Explicit" refer to two types of time integration methods used to perform dynamic simulations. Explicit time integration is more accurate and efficient for simulations involving – Shock wave propagation – Large deformations and strains – Non-linear material behaviour – Complex contact – Fragmentation – Non-linear buckling. Typical applications are drop tests and impact and penetration. ANSYS Explicit Dynamics analysis software provides simulation technology to help simulate structural performance long before manufacture.

ANSYS explicit dynamics analysis software solutions are capable of solving short-duration, large-strain, large-deformation, fracture, complete material failure, and structural problems with complex contact interactions.

A time integration method used in Explicit Dynamics analysis system. It is so named because the method calculates the response at the current time using explicit information Once the body is meshed properly, the next step is to define initial conditions or boundary conditions. At least one initial condition is required to complete the setup.
After defining the initial conditions (initial velocity, Angular velocity), the analysis setting has to be maintained as per the problem requirement.

In the analysis setting, time steps have to be defined explicitly. The solution time depends on the time steps.

Time steps include;

- Initial time step
- Minimum time step
- Maximum time step
- Time step safety factor

In case of drop test the standard earth gravity is also taken into account

ANSYS Explicit Dynamics is included in the ANSYS Mechanical Enterprise-level license and is not available as a product by itself

- It utilises the Autodyn solver within the standard ANSYS Mechanical interface to analyse transient structural events
- It is used for simulating fracture, cutting, failure, buckling, impact, drop as well as highly nonlinear quasi-static simulations that the implicit APDL-based solvers would struggle to converge
- Users with an Autodyn level license have access to the Explicit Dynamics interface in Mechanical as a method to preprocess their structural geometry
-

8.8.1. Side Impact analysis performed on existing material bumper

Figures 8.13 and 8.14 show the total and directional deformation of the model respectively. The side impact analysis on the model with existing plastic material, that is, PP+EPM-TD15, was carried out with the help of a side impact beam while the model was sped at a speed of 50 km/hr towards the beam.

(i) Total Deformation

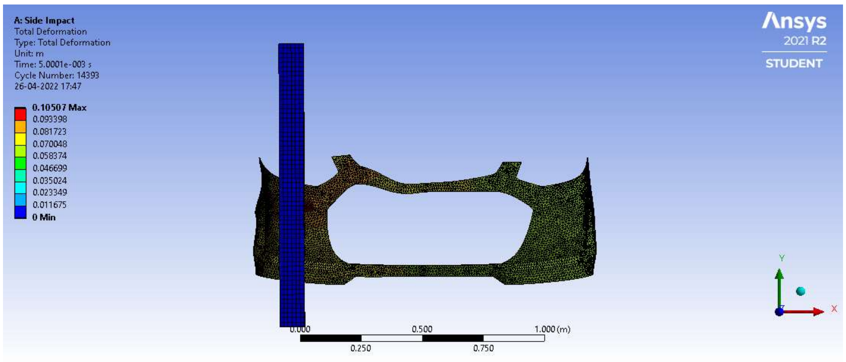


Figure 8.13 Total deformation of Existing material bumper

(ii) Directional Deformation

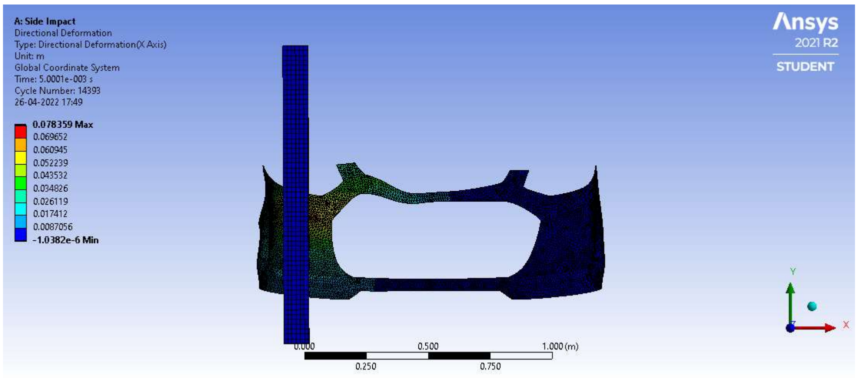


Figure 8.14 Directional Deformation of Existing material bumper

8.8.2. Side Impact analysis performed on Hybrid composite material bumper

Figures 8.15 and 8.16 show the total and directional deformation of the model respectively. The side impact analysis on the model with hybrid composite material, that is, Polyester with E-Glass Fibre and Coconut Coir, was carried out with the help of a side impact beam while the model was sped at a speed of 50 km/hr towards the beam.

(i) Total Deformation

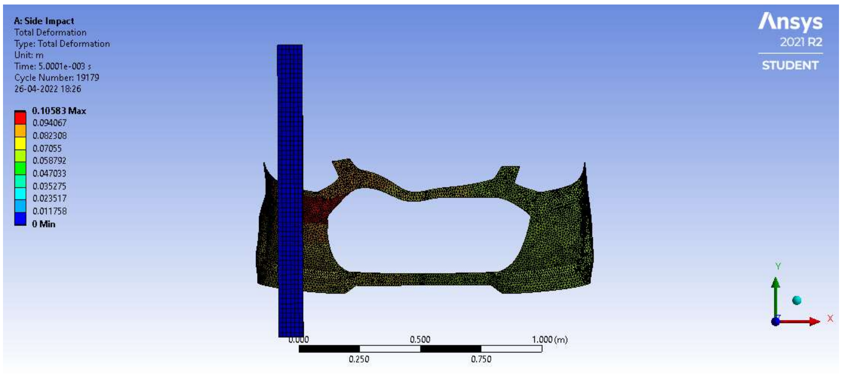


Figure 8.15 Total deformation of Hybrid Composite material bumper

(ii) Directional Deformation

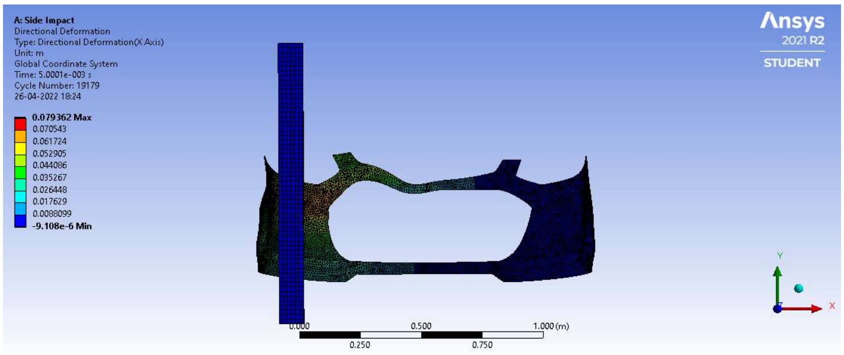


Figure 8.16 Directional Deformation of Hybrid Composite material bumper

Table.8.5 Comparison of Side impact Analysis Results for Existing Material Bumper with Hybrid Composite Material Bumper

Description	Existing Material	Hybrid Composite
Total Deformation (m)	5.8271e-002	6.0288e-002
Directional deformation (m)	1.147e-002	1.6443e-002

From Table 8.5, it is inferred that the values of total deformation and directional deformation is higher for the hybrid composite model, thus proving that the hybrid composite model absorbs impact more efficiently than the conventional plastic model during side impact.

8.8.3 Frontal impact analysis performed on existing material bumper

Figures 8.17 and 8.18 show the total and directional deformations of the model respectively. The frontal impact on the model with existing plastic material, that is, PP+EPM-TD15, was carried out with the help of a fixed wall while the model was sped at a speed of 50 km/hr towards the fixed wall.

(i) Total deformation

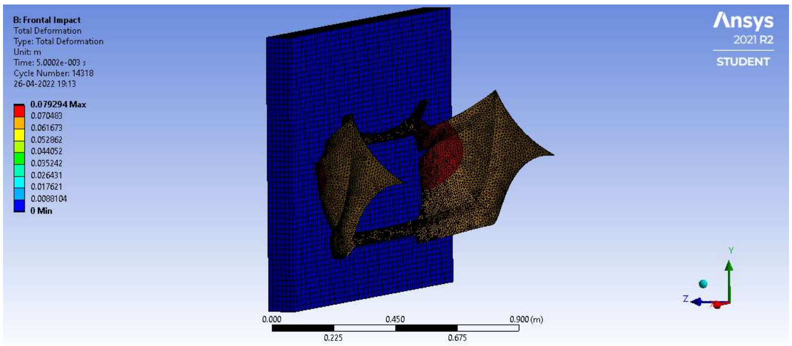


Figure 8.17 Frontal impact Total deformation of Existing material bumper.

(ii) Directional Deformation

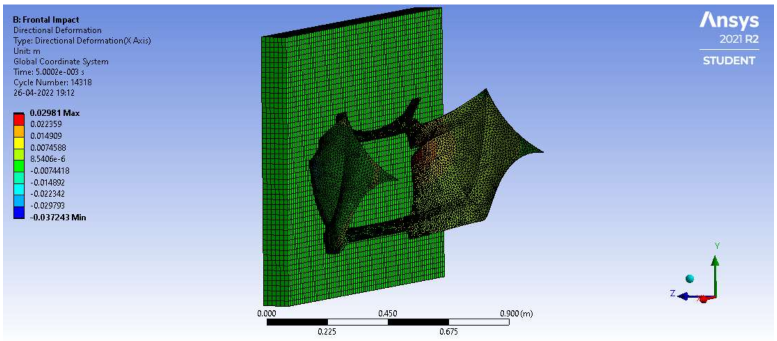


Figure 8.18 Frontal impact Directional deformation of Existing material bumper.

8.8.4 Frontal impact analysis performed on Hybrid composite material bumper

Figures 8.19 and 8.20 show the total and directional deformations of the model respectively. The frontal impact on the model with hybrid composite material , that is , Polyester with E-Glass Fibre and Coconut Coir , was carried out with the help of a fixed wall while the model was sped at a speed of 50 km/hr towards the fixed wall.

(i) Total deformation

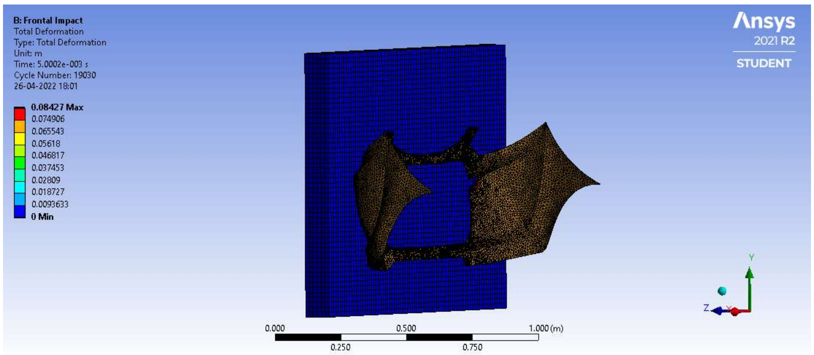


Figure 8.19 Frontal impact Total deformation of Hybrid Composite material bumper.

(ii) Directional Deformation

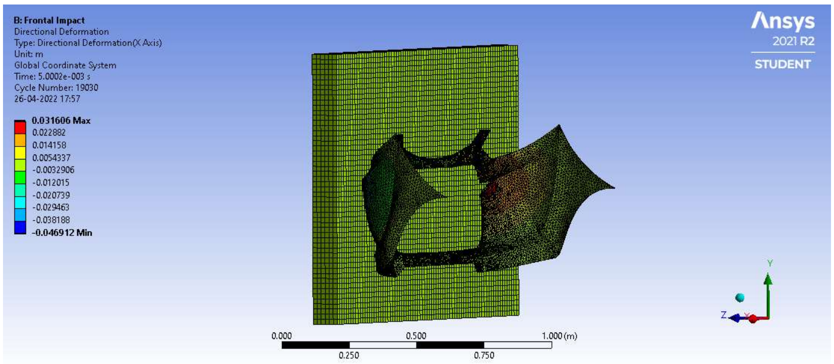


Figure 8.20 Frontal impact Directional deformation of Hybrid Composite material bumper.

Table.8.6 Comparison of Frontal Analysis Results for Existing Material Bumper with Hybrid Composite Material Bumper

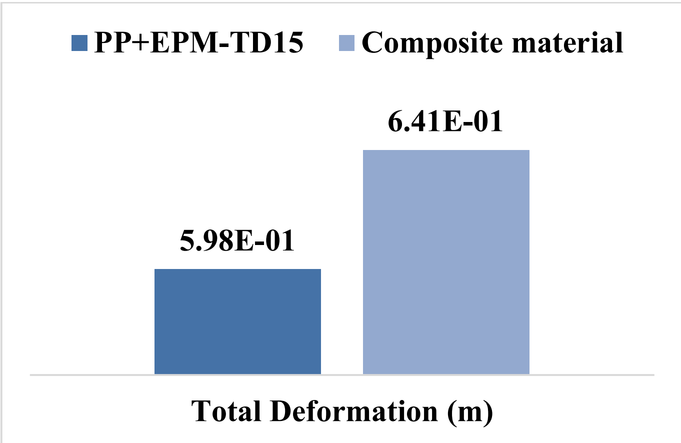
Description	Existing Material	Hybrid Composite Material
Total Deformation (m)	2.0341e-02	2.0454e-002
Directional deformation (m)	-3.0979e-005	-1.1426e-004

From Table 8.6 , it is inferred that the values of total and directional deformation is higher for the hybrid composite model , thus proving that the hybrid composite model absorbs impact more efficiently than the conventional plastic model during frontal impact.

CHAPTER 9
RESULT AND DISCUSSION

9.1. STRUCTURAL ANALYSIS

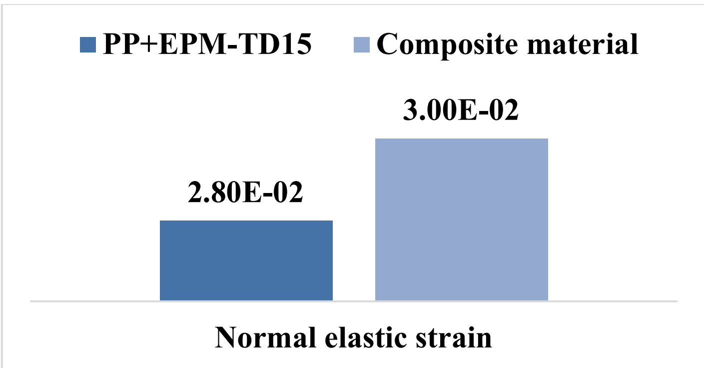
9.1.1 Total Deformation



Graph 9.1 Comparison of Total deformation (structural analysis)

From Graph 9.1, it is inferred that the total deformation on the existing model is lesser than that of the model with new material, thus concluding that the model with new material deforms more than the existing model under the application of same load of 5 KN

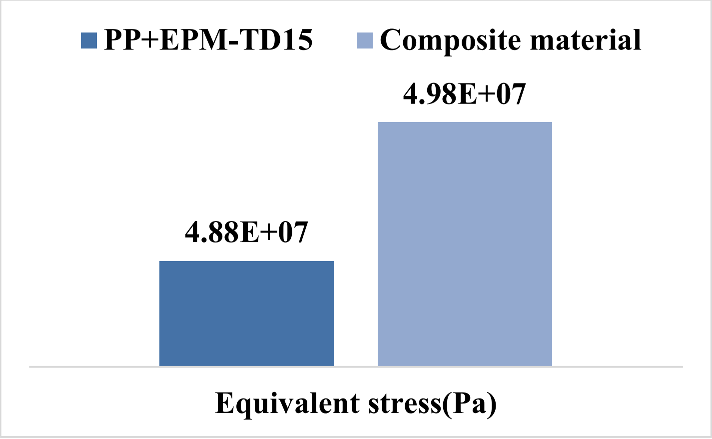
9.1.2 Normal Elastic strain



Graph 9.2 Comparison of Equivalent elastic strain (structural analysis)

From Graph 9.2 , it is inferred that the normal elastic strain is higher on the model with new material signifying the model deforms more in response to application of force compared to the existing model , thus , complementing and adhering to the findings from graph 9.1

9.1.3 Equivalent stress

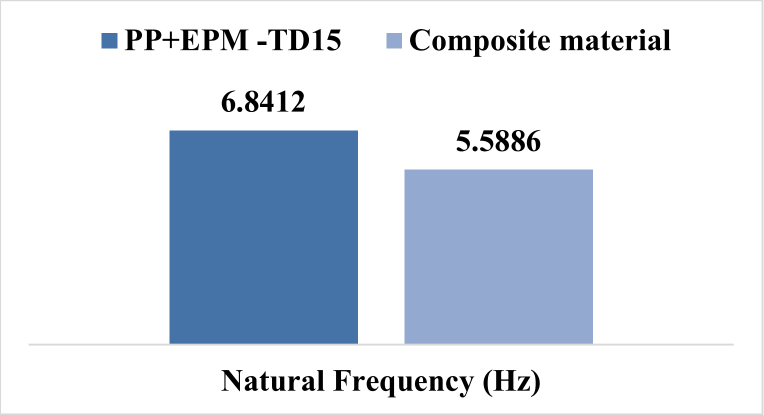


Graph 9.3 Comparison of Equivalent stress (structural analysis)

From Graph 9.3, it is inferred that equivalent stress is higher on the model with new material signifying the model with new material is capable of withstanding and transferring loads with larger magnitude compared to the existing model, thus, confirming the findings from graphs 9.1 and 9.2

9.2. MODAL ANALYSIS

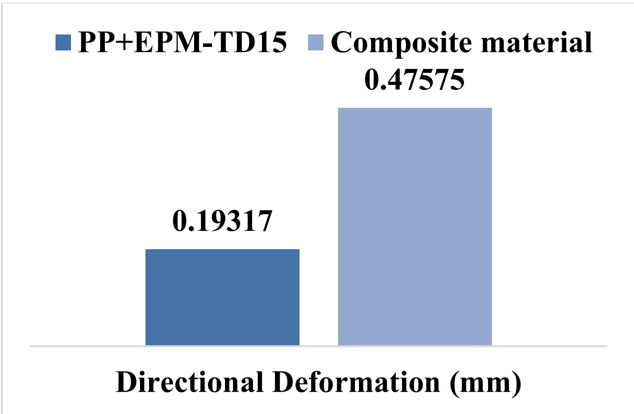
9.2.1 Total deformation (Natural Frequency)



Graph 9.4 Comparison of Natural frequency (Modal analysis)

From graph 9.4, it is inferred that the natural frequency is higher for the existing model, compared to the new model with composites, signifying that the existing model tends to vibrate more when subjected to certain external forces. Since, natural frequency is inversely proportional to stresses, this finding confirms that model with hybrid composites has higher deformation than the existing model

9.2.2 Direction deformation



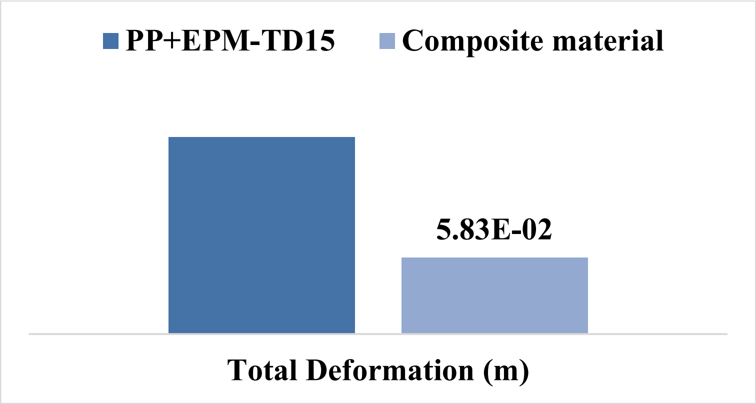
Graph 9.5 Comparison of Directional deformation (Modal analysis)

From graph 9.5, it is inferred that the directional deformation of the model with hybrid composite incorporation has higher directional deformation compared to the existing model. This implies that the new model under dynamic loading condition, tends to deform more than the existing model.

9.3. EXPLICIT DYNAMIC ANALYSIS

9.3.1 Side Impact Analysis

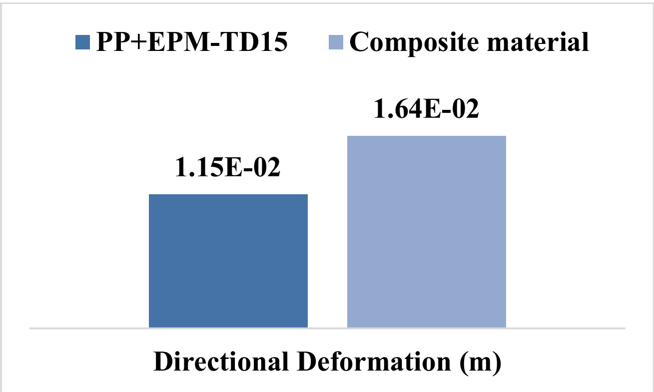
(i) Total deformation



Graph 9.6 Comparison of Total deformation (Side impact analysis)

From Graph 9.6, it is inferred that during the course of a crash, the model with hybrid composites tends to deform more than the model with conventional plastic material. This signifies that the hybrid composite model tends to better absorb energy during impact.

(ii) Directional deformation

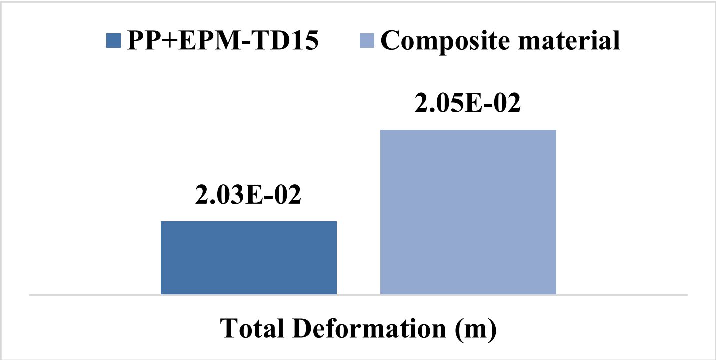


Graph 9.7 Comparison of Directional deformation (Side impact analysis)

From Graph 9.7, it is inferred that during the course of a crash, the model with hybrid composites tends to deform more in the direction of the application of force/load than the model with conventional plastic material. This signifies that the hybrid composite model tends to better absorb energy during impact and confirms the findings from graph 9.6.

9.3.2 Frontal Impact Analysis

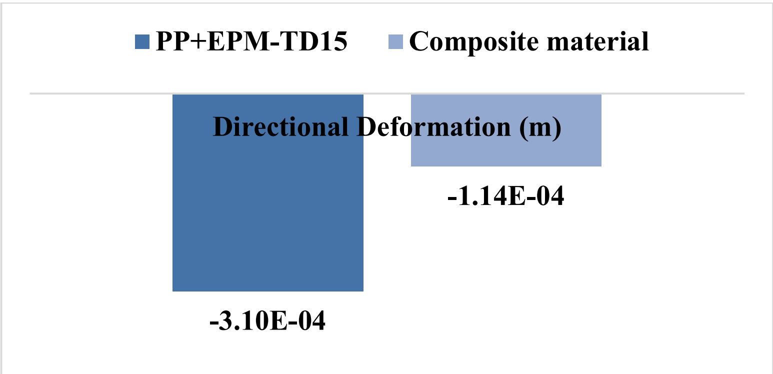
(i) Total deformation



Graph 9.8 Comparison of Total deformation (Frontal impact analysis)

From graph 9.8 , it is noted that when the model is crashed into a fixed wall , the model with hybrid composites deforms better than the model with conventional plastic , which signifies that during frontal impact , the hybrid composite model tends to better absorb the impact.

(ii) Directional deformation



Graph 9.9 Comparison of Directional deformation (Frontal impact analysis)

From graph 9.9 , it is noted that when the model is crashed into a fixed wall , the hybrid composite model deforms more in the direction of application of force , which in turn adheres to the findings from graph 9.8.

CHAPTER 10

CONCLUSION

This work compares the newly designed bumper with the existing plastic bumper of an Alto 800. The crash tests were executed in a software environment. All the analyses were executed using Ansys. The hybrid composite used Polyester as the matrix and E-Glass Fibre and Coconut Coir as the reinforcements, while the conventional plastic bumper used Polypropylene as the plastic. The existing model absorbed 1301.98 Joules of energy while the hybrid composite model absorbed 1396 Joules of energy. The hybrid composite model thus has 7 % increase in energy absorption over the existing plastic material. This higher energy absorption paired with findings from structural, modal and crash analyses demonstrate that the hybrid composite has better strength and load withstanding capabilities over plastic.

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INDIVIDUAL CONTRIBUTION

1. Thirumarran T
    - Collecting Papers
    - PPT content collection
    - PPT Editing
2. Dinesh Kumar S
    - Collecting Material Properties
    - Modal Analysis
    - Crash Analysis
3. B Abhishek
    - Purchasing Existing Bumper
    - Designing of Bumper
    - Report Editing
4. Harish S
    - Report content collection
    - Designing of Bumper
    - Structural Analysis

PO – PROJECT MAPPING

PO NO.	PO DESCRIPTION	PROJECT MAPPING
PO 1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3
PO 2	**Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3
PO 3	**Design Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	3
PO 4	**Conduct Investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	3
PO 5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	3
PO 6	**The Engineer & Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety,	2

	legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	
PO 7	**Environment & Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	3
PO 8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	2
PO 9	**Individual & Team Work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	3
PO 10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	2
PO 11	**Project Management & Finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	2
PO 12	**Life-Long Learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	3

PSO – PROJECT MAPPING

PSO NO.	PSO DESCRIPTION	PROJECT MAPPING
PSO 1	Design, Analysis, Fabrication and Testing of vehicles, which enable the students to compete globally.	2
PSO 2	Carry out research in fuel economy, emission reductions, alternate fuels and solar vehicle for the benefit of the society and environment.	3