ANALYSIS AND OPTIMIZATION OF CAR BUMPER USING HYBRID BIOCOMPOSITE MATERIAL

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CANDIDATE'S DECLARATION

I, Vipul Jain, Roll No. 2k17/CDN/06 student of M.Tech (Computational Design), hereby declare that the project dissertation titled "Analysis and optimization of car bumper using hybrid biocomposite material " which is submitted by me to the Department of Mechanical Engineering, Delhi Technological university, Delhi in partial fulfillment of the requirement for the award of the degree of Master Of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the project dissertation titled “Analysis and optimization of car bumper using hybrid biocomposite material " which is submitted by Vipul Jain, Roll No. 2k17/CDN/06 to Mechanical Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

A large amount of non-recyclable and non-biodegradable waste gases is being produced by the automotive sector. Automotive components made of traditional materials like steel and its alloys are heavy which lead to an increase in consumption of fuel. The Automobile industry is increasing focus on investigation of environment-friendly, sustainable and lightweight materials to replace the existing ones. Biocomposite materials are lightweight and have the potential to overcome the problems of agricultural residues and environmental toxicity.

Therefore this research work is focused on pineapple leaf and glass fibres reinforced hybrid biocomposite material to be used for automotive car bumper. In this work, a bumper of Ambassador Car is designed in CATIA V5R18 and analysed in ANSYS18.1 for static and impact test. Geometric optimizations are a important parameter in structural strength improvement. Providing the strengthening ribs, changing the cross section and by increase in the thickness of bumper has increased the mechanical strength of this automotive component. For both static and impact analysis, this biocomposite material shows a lower value of deformation and higher value of strength in comparison to steel and aluminium bumpers. The results of analysis and reduction in mass of bumper prove the potential for utilization of hybrid biocomposite material in automotive structural components.

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"It is not possible to prepare a report without the assistance & encouragement of other people. This one is certainly no exception. "

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

PALF - Pineapple leaf fibres

FEA - Finite Element Analysis

v - Final velocity

u - Initial velocity

t - Time

a - Acceleration

F - Force

A - Area

CHAPTER1

INRODUCTION

1.1 BIOCOMPOSITE MATERIALS

Biocomposites materials are those that have at least one phase consisted of a biological origin. The reinforcement can be fibres obtained from natural sources such as hemp, flax, pineapple leaf, kenaf, sisal or fibres from waste paper or wood, or can be by-products from agriculture crops. Matrices consist of polymers derived from natural resources like vegetable oil and starch.

Polymer composites are being widely explored in different fields for a variety of applications. Composites are lightweight weight materials having high strength and better mechanical properties. However, the problem of generation of solid and toxic waste has restricted their usage. This waste generated is non biodegradable and leads to environmental toxicity. To overcome the problem, researchers are focusing their interest on development of biocomposites with nature base. These composites are known as green composite materials.

The usage of the biocomposite materials is yet to be seen in wide range of application. The exhaustion of petroleum resources, problems of green house emissions, generation of non biodegradable waste, issue of environmental pollution leads to development of new green materials that are companionable with the atmosphere and their development is not dependent on petroleum based resources. The development of natural fibre reinforced biocomposites materials encourages the use of eco-friendly materials and sustainable development. The utilization of biocomposite materials gives another way to eradicate the issues related to agricultural waste.

Agricultural waste obtained from crops like pineapple leaf, banana, kenaf and coconut fibres are being obtained in very large quantity. They can be obtained in large amount and have low value of cost. Another advantage of using these residues is that they are renewable and recyclable in nature. From this large quantity of agricultural waste, very small proportion from these agriculture residue is utilized as fuel in the houses and as fertilizer in fields and the remaining portion of residues is burned in the field which creates the problem of environmental pollution. Burning of this large amount of agriculture residues pollutes the air and can cause the respiratory problems. This increases the concern of the researchers to use the agricultural residues for some meaningful purpose. One of the best solutions provided for this problem is to utilize these residues for reinforcements for developing the naturally favourable biocomposites.

Mechanical performance of natural fibres reinforced biocomposites materials is affected by many parameters. These parameters can be selection of fibre and matrix, fibre content, interfacial strength of fibres and matrix, fibre dispersion, orientation of fibres, their manufacturing process and porosity. Fibres can be obtained from different sources such as plant, animal or mineral. Plant fibres are easily available and have good strength which makes them more suitable. Proper selection of matrix provides a barrier against unfavourable conditions, protects the surface of the fibres from abrasion and it transfers load to fibres. Because stress is transferred between the interface of matrix and fibres, strong bonding is necessary at the interface for the maximum reinforcement. Suitable manufacturing process is essential for a development of strong biocomposite material. Physical and chemical treatments can improve the strength of the biocomposite materials.

Due to increasing awareness for the environmental problems and sustainability concept, the focus has been shifted towards the study of natural fibres reinforcement biocomposite materials. These fibres obtained from natural resources have been utilized for reinforcement and can be found utililized in several fields for a wide range of applications such as automobile interior parts, defence equipments and sports goods. Moreover, the natural fibres offers different advantages which includes lightweight nature, fully biodegradable, renewable, environmental friendly, non-toxic nature, low cost, high toughness, high-quality thermal properties, high insulation for noise and heat transfer, greater tool life, reduced skin and respiratory problems, and lesser abrasiveness.

The consequences of ecological problems and environmental toxicity have lead to a new trend which resulted in development of new materials which are environmentally safe. The biocomposite materials are the one which are environment friendly and can be used in different applications such as in automotive sector.

1.2 APPLICATION OF BIOCOMPOSITES IN AUTOMOTIVE SECTOR

The automotive sector is one of the biggest metal product consumers. The automobile industry is the second largest steel consumer after the construction sector. Steel and its alloys are used in the manufacturing of vehicle bodies, engine, wheel, chassis and many other components. But steel comes with its disadvantage as the parts made of steel are heavy and leads to an addition in the weight of the automobile body. So aluminium became a replacement for the steel components because of its lightweight property.

With further advancement in the automotive sector, the researchers have focused their attention on the composite materials. The areas of application of composite materials have grown rapidly and have found a new market in the world of automobiles. Aircraft and automobile industries prefer to use glass and carbon fibres reinforced polymers composites due to their better mechanical properties than steel and aluminium.

Composite materials made from synthetic fibres like carbon and glass fibers, or other synthetic fibres fibres have good mechanical and thermal properties and are widely used in different applications of the automotive and construction sector. However, the biodegradation of these synthetic fibre reinforced composites is not a simple task and requires a lot of efforts, and leads in the formation of toxic non biodegradable waste, which is harmful for the environment. To solve the problem, researchers are focusing more on utilization of biocomposite materials to reduce the problems of non-recyclable waste, environmental pollution and greenhouse emissions.

Yan Cao and Weihong Wang *et al.* [1] have studied and found that biocomposite materials have the ability to serve as a replacement for the glass fibre reinforced composites in various applications because of their low density, bio-degradability and ease of recyclability. A large amount of toxic and non biodegradable waste is generating due to use of synthetic fibres based composites in the automotive sector. So biocomposites have become increasingly popular with the car manufacturers because they can reduce weight, which improves their performance and lowers CO2 emissions.

Biocomposites materials are those that consist of at least one phase from the natural resources. The reinforcement can be fibres obtained from natural sources such as oil palm, flax, pineapple leaf, kenaf, sisal or fibres from waste paper or wood, or can be agricultural residues. Matrices consist of polymers taken from natural resources like vegetable oil and starch.

Biocomposites are formed from renewable, recyclable and sustainable agricultural crop residues such as oil palm, pineapple leaf, banana, and sugar palm which are found in abundance and help to solve the problem of agricultural residues. Development of bio-composite materials makes them more suitable due to their environment-friendly nature. The research work on strength and biodegradable nature of an epoxy thermoset was done and these properties of the material were improved with the reinforcement of pineapple leaf and coir fibres. This makes them suitable for utilization in the different fields [2].

Different natural fibres have been widely used by the researchers for the development of the biocomposite materials. Natural fibres like Jute, Kenaf, Flax Hemp and Pineapple leaf fibres have good strength and have potential to be used in different industries for various applications.

There are a variety of natural fibres present in the environment that can be obtained from different resources of nature like plants and minerals. These fibers differ are different due to different value of properties they possess which makes them suitable for various application as per the requirements.

The mechanical and physical properties of different synthetic fibers are presented in following table 1.1 [8, 50]: Value of different properties like density of the fibres, their tensile strength and Young's modulus have been shown in the table. According to their values they can be used for different application in various fields by the researchers and the scientists.

Table 1.1: Physical properties of the natural fibres and synthetic fibres

Fibre	Density (g/cm3)	Tensile strength (MPa)	Stiffness/Young's Modulus (Gpa)	Elongation at break (%)
Alfa	0.89	350	22	5.8
Bamboo	0.8	200	15	-
Banana	1.34	500	11-13	5.87
Coir	1.2	173-174	5	30
Cotton	1.55	280-600	8	7.5
Date palm	1.1	112	3	3.25
Flax	1.3-1.6	345-1034	27-28	3
Hemp	1-1.5	680-695	72	1.5-1.6
Henequen	1.2	430-570	16.3-10.1	3.7-5.9
Jute	1.3	393-773	26.5	1.5-1.8
Kenaf	-	930	53	1.6
Oil Palm	0.7-1.55	248	3.2	25
Pineapple	0.8-1.6	1.44	400-627	14.5
Sisal	1.5	511-635	9.4-22	2-2.5
E-glass	2.5	2000-3000	70	2.5

Environmental awareness and sustainability concept have attracted the scientists and researchers towards utilization of natural fibres reinforced biocomposites. Natural fibre reinforced composites have the great advantage due to their lightweight, high strength to weight ratio, renewability, wide availability, lower density, less wear and tear in processing, lower energy requirements for processing, biodegradability and relative non-abrasiveness over traditional reinforcing fibres such as glass and carbon. These properties of natural fibres make them suitable to be used in the automotive sector. Pradeep et al. [3] have found that the palm and coir reinforced biocomposites can be used for the fabrication of lightweight automobile parts.

Biocomposites with natural fibre reinforcements possess low mechanical strength than glass and carbon fibre reinforced composites. This limitation of natural fibre composites can be overcome by hybridizing them with other synthetic or natural fibres of superior mechanical properties. The hybrid composite reinforced with equal volume content of pineapple leaf fibre and coconut husk fibre possesses the highest tensile, flexural, and impact strength [4]. Hybrid composites shows the advantages of weight savings, enhanced toughness, longer fatigue life, and very good impact resistance compared to composites made from single reinforcement. M. Jawaid *et al.* [5] have found in his research work that hybrid composites have improved mechanical and thermal properties which prove them a potential material for medium load-bearing applications in automobile parts.

European car manufacturers explored the potential of natural fibres in the automobile sectors for the aesthetic automotive components. Limited application of natural fibre reinforced composites is found in structural components of automobiles. Hybridization with other reinforcements or matrices can improve the mechanical properties of natural fibre composite and make them useful for structural automotive components. Mohit Mittal et al. [6] has investigated the effect of fibre content on thermo-mechanical performance of palf/Epoxy and coir/Epoxy Composites. Moreover, geometric optimizations have a significant role in structural strength improvement.

Car bumpers are the structural components made of steel, aluminium, plastics and composites that are mounted on the front and rear of a passenger car. Very less research has been done on the application of natural fibre reinforced composite materials in automotive car bumpers. In this research work, we can suggest the use of pineapple leaf fibres (PALF) and glass fibres reinforced biocomposite material instead of traditional steel and aluminium alloys for the automotive application. The use of biocomposite material for the bumper structure will lead to a weight loss of vehicle, lower fuel consumption and pollutant emissions of greenhouse gases, and higher resistance to impact and corrosion.

CHAPTER 2

LITERATURE REVIEW

2.1 NATURAL FIBER BIOCOMPOSITES

Natural fibre composites are not only biodegradable and renewable but also possess several other advantages such as lightweight, low cost, high specific strength, high modulus, reduced tool wear and safe manufacturing process when compared with synthetic fibre composites. Several applications of natural fibre composites can be found in construction, packaging, furniture and automotive fields. Most of the interiors of the automobiles, like door panels, trunk liners, seal backs, packages, speaker trays, engine and transmission covers, are made using natural fibre composites.[7]

Govardhan goud [7] investigates the effect of fibre content and alkali treatment on tensile, flexural and impact properties of unidirectional Roystonea regia natural-fibre-reinforced epoxy composites. It is concluded that Tensile strength, tensile modulus and percentage of elongation of untreated and alkali-treated Roystonea regia natural fibre-reinforced epoxy composites were increased with increase in fibre content and are highest at 20% wt. Alkali-treated fibre composites have shown superior tensile properties than untreated composites. This study also reveals that maximum strength and maximum toughness can not be achieved simultaneously and optimum combinations of desired mechanical properties are possible only through careful design of composites.

K.L. Pickering et al. [8] studied recent developments in natural fibre composites and their mechanical performance provide an overview of the factors that affect the mechanical performance of NFCs and details achievements made with them.

D. Verma et al. [9] discussed the Coir Fibre as reinforcement in Polymer Composite materials because of their presence in abundance and found the potential use of the Coir fibre polymer composites.

Low-cost lignocellulosic fibres, such as bamboo, jute, sisal, hemp, flax, ramie, coir, etc. have received considerable attention in the recent years. These materials provide unique opportunities for utilization in fabricating inexpensive composite materials [10]. Pradeep, P. studied the effects of fiber combinations (palm fibre and coir fibre) with polyester resin on mechanical properties like tensile strength, flexural strength, impact strength, wear resistance and water absorption behaviour and concluded that the developed palm based composite possess superior property and can be recommended for fabrication of light weight high strength automobile parts. A.L.LEAO et al. [11] studied the utilization of pineapple leaf fibres as reinforcements in thermoplastic and thermosetting reins and examines the industrial application of PALF in production of low cost and light weight because of their wide availability, biodegradability, low density and non abrasive nature.

Researchers have found different factors that affect the strength of these natural fibres reinforced bio composite materials. Effect of fibre length and fibre content on mechanical properties of banana fibre/epoxy composite was studied by N. Venkateshwaran et al. [12]. Experiments are carried out as per ASTM standards to find the mechanical properties namely, tensile strength and modulus, flexural strength and modulus, and impact strength. In addition to mechanical properties, water absorption capacity of the composite is also studied. It was found that the optimum fiber length and weight ratio are 15mm and 16%, respectively for banana fiber/ epoxy composite. . Moisture absorption percentage of banana/epoxy composite for all length and weight percentage is around 5. . Also, the moisture uptake capability of the composite is greatly influenced by fibre content than length.

Natural fibre is composed of cellulose, hemicelluloses and lignin and rich in pectin. This resulted in the important problem of compatibility between fiber and matrix due to weakness in the adhesion between the surface fibres and the polymer matrix, so changing the fibre surface by treatment. It is the best method that researchers use to improve the strength and the compatibility between the interfacial bond strength [13].

Natural fibres have numerous advantages including renewability, sustainability, lightweight design, eco-friendliness, low cost, and sound abatement capability.

Unfortunately, impact properties of natural fibre reinforced composites cannot compete as well as their other mechanical properties with glass fibre reinforced composites. Hence, hybridization (use of more than one fibre in matrix) can facilitate the achievement of biocomposites with great load-carrying capacity and better impact energy absorption while being environmentally friendly [14].

2.2 HYBRID FIBRE BIOCOMPOSITES

Hybrid composites, made by using two or more different kinds of reinforcements, offer three main advantages over composites made from one kind of reinforcement. First, they provide designers with new freedom of tailoring composites to achieve required properties. Second, a more cost-effective utilization of expensive fibers such as carbon and boron can be obtained by replacing them partially with less expensive fibers such as glass and aramid. Third, they provide the potential of achieving a balanced combination of properties like strength, stiffness, and ductility. Hybrid composites have also demonstrated weight savings, reduced notch sensitivity, improved fracture toughness, longer fatigue life, and excellent impact resistance compared to composites made from single reinforcement.[15]

Asim Shahzad [15] studied the effect of hybridization of hemp fibres with glass fibres on the impact and fatigue properties of the hybrid biocomposites made from them. It has been found that when compared to hemp fibre composites, hybrid CSM glass–hemp fibre composites showed up to 75% increase in tensile strength and up to 15% increase in tensile modulus. Hybrid composites showed improvement in fatigue strength but no improvement in fatigue sensitivity was observed compared to hemp fiber composites.

Hybrid composites are systems in which one kind of reinforcing material is incorporated in a mixture of different matrices (blends), or two or more reinforcing and filling materials are presented in a single matrix or a combination of both the approaches. Different researchers concentrated on hybrid polymer composite material and found different results.

Suhad D. Salman et al. [16] reviewed the published and ongoing research work on Kenaf/synthetic and kelvar /cellulosic fibre reinforced composite material and found this as potential hybrid composite material for different industries.

Mohit Mittal et al. [17] have worked on development of PALF/Glass and COIR/Glass Fiber Reinforced Hybrid Epoxy Composites. The untreated and alkali treated PALF/Glass and Coir/Glass hybrid epoxy based composites were developed by hand lay-up technique, keeping the total fiber to resin ratio 30:70 v/v. The hybrid composites were characterized in terms of tensile, flexural, impact, and water absorption properties according to the ASTM D 638, 790, 256, and 570 standards respectively. The results showed that the 15/15 (v/v) PALF/Glass hybrid composite has higher tensile and flexural properties as compared to the other hybrid formulations. The alkali treated 15/15 (v/v) PALF/Glass composite possess 35.13% higher flexural strength than that of pure Glass-Epoxy composite. Alkali-treated composites have better mechanical and water resistance properties than that of untreated reinforced composites. This was because of the good interfacial adhesion between reinforcing fibers and polymer matrix. This was attributed to the synergistic hybridization between pineapple leaf fiber and glass fiber.

It has been found that hybridisation of kenaf and glass fibers have improved the degradation coefficient of final composite by Mohaiman J. Sharba et al. [18]. Kenaf hybrid composite is lightweight, environment friendly and has a considerable balance in static and fatigue strength, it is strongly recommendable for structural applications.

Utai. Meekum et al. [19] investigated on manufacturing of lightweight sandwich structure engineered wood reinforced with glass fibres and found that this hybridised composite material have better mechanical and durability properties.

Suhara Panthapulakkal et al.[20] have found that natural fibres based thermoplastic biocomposites have low strength which can be increased by hybridization with small amounts synthetic fibres and makes them suitable for technical applications such as automotive interior parts Incorporation of glass fibres is found to improve the tensile, flexural, and impact properties of short hemp fibre composites. A value of 101 MPa for flexural strength and 5.5 GPa for the flexural modulus is achieved from a hybrid composite containing 25 wt % of hemp and 15 wt % of glass.

Mostafa Yusefi et al.[21] investigate the reinforcing effects of cow dung (CD) on poly(lactic acid) (PLA) properties. It is found that the potential of using PLA/CD biocomposites in some applications from automotive, structural, housing, furniture and decking are huge due to their excellent thermal and mechanical properties and their eco-friendly nature and biodegradability makes them an attractive option compared to commercially available fibre/polymer composites.

M H Zin et al.[22] studied on the fabrication method of bio-sourced hybrid composites for aerospace and automotive applications. It is found that Each method is unique and some of them can be combined or integrated to achieve better results. For large size aircraft components, methods such as hand lay-up, spray-up, vacuum bagging and vacuum infusion are suitable due to their ability to suit with a big mould and working area. Meanwhile, for intricate geometry part, methods such as pultrusion, compression moulding and resin transfer moulding are more appropriate due to the pressure applied during fabrication process.

A successful attempt has been made on enhancing the properties of hybrid kenaf/coconut fibres reinforced vinyl ester composites by incorporating nanofillers obtained from coconut shell by H.P.S. Abdul Khalil et al. [23] and found Incorporation of 3% of nano fillers resulted in improved mechanical properties of composites including tensile strength, tensile modulus, flexural strength, flexural modulus, and impact strength. This was due to the incorporation of high density coconut shell nanoparticles in low density vinyl ester matrix. Nanoparticles tend to fill the voids and led to the reduction of void content in the hybrid composites.

Seong Sik Cheon et al. [24] investigated the impact energy absorption characteristics of glass fiber-reinforced hybrid composites. The progressive impact fracture model that was proposed to calculate the dynamic fracture load and energy absorption characteristics during the impact of composite specimens was found to predict relatively well the experimentally obtained impact energy absorption characteristics.

2.3 MATERIALS USED FOR DIFFERENT AUTOMOTIVE PARTS

J. Sahari et al. [25] studied the development and properties of natural fibre reinforced biodegradable polymer composites. They are the materials that have the capability to fully degrade, compatible with the environment which can compete with fossil plastic materials and can be used for wide range of applications.

Application potential of composite materials in automotive industry is studied by Ing. Dušan Sabadka [26] and concluded that composite materials has indisputable advantages for the automotive manufacturing but limited their usage due to high production cost.

Sistanley Jones Lima Bispo et al.[27] analysed the Mechanical Properties of Polypropylene Biocomposites Reinforced with Curaua Fibre and found that it is feasible to use these materials in industry, facilitating its recycling and improving its final mechanical properties. The addition of curaua fibers in PP reduces the effect caused by thermal degradation of polypropylene during the extrusion process and in the HDT test the addition of curaua fibers increased the heat deflection temperature of the composite, improving its thermal stability and providing a quality material in high-temperature applications.

Paul A Fowler et al.[28] investigated technological challenges being faced in bringing biocomposite materials to a wider market together and found the potential solutions of the problem. It is stated that investment is still needed in research and development if a sustainable biocomposites industry is to be established.

Swarup Kumar Nayak et al. [29] worked to prepare a biodegradable biocomposites by extracting cellulose from natural fibre which had extracted from century plant of agavaceae family and intended to replace existing materials with a biodegradable composite that are prepared from natural fibres which is biodegradable, high stiffness, low weight, renewable, non-toxic, eco-friendly to the environment.

B. Narayana Swamy et al. [30] performed 14ehaviour and analysis of light vehicle by Pro-E and ANSYS software respectively. From the results, it is observed that the polymeric composite heavy vehicle chassis is lighter and more economical than the conventional steel chassis with similar design specifications

Natural fiber components in the automotive industry can provide numerous advantages compared to synthetic conventional such as reduction of weight and cost, recyclability, renewability and in addition to eco-efficiency. To fulfil application in automotive structures, a few modification in design, fibre treatment, the use of the additive, material selection and method for production are necessary.[31]

Arvind. S. Sorthiya et al. [32] studied the various researches done in past to reduce weight of flywheel by changing design and materials. The main problem with flywheel is its higher weight which results in lower rotational speed. It was found that flywheel made composite materials have lightweight, higher specific energy, low values of stresses and decrease in deformation.

Crash analysis of a composite car body is performed by L Praveen et al. [33]. In this research hatch back body of car is designed by using Solid works 2016 software, Crash analysis is performed in Ansys workbench software by Explicit Dynamic module by using different material for car body and different speed of car body, stresses formed and deformation and areas of deformation of car body are found after analysis. Four different materials such as aluminium alloy, aluminium metal matrix (KS1275), and Kevlar-49 and High strength carbon fibre are used as car body materials. It was concluded that Kevlar -49 is best material for car body as it provide max safety and less weight resulting in lesser fuel consumption also. According weight optimization Kevlar -49 showing least weight i.e. 641.668kg which is very less compare to generally used aluminium alloy material.

Yuxuan Li et al. [34] studied Glass mat thermoplastic (GMT) material using the split Hopkinson pressure bar technique to analyze its dynamic mechanic characteristic under different strain rate. The computer simulations is carried out for a car crashing into a rigid wall before and after some of its parts are replaced from original steel sheet to

GMT sheet. The simulation result shows that GMT material replacement has little impact on automobile body crashworthiness and strength while reducing the body weight by 41 kg.

A thermoplastic composite roof access door that replaced an aluminium access door was successfully designed, analyzed, and manufactured using a form-fit-function approach for a mass transit bus by Haibin Ning et al. [35]. It has been found that the manufactured composite door possesses paintable and aesthetically appealing surface, enhanced rigidity with 42% reduced free-standing deflection compared to the aluminium counterpart, and 39% weight saving over the aluminium baseline, reduction in vibration and noise emission from the roof.

In a research work, an open section thin-walled thermoplastic composite frame segment (sub-element) of a mass transit bus was designed, analyzed and manufactured to replace a conventional metal-based design. Finite element analysis (FEA) of the frame configurations was carried out with the aid of Pro/Engineer, Hypermesh and ANSYS. A successful design concept to manufacture strategy of the open thin-walled carbon/PPS thermoplastic composite frame segment was demonstrated [36].

The behaviour of twill type woven fabric carbon/epoxy composite T-joints, located at the intersection of the B-pillar with the longitudinal rocker of a car body, has been investigated using experimental and numerical methods by Ermias Gebrekidan Koricho et al. [37]. It can be conclude that numerical results for stress distribution and load carrying capacity of T-joints are in a reasonably good agreement with experimental results.

2.4 DESIGN AND ANALYSIS FOR CAR BUMPERS

V. Kleisner et al. [38] analysed a bumper reinforcement made of composite materials. The PAM-Crash software is used for the simulation. After modification of the material structure, two profiles are found to have greater stiffness that the original steel structure and they are selected for latter damage analysis. The damage analysis proved one of the profiles to be a suitable replacement for the original part as it showed no fracture and, moreover, a great mass reduction could be achieved with the use of the composite structure.

Modelling of car bumper made from new composite materials is studied by Adrian Calienciug et al. [39].Study on new composite materials showed that the composite material of glass fiber reinforced nylon has a breaking strength greater than fibre glass reinforcing fabric and ABS.

Alen John et al. [40] investigated the Composite Materials used for Automotive Bumper in Passenger Vehicles. The commonly used composite materials used for the automotive bumper design are Carbon fibre reinforced epoxy, Glass fibre reinforced epoxy, Carbon fibre reinforced polypropylene, Glass fibre reinforced polypropylene, Glass fibre vinyl ester Sheet Moulding Compound (SMC), and Glass fibre reinforced polyester. All the composites have some desirable properties like lightweight, corrosion resistance, high strength to weight ratio
and high durability. In order to find an optimized composite for the automotive bumpers both static and dynamic study has to be carried out. The dynamic study includes impact analysis and modal analysis.

Design and Fabrication of Composite Bumper for Light Passenger Vehicles is carried using E- Glass/ Epoxy bidirectional laminates out by S. Prabhakaran et al. [41]. Model of the bumper is analysed in ANSYS. Compared to steel bumper, the composite bumper is found to have 64% higher factor of safety, 80% less in cost and the weight reduction of 53.8%. It is concluded that fiber reinforced composite material is a suitable material for manufacturing the bumper.

Alen John et al. [42] have done modelling and Analysis of an Automotive Bumper used for a Low Passenger Vehicle using software CATIA, ANSYS and ABAQUS. It can concluded that carbon composite is the best material which can use as the bumper material when compared to Aluminium B390 alloy, Chromium coated mild steel

M.M. Davoodi et al. [43] studied the Concept selection of car bumper beam with developed hybrid bio-composite material. The low-speed impact test was simulated under the same conditions in Abaqus V16R9 software. It is concluded that double hat profile (DHP) with defined material model can be used for bumper beam of a small car and resulted that bio-based composite material has a potential to be used in automotive structural components by structural optimization.

A study focused on the mechanical properties of a hybrid kenaf/ glass epoxy composite for utilization in a passenger car bumper beam.is performed by M.M. Davoodi et al. [44]. The results indicated that some mechanical properties such as tensile strength, Young's modulus, flexural strength and flexural modulus are similar to typical bumper beam material called glass mat thermoplastic (GMT), but impact strength is still low, and shows the potential for utilization of hybrid natural fibre in some car structural components such as bumper beams.

Siddhant R Kale et al. [45] presented the analysis & optimization of automotive bumper beam with composite materials using FEA. The Deformation and Impact force for various materials used for bumper like Structural Steel, Aluminium alloy, PVC Foam, SAN Foam, Resin Epoxy, Carbon Epoxy and S2 Glass Epoxy are calculated by the use of different software. It is found that S2 glass epoxy is performing well when compared to other materials. The stress is diminished by 45.14% and the deformation is decreased by 55.25%.

Vysyaraju Neelima et al. [46] done the design and analysis of bumper beam with composite materials and conventional materials like steel, magnesium and aluminium were studied and their impact behaviour is discussed. It was proposed that S2- glass epoxy and the new and modified bumper is performing very well when compared to the existing bumper beam. In the design of the automotive bumper beam, the deflection of the bumper beam should be below the critical value; 20mm is considered in that study. The S2 Glass epoxy material with 7 mm thickness has shown better stress and deflection results incorporative to steel. In order to achieve higher stability, cost effective and manufacturability of the product, the S2 glass epoxy is proposed that could replace the steel, based on strength and weight criteria.

The careful design and analysis of bumper beam effective parameters can optimize the strength, reduce the weight, and increase the possibility of utilizing biodegradable and recyclable materials to reduce the environmental pollution and toxicity. [47].

Ramin Hosseinzadeh et al. [48] done the Parametric study of automotive composite bumper beams subjected to low-velocity impacts. SMC composite was proposed to replace GMT and changes in the structure showed very good impact behaviour compared with other structures, which all failed and showed manufacturing difficulties use of more dense materials. Conventional materials (steel and aluminium) showed inappropriate characteristics such as structural failure and weight increase at the time their specifications were assigned to the model.

R.R. Magalhaes et al. [49] presented a method for stress analysis in the automotive industry. A front bumper fascia was taken as a case study to solve a problem involving stress analysis using the BEM sub-model. It is found that the results confirm the consistency of the proposed procedure compared to the finite element method (FEM), a consolidated method for stress analysis in the automotive industry.

CHAPTER 3

METHODOLOGY

3.1 MATERIAL USED:

In this research work, alkali-treated Pineapple and glass fibres reinforced hybrid biocomposite is used as material for the car bumper which is taken from the literature work. The properties of this hybrid biocomposite material used for the car bumper are taken from Reference [17].

Pineapple leaf fibres (PALF) and synthetic glass fibres are used as reinforcement with epoxy resin as matrix material. When compared to other fibres pineapple leaf fibres is better because pineapple leaf fibre contains high cellulose (70-85%) content which resulted in better flexural and tensile properties than that of jute, flax, sisal and cotton fibres. The other advantages include that they are found in abundance, lightweight in nature, favourable aspect ratio, and low micro fibrillar angle. Hybridization with synthetic glass fibre and alkali treatment of the material increases the mechanical strength which makes them suitable for the development of car bumper.

The properties of the PALF and glass fibres reinforced hybrid biocomposite material are shown in the following table:

Properties of material	Values
Density (g/cm3)	1.142
Tensile strength (MPa)	49.28
Young's modulus (GPa)	1.57
Flexural strength (MPa)	152.21
Flexural modulus (GPa)	6.86
Poisson ratio	0.31

Table 3.1: Properties of PALF/glass fibres reinforced biocomposite

3.2 DESIGNING OF THE CAR BUMPER

In this research work, rear bumper of the ambassador car has been designed. The dimensions of the car bumper have been taken from Reference [42] with some modifications in the geometry. CATIAV5R20 is used for modelling this rear car bumper.

The designing of the rear car bumper involves the following steps:

Open CATIA v5 software.

STEP 1: First click on the start icon, select mechanical design and then part design.

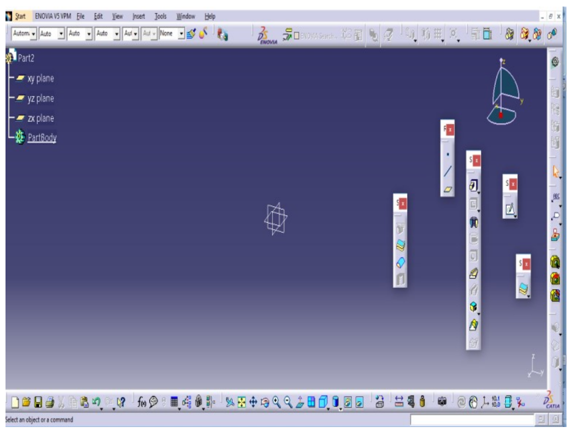

Fig. 3.1: Part design module of CATIA

STEP 2: By selecting the X-Y plane, go the sketcher option of the software as shown in Fig. 3.2

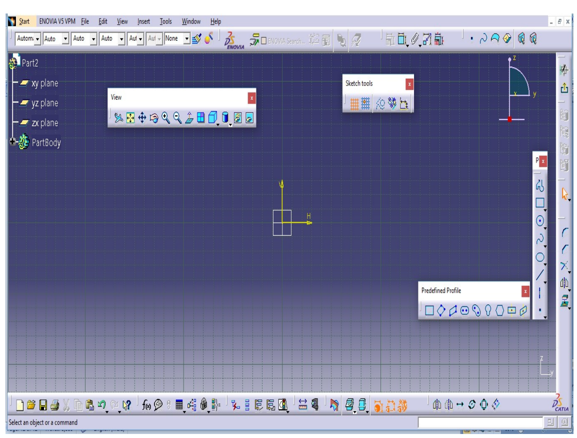

Fig. 3.2: Sketcher module of CATIA

STEP 3: Then by using different features of profile toolbar like line, arc etc. Draw the basic sketch of the car bumper giving the dimensions to the car bumper. A line of 1132.50mm is drawn, connected to two arc of radius at the end of line of 251.03 mm. And a width of 45.25mm is given and the sketch is closed as shown in Fig.3.3

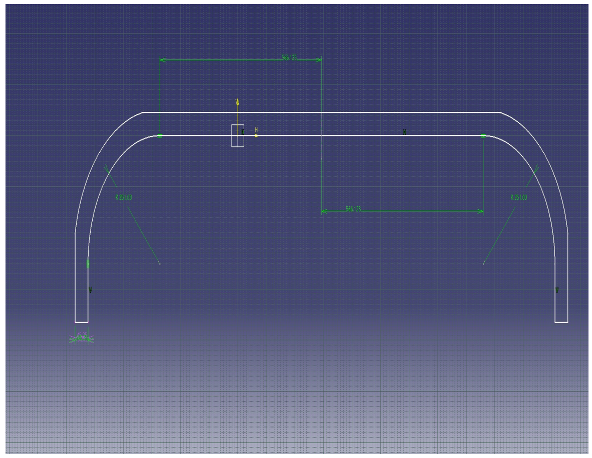

Fig. 3.3: Basic sketch of car bumper

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STEP 4: Exit the sketcher module using exit workbench option.

STEP 5: Now convert the two dimensional sketch to three dimensional drawing by using pad option from sketch based features of part design. The sketch is extruded 64mm in z direction.

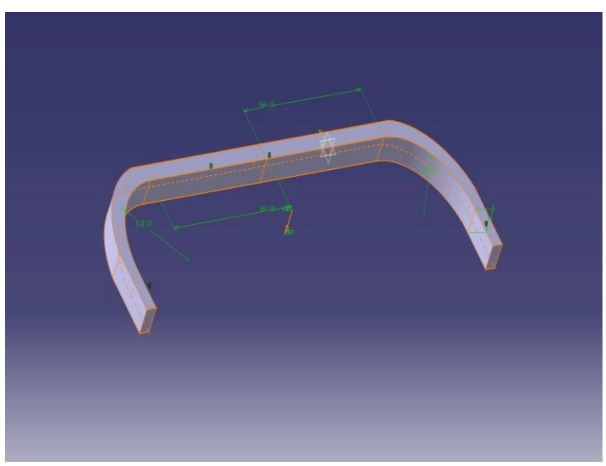

Fig. 3.4: Design of bumper after extruding in z direction

STEP 6: Then by giving a thickness of 2mm, remove the remaining portion of the bumper using the pocket option.

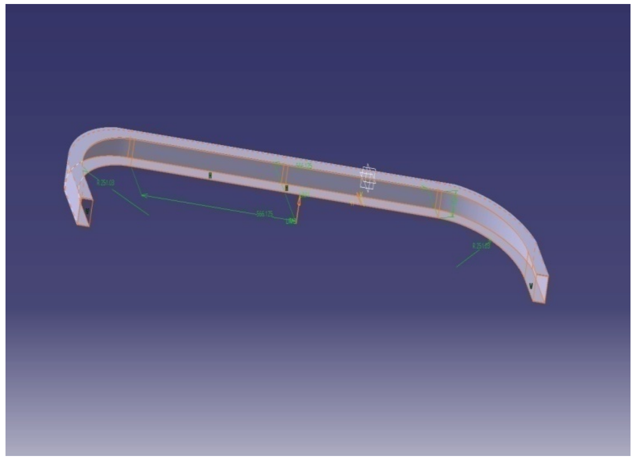

Fig. 3.5: Design of bumper after giving thickness

STEP 6: Now draw two circles of 25 mm at distance of 383.175 from centre. Extrude them by giving a thickness of 2mm up to a length of 30mm.

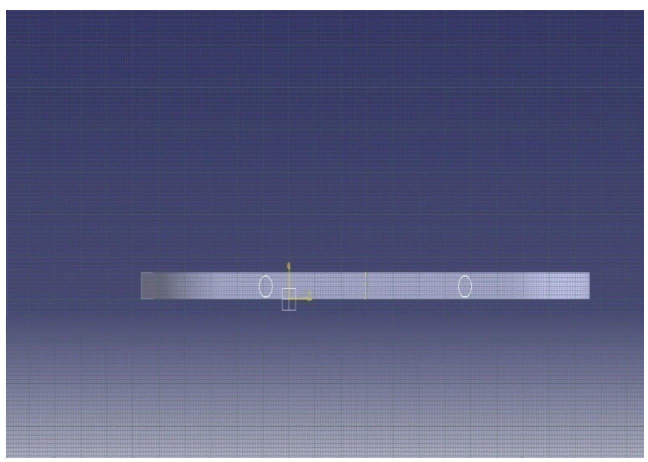

Fig. 3.6: Sketch of supports are drawn on bumper

STEP 7: After performing all the necessary steps we get the final model car bumper as shown in the Fig.3.7

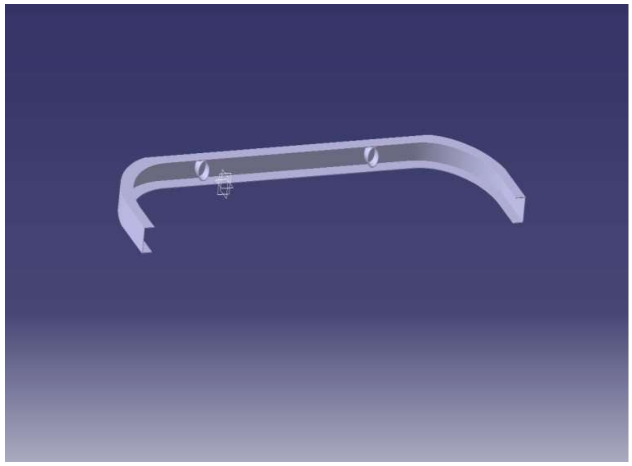

Fig. 3.7: Basic design of car bumper

STEP 8: Save the cad model of the car bumper made.

STEP 9:Go to the drafting option from start menu. Select the sheet size as A4 and get the different views of the model as shown in the Fig.3.8

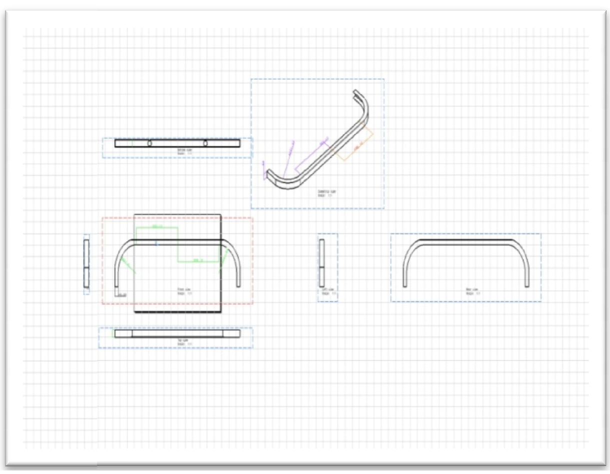

Fig. 3.8: Drafting of car bumper showing its different views

3.3 FINITE ELEMENT ANALYSIS OF THE CAR BUMPER

Finite element analysis of the car bumper is done within the workbench of ANSYS 18.1 software.

The ANSYS computer program is a used for the different purpose in the finite element analysis, which can be used for analysing different problems of industrial models.

Different problems are solved in ANSYS which includes static and dynamic structural analyses; steady-state problems, mode frequency and static or time-varying magnetic analyses problems and transient heat transfer problems. Finite element analysis of the model is done in the workbench of the software ANSYS18.1.The design of the car bumper obtained is saved in .stp format and imported in ANSYS workbench for the static and impact analysis of the cad model.

3.3.1 Static Analysis of car bumper

The static analysis is carried out to find out the deformation, stress distribution over the structure. Boundary conditions play an important role in the static analysis of the model and load applied can be calculated as shown below:

Mass of Ambassador car =1600 kg

The mass of 4 persons can be taken as =300 kg

Sum of both the mass =1600+300

=1900 kg

Assume velocity of the car =36 km/hour

= 10 m/s.

Let the car is hitting the same ambassador car and assume the stopping time as 0.1sec.

Deceleration of the car =v-u/t

= (10-0)/0.1

= 100 m/s2

Force on the front face of bumper = m*a

=1900*100

= 190 KN

Front face of bumper has area =l*b

=1133*64mm2

=0.072512m2

Here l and b are length and width of front face of bumper

Pressure acted on the bumper = F/A

=2612322.64 N/m2

= 2.61*106 N/m2

For the static analysis.of car bumper we will perform the following steps:

STEP 1: Save the cad model of the bumper made as Step file in .stp format.

STEP 2: Open the workbench of ANSYS 18.1

STEP 3: From the list of analysis system choose the Static Structural option in which have different options as shown in Fig.3.9

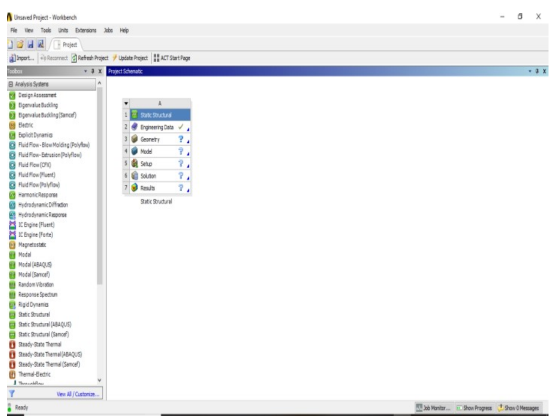

Fig. 3.9: Different analysis option in ANSYS

STEP 4: In the Engineering Data option, define the material by entering the values of density, Young's Modulus and Poisson's Ratio as 1.142 g/cm3, 1.57GPa and 0.31.

STEP 5: Now we import the saved step file of the car bumper in the Geometry option available.

STEP 6: Right click the Model option and select Edit option from the list opened. Then a new screen is opened with the car bumper imported in it as shown in Fig.3.10

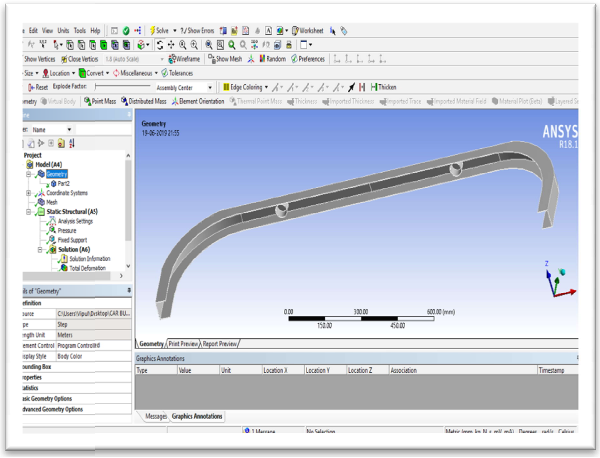

Fig. 3.10: Imported model of car bumper in ANSYS

STEP 7: Apply the defined material to the car bumper structure in this step.

STEP 8: Meshing the car bumper is done by using the Mesh option available in the analysis.

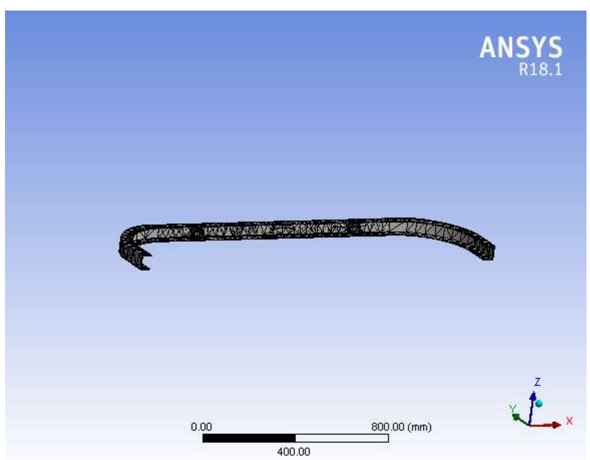

Fig. 3.11: Meshing of car bumper

STEP 9: Now apply the boundary conditions to the car bumper required for static analysis.

STEP 10: Fix the two extruded supports at the back face of the car bumper by using the Fix support option.

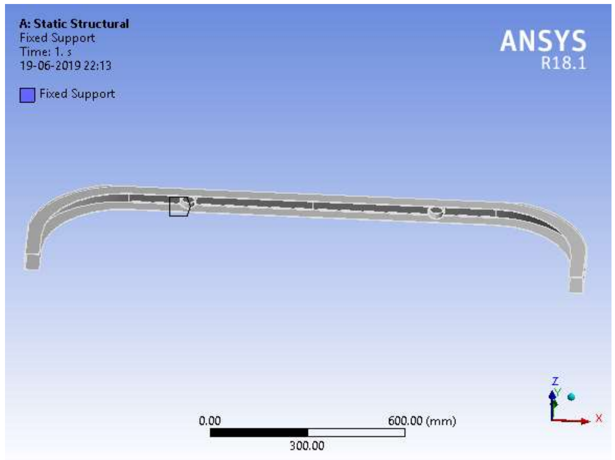

Fig. 3.12: Fix support in car bumper

STEP 11: A uniformly distributed load (pressure force) of 2.61MPa which is already calculated is imposed on front face of the bumper.

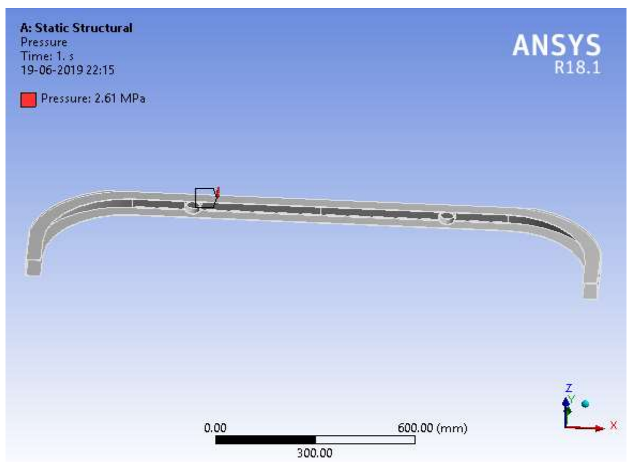

Fig. 3.13: Pressure applied to front face of car bumper

STEP 12: Finally in the solution option of the tree we insert the deformation, Von Misses Stress and other requirements for the analysis.

STEP 13: Right click the on the solution option and click on Solve option of the menu generated.

STEP 14: The calculation are done by the software and values of stress, deformation are generated.

3.3.2 Impact Analysis of car bumper

Impact analysis of car bumper is done by performing the following steps:

STEP 1: A wall is made against the car bumper at a distance 50 mm for the impact analysis and the file is saved in .stp format for analysis in ANSYS.

STEP 2: Impact analysis is performed in the Dynamic-explicit option available in workbench of ANSYS.

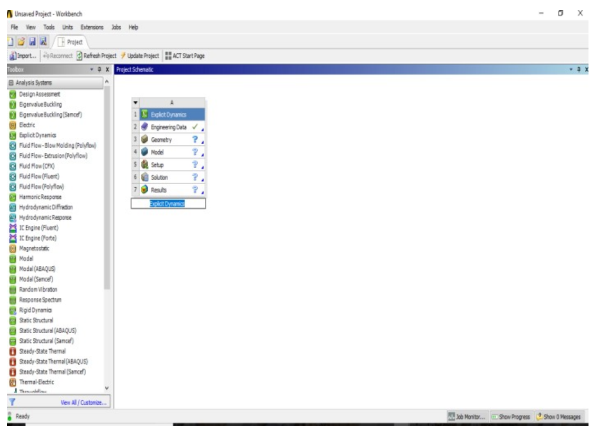

Fig. 3.14: Dynamic-Explicit option of ANSYS

STEP3: Material is defined in Engineering data option, step file is imported in Geometry option and edited in Model option of the analysis similar to static analysis after which a new screen will open.

STEP 4: Material defined is applied to the imported car bumper and material applied to wall is concrete which is available in the library of the ANSYS. Meshing is done as performed earlier in static analysis.

STEP 5: Next step is the application of the boundary condition which involves fixing the wall at which the car bumper is crashed.

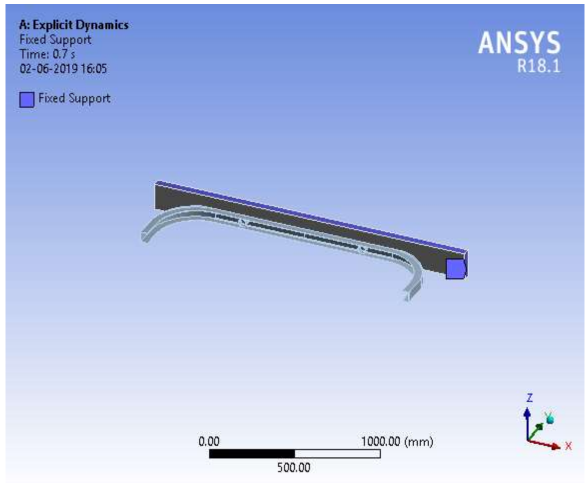

Fig. 3.15: Wall is fixed for impact analysis

STEP 6: For impact analysis, a velocity of 36km/hr which is equivalent to 10m/s is given to the bumper in the y-direction of the model which is shown in Fig.3.16

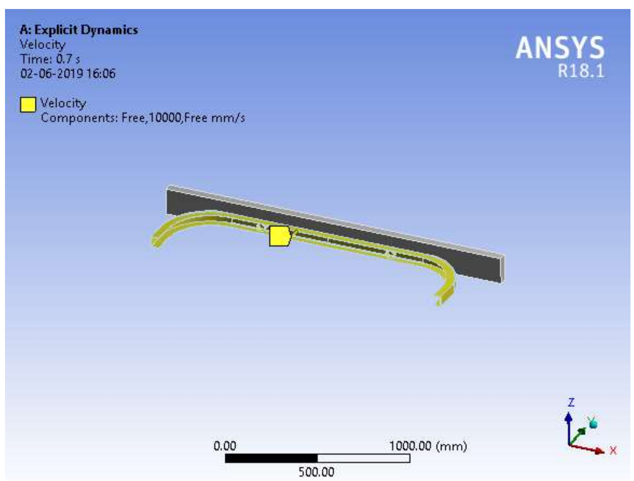

Fig. 3.16: Velocity of 36km/hr is given in y direction

STEP 7: In the analysis settings option, end time is entered as 0.007 seconds for the analysis.

STEP 8: The parameters to be calculated are inserted in the solution option of the analysis. Total deformation and Von Misses Stress are required to calculate.

STEP 9: Right click the on the solution option and click on Solve option of the list generated.

STEP 10: The calculation are done by the software and values of stress, deformation are generated.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS OF FINITE ELEMENT ANALYSIS OF CAR BUMPER

4.1.1 Results of static analysis

The results are obtained after the finite element analysis of the car bumper in workbench of ANSYS. The deformation value for static analysis using Palf and glass fibres reinforced biocomposite material is 1584.1mm as shown in Fig.4.1.

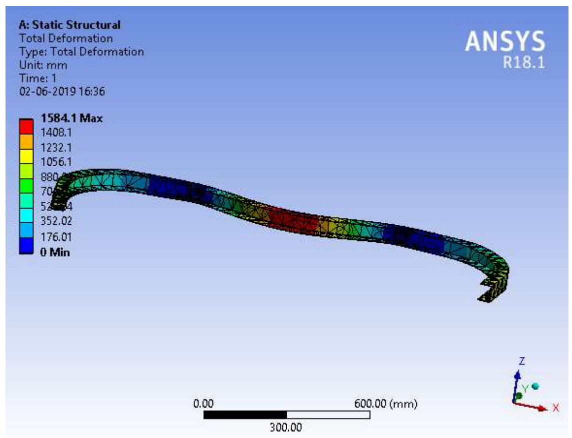

Fig 4.1: Deformation obtained for static analysis

4.1.2 Results of impact analysis

After completing all the necessary steps, results are obtained for the impact analysis. The value of deformation for the impact test is 465.65mm.

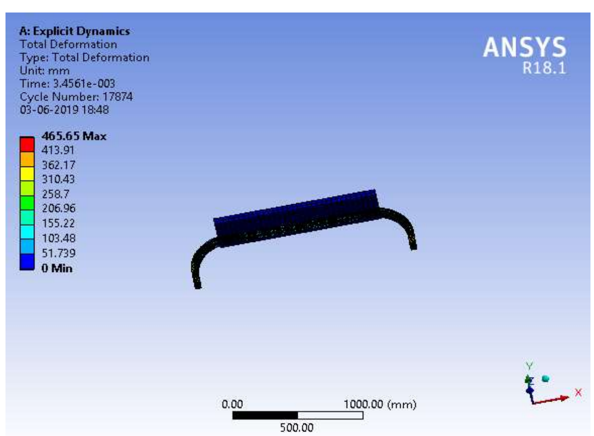

Fig. 4.2: Deformation obtained for impact analysis

These deformation values are large so we need to optimize the design of the bumper by performing some structural changes to use the biocomposite material in automotive car bumper.

4.2 DESIGN OPTIMIZATION OF BASIC CAR BUMPER

To replace the car bumpers made of steel and aluminium with the biocomposite material some design modifications need to be performed in the basic design of car bumper. Optimization in geometry will lead to increase in improvement of the mechanical strength. There are different effective parameters to improve the mechanical performance of the natural fibre reinforced biocomposite car bumper which is as follows:

Strengthen rib: Strengthening ribs raise the distortion resistance, improves rigidity and provides structural stability. So three strengthening ribs are provided in front and rear portion of the basic design of car bumper. One rib is provided in the centre of the bumper and other two at a distance of 21 mm from the centre rib. These modifications are done using CATIA by generating the plane and drawing the sketch at these planes. The sketches drawn are extruded and it forms the rib at the desired position in the car bumper.

Cross-section: Giving a better cross-section to a structure will magnify the strength, structural stiffness and damping capability. In this research, the cross-sections of the bumper are changed to I SECTION to increase its strength and reduce deformation.

Thickness: Increasing the thickness of the front of the car bumper improves strength and energy absorption. The value of deformation is large at the front face of the car bumper so the thickness is increased at this face of bumper. To increase the strength thickness of front face is increased from 2mm to 4mm. However, it increases the weight of bumper which can be compensated due to the low density of PALF and glass fibres reinforced bio-composite material.

We perform the above mentioned geometric changes in the basic design of the car bumper in CATIA and make our final design. Several designs are made by incorporating the structural changes and tested them in ANSYS. After analysing, material is removed from the portion wherever required and strength is provided at the weaker portions of the bumper. So, after making several designs and testing them in ANSYS the final design is made which can be viewed in the Fig.4.3

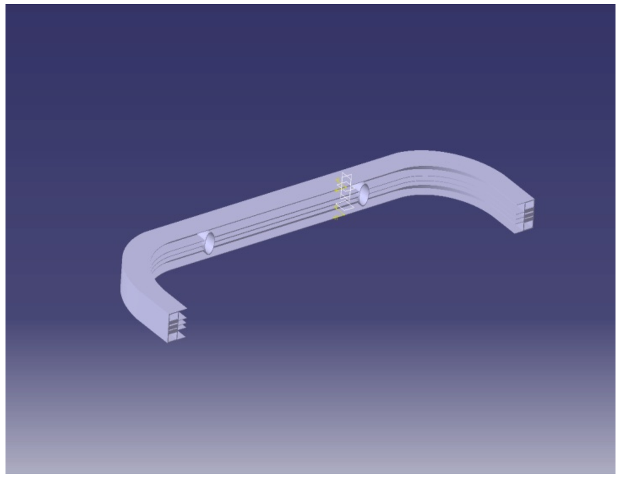

Fig. 4.3: Isometric view of design after geometric optimizations

Drafting of the car bumper is done in the software after the design modifications. Different views are generated with the dimensions in the drafting of the bumper which can be seen in the Fig.4.4

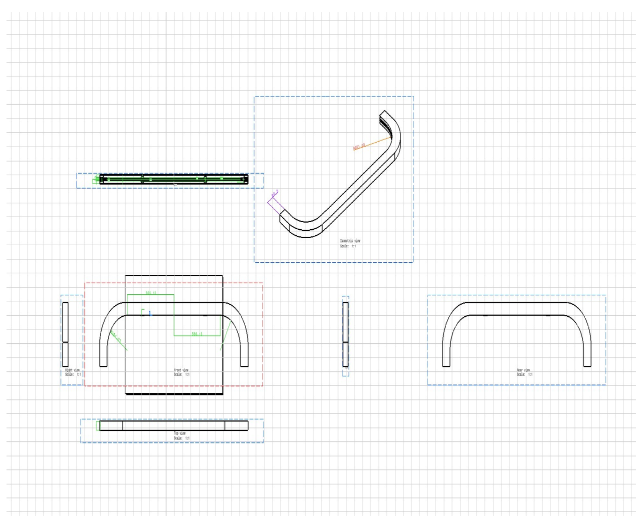

Fig. 4.4: Different views of car bumper after design optimization

Finite element analysis of the car bumper is performed after the design modifications provided in the car bumper. Static and impact analysis is performed again to find the values of deformation and stresses.

4.2.1 Results for static analysis of car bumper after design optimization

Results for static analysis are obtained using ANSYS for the hybrid biocomposite material, the maximum Von Misses stress value is 1696MPa. Von Misses stress gives the information of the load bearing capacity of the structure.

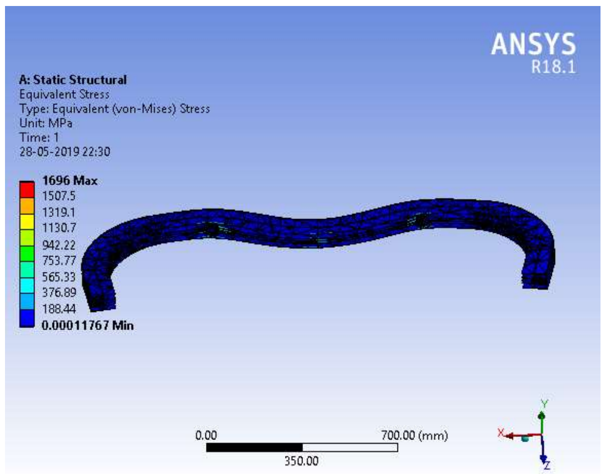

Fig. 4.5: Von Mises' stress distribution for static analysis

The deformation value obtained is 149.54 mm. The results after optimization of design show a large decrease in value of deformation.

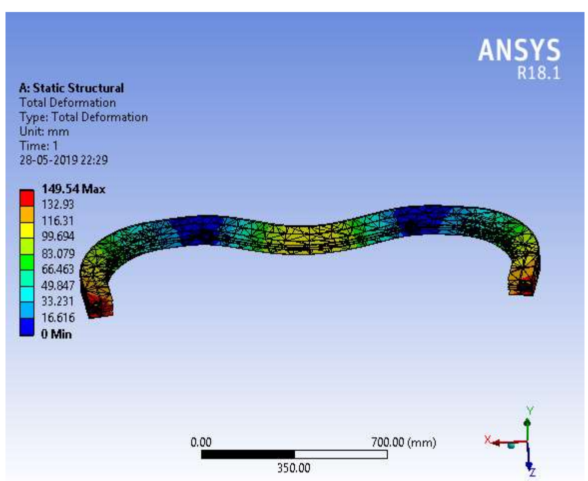

Fig. 4.6: Deformation obtained for static analysis after design optimization

4.2.2 Results for impact analysis of car bumper after design optimization

The impact analysis was done on the PALF-glass fibres reinforced biocomposite material by providing the car bumper with a velocity of 36km/hr against a wall. Biocomposite material has the value of the maximum stress which is equal to 1374.8MPa.

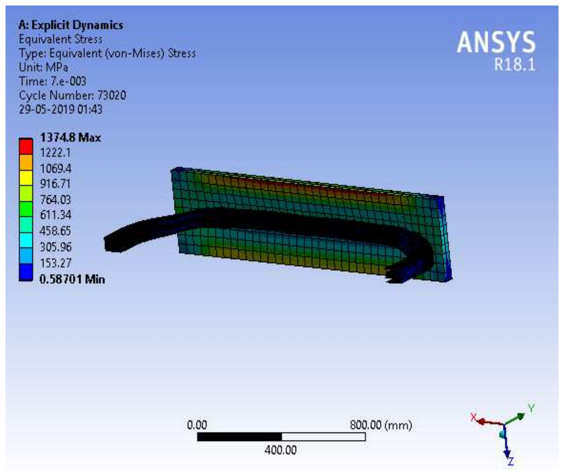

Fig. 4.7: Von Mises' stress distribution after impact test

It shows the value of deformation which is 92.49mm and is seen at the front face of bumper. This value is decreased after design optimization from initial value of 465.65mm.

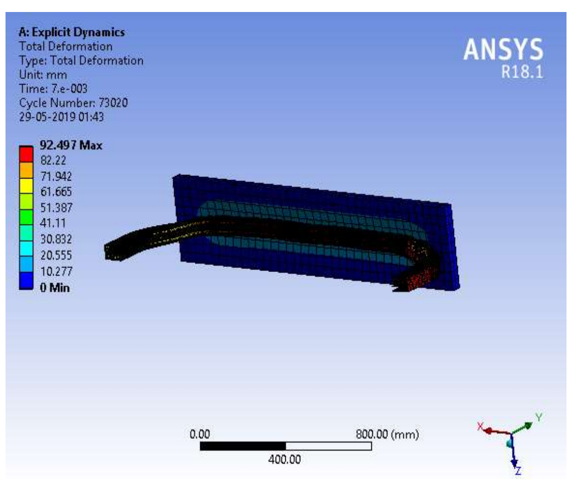

Fig. 4.8: Deformation obtained for impact analysis after design optimization

4.3 COMPARISON OF CAR BUMPER MADE FROM BIOCOMPOSITE MATERIALS WITH THE TRADITIONAL MATERIALS

The finite element analysis for the car bumper made of steel and aluminium has already been performed in the previous research work. The values of stresses and deformation for the car bumper made of Chromium coated mild steel and Aluminium B390 alloy during static and impact analysis under similar loading condition can be obtained from the Reference [42] and shown in table 4.1 and 4.2. We can compare these values of deformation and stresses with the results obtained from finite element analysis of car bumper made of PALF and glass fibres reinforced biocomposite material having geometric changes in design.

Table 4.1: Various stresses and deformation obtained during static analysis.

Material	**Max. Von mises Stress (MPa)**	**Deformation (mm)**
Chromium coated Mild Steel	958.7	273.2
Aluminium B390 alloy	843.2	422.4
PALF/glass fibres hybrid biocomposite	1696	149.54

Table 4.2: Various stresses and deformation obtained during impact analysis

Material	**Max. Von mises Stress (MPa)**	**Deformation (mm)**
Chromium coated Mild Steel	971	151
Aluminium B390 alloy	846	196
PALF/glass fibres hybrid biocomposite	1374.8	92.49

It can be observed from the table that the value of deformation is lowest for both the static and impact analysis in case of PALF/glass fibres reinforced hybrid biocomposite material. When compared with the other materials, biocomposite material shows the maximum value of stress and hence it is the strongest material.

The mass of the car bumpers made from different materials can be obtained by using ANSYS Workbench. The material properties of Chromium coated mild steel, Aluminium B390 alloy and this biocomposite material are entered into software and values of the mass of different bumpers are evaluated as shown in table 4.3. The mass of the bumper made from PALF and glass fibres reinforced biocomposite material is least when compared to the other two materials.

Table 4.3: Mass of different bumpers

Material	**Density (kg/m3)**	**Mass of bumper (kg)**
Chromium coated Mild Steel	7800	12.94
Aluminium B390 alloy	2710	4.49
PALF/glass fibres hybrid biocomposite	1142	4.46

CHAPTER 5

CONCLUSION

Biocomposite materials have the potential to provide an alternative to traditional steel and aluminium in various applications because of their low density, biodegradability and ease of recyclability. Pineapple leaf fibres and glass fibres reinforced biocomposite material has good mechanical properties which make them suitable for use in structural applications in automotive components. The use of this biocomposite material in automobiles can reduce weight, which improves their performance and lowers CO2 emissions.

An Ambassador Car bumper is designed in software CATIA V5R18 and imported to the workbench of ANSYS 18.1 for static and impact analysis. It has resulted that biocomposite materials have the potential to be used in automotive car bumpers by structural optimization. The results of finite element analysis proved the replacement of traditional steel and aluminium bumper with hybrid PALF and glass fibres reinforced biocomposite material as it showed the least deformation value and a great reduction in mass.

The value of deformation for static analysis is decreased to 149.54mm from 1584.1mm and 465.65mm. to 92.49mm for impact analysis after the design optimization. The mass of the bumper made of this hybrid biocomposite material shows a 65.53% reduction of mass when compared to traditional steel bumpers.

The use of PALF and glass reinforced biocomposite material for the development of car bumper will lead to environmental sustainability, weight loss of vehicle, lower fuel consumption and low pollutant emissions of greenhouse gases.

In future work, a numerical analysis can be done after using properties of these materials for the validation of the result. Also, the use of fully biodegradable material in structural components of automobile parts is yet to be seen.

Following conclusions can be made after the analysis of the car bumper:

- Use of biocomposite material promotes the concept of the environmental sustainability and helps to reduce the amount of non-biodegradable and non-recyclable waste produced from automotive sector.

- By design optimization we can use pineapple and glass fibres reinforced biocomposite material for the structural application.

- After the design optimization the value of deformation for static analysis is decreased to 149.54mm from 1584.1mm and 465.65mm to 92.49mm for impact analysis.

- Car bumper made of biocomposite material are lightweight and shows 65.53% reduction in mass when compared to bumpers made of steel. This will lead to a weight loss of vehicle resulting in lower fuel consumption.

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