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DESIGN AND ANALYSIS OF INTEGRATED FRAME USING COMPOSITEMATERIAL

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Abstract
Nowadays, transportation industry plays major role in the economy of modern developing and industrialized countries. Weight reduction is now the main issue in automobile industries. Chassis is the main support structure of the vehicle which is also known as 'Frame'. It bears all the stresses on the vehicle in both static and dynamic conditions. Every vehicle whether it is a two- wheeler or a car or a truck has a chassis-frame. In present scenario, light weighting becomes a main issue of 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 light weight integration into vehicle, and maximizing their fuel economy. Our project is on Designand Analysis of Integrated frame using Composite materials likeEpoxy E-Glass, Epoxy S-Glass and Epoxy Carbon. These are comparing with conventional material like 4130. Aim of our projectis to reduce the overall weight of the frame to increase performance, fuel efficiency of the vehicle without compromising on Strength and Stiffness of integrated chassis frame. Designing integrated frame using different composite materials by using CATIA V5 software andanalyzing the designed model using ANSYS software. Integral Frameis going to be simulated with static analysis and Dynamic analysis.

I. Introduction

1.1 Chassis Development

A key aspect in the design and analysis of an ICE vehicle is the structure that encompasses all other subsystems of the vehicle. With mass optimization being critical in achieving the desired vehicle performance and minimizing material cost, composites have become integral with chassis design. By reducing the mass of the body and chassis the load on components such as suspension is reduced, along with the required energy to achieve the same level of vehicle performance. This allows for a creating a knock-on effect. Carbon fiber chassis have become synonymous with modern high- performance supercars, to the extent that the use of the material has significant marketing implications. In order to design composite monocoque chassis structural analysis would need to be done toensure the chassis could withstand all the loading that would beexperienced under normal driving conditions, as well as irregular shock loading, such as pothole or kerb impacts which cause high
loading but are not an 2 Everyday occurrence. The CATIA V5 and ANSYS software, which is capable of design and easing finite element analysis of composite structures, was applied for design and analysis purposes.

1.2 Chassis Design

A chassis is a structure whose function is to connect the wheels to thevehicle and absorb all the torsion and bending loads the vehicleexperiences, while neither sagging, twisting, nor deflecting excessively. The chassis needs to be able to support all the required components of the vehicle and offer adequate mounting points.

1.3 Contemporary Chassis Designs

Several types of chassis designs are currently used in vehicles. The defining characteristics of each design may remain constant, however,the method of manufacture and materials used are constantly changing as new developments arise. For instance, composite body vehicles are becoming more prevalent in modern designs.

1.3.1 Space Frame

A space frame chassis forms of circular or rectangular cross section tubing welded together to form a triangulated structure. In an ideal or true space frame chassis all the joints could be flexible without the structure losing stiffness. The loading at the joints should have no bending moments and should therefore only be subject to tension and compression forces. Space frames are lightweight, have a high torsional stiffness, and can be assembled with simple welding. However due to the complexity of the manufacturing process, automated manufacture is not achievable. Due to a high manufacturing time and the inability to be produced in an automated process, space frame chassis are limited to low volume production. Figure 2-1 shows a space frame chassis.

Figure 1.1 Space frame chassis

1.3.2 Ladder

One of the simpler chassis designs is the ladder frame chassis. This design incorporates two main longitudinal beams with several cross members to form the load bearing structure of a vehicle. The ladder chassis offers good beam stiffness and is relatively easy tomanufacture, however the design has a poor torsional stiffness. The torsional stiffness can be improved using cross members and byadding the body, however convertible car bodies have less of an effect as the roof helps to stiffen the assembly. Figure 2-2 shows a custom designed ladder chassis**.**

Figure 1.2 Ladder frame chassis

1.3.3 Backbone

A backbone chassis incorporates a main central support member, linking the front and rear axles, which is usually a tubular beam witha rectangular or circular cross section. Since the support member is hollow, the drive shaft of the vehicle can be placed within it. Due to the chassis being required to fit within the center of the body, the stiffness is limited by the size the support member's cross section, which can be made larger until it encroaches on the vehicles interior space. With the structural member being at the center of the structure,the chassis offers little protection from side collisions and the vehicle has to rely on the body of the vehicle for passenger safety. Figure 2-3 shows the backbone chassis**.**

Figure 1.3 Backbone frame chassis

1.3.4 Monocoque

A monocoque chassis is a single structure, a combination of the body and chassis, in which the surface panels carry stresses of the vehicle in shear, as well as define the vehicle shape. This approach to chassis design is highly space efficient, since there is no need for a central box or high sills and offers a good crash protection for the passengers. Crumple zones can be incorporated into the design to increase occupant safety. Steel monocoque chassis have a low manufacturing cost for high-volume production, however for low-volume production the first costs for the tooling and machinery are too high for it to be viable. Steel monocoque chassis are produced by welding pressed panels together to form the single structure, which can be robotized allowing for a rapid production time per chassis. The downside to steel monocoque 5 chassis is their high mass, which can be overcome by using other materials such as aluminum and various composites which drastically reduce the mass while keeping the structural strength and stiffness. These chassis can be full or semi monocoque, with the semi monocoque chassis typically incorporating space frame sub-structures. Figure 2-4 shows a carbon fiber reinforced polymer monocoque chassis for the Porsche 918 Spyder.

Figure 1.4 Porsche 918 Spyder CFRP monocoque chassis

1.3 COMPOSITES

A COMPOSITE IS A MATERIAL THAT IS MADE UP OF MANY DIFFERENT CONSTITUENTS WHICH DO NOT INTEGRATE MICROSCOPICALLY WITH EACH OTHER. THAT IS, THE ATOMS OF THE DIFFERENT CONSTITUENTS DO NOT COMBINE WITH EACH OTHER, AND YOU CAN VISUALLY SEE THE DIFFERENT CONSTITUENTS DISTINCTLY WHEN YOU HAVE A CLOSER LOOK AT THE COMPOSITE. COMPOSITES MATERIAL PROPERTIES ARE DIFFERENT IN EVERY DIRECTION AT A POINT. SO, THE COMPOSITE IS CALLED ANISOTROPIC MATERIALS.

Composite examples from Day-to-Day Life:

1. Straw-bricks
2. Concrete
3. Wood (cellulose + lignin)
4. Human body (muscles + bones)
5. Tyres
6. Plywood

1.4.1 Composite- Constituents:

The constituents in a composite material are:

- **Reinforcement:** discontinuous, stronger, and harder Reinforcement materials can be split into the several categories, namely continuous fibers, discontinuous fibers, particles and whiskers. For the purpose of this review, only fiber reinforced composites were investigated, as particle and whisker reinforced composites are rarely used in vehicle applications for structural components. A fiber is defined as a cylindrical material formation that has a high aspect ratio; that is, its length is much greater than its diameter, generally largerthan a factor of 100 (Campbell, 2010). Continuous fibers in a continuous fiber reinforced composite run unbroken through the matrix material and are the primary load carriers along the load direction. Continuous fibers can be used in a uniaxial orientation, a multi axial orientation or a random orientation incontinuous mats. Discontinuous fibers are short fibers which can be randomly orientated or arranged preferentially in the direction of known loads. While there are many aspects to deciding which category and type of material to use in a design, cost plays a large role. Continuous fiber manufacture can be costly in both the manufacture of the fibers themselves and in the methods used to produce continuous fiber reinforced composite products. Discontinuous fiber reinforced composites are a less expensive alternative to continuous fiber reinforced composites; however, they offer reduced mechanical properties (Barbero, 2010).

The functions of a reinforcement are:

1. Contribute desired properties
2. Load carrying
3. Transfer the strength to matrix

- **Matrix: Continuous**

The matrix material fulfils a number of roles. The matrix bindsthe fibers together and transfers loads between fibers. Without the matrix material fibers would not be able to transmit compressive loads. The matrix material carries some of the loads experienced by the composite, particularly via transverse stress, inter laminar shear stresses and bearing stresses. Service properties such as acceptable temperature range, chemical resistance, abrasion resistance and resistance to moisture and fluids are matrix dependent. The surface finish of 7 the cured composite is also heavily affected by the matrix.Selecting a matrix material is critical in that it limits the manufacturing processes and techniques available to the designer. Therefore, selecting a material that fits within predicted design limitations and constraints is best done at the beginning of the design phase. Matrix materials can be polymers, metals, or ceramics. Polymers are the most commondue to low cost and the ease of manufacturing high complexity parts and will be focused upon in this review. Polymer matrices can come in the form of either thermosetting or thermoplastic resins (Mallick, 2007).

The functions of a matrix are:

1. Holds the fibers together
2. Protects the fibers from environment
3. Protects the Fibers from abrasion (with each other)
4. Helps to keep the distribution of fibers
5. Distributes the loads evenly between fibers
6. Supplies better finish to final product

1.4.2 Classification of Composites:

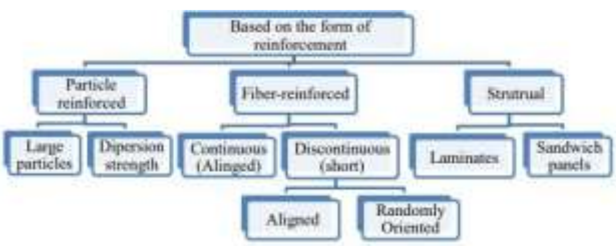

FIGURE 1.5 CLASSIFICATION OF REINFORCEMENT

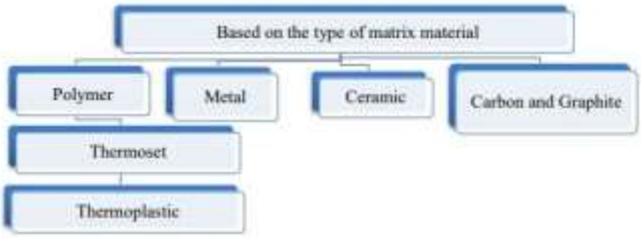

Figure 1.6 Classification of Matrix

1.4.3 Types of Fibers

1. Advanced Fibers: Fibers owning high specific stiffness [E/ρ]and specific strength[σ/ρ])

a) Glass fibers:

- Ancient Egyptians made containers from coarse fibersdrawn from heat softened glass
- Produce by extruding molten glass at 1200ºC
- Passed through spinnerets of 1-2 mm diameter
- Then drawing the filaments to produce fibers of diameterbetween 1-5 μm
- Individual filament is small in diameter, isotropic in behaviorand very flexible
- **Variety of forms:**

E glass: High strength and high resistivity

S2 glass: High strength, modulus and stability under extremetemperature, corrosive environment

R glass: Enhanced mechanical properties Glass: Resists corrosion in an acid environmentD glass: Dielectric properties

b) Carbon fibers:

- Precursor fiber is carbonized rather than melting. Based on the type of matrix material Polymer Thermoset ThermoplasticMetal Ceramic Carbon and Graphite 9
- Filaments are made by controlled pyrolysis (chemical deposition by heat) of a precursor material in fiber form byheat treatment at temperature 1000-3000º C
- Different fibers have different morphology, origin, size and shape. The morphology is very dependent on the manufacturing process. • The size of individual filament ranges from 3 to 14 µm. Hence, very flexible. • Maximum temperature of use of the fiber's ranges from 250 ºC to 2000 ºC. Properties changes with temperature at higher temperature.
- The maximum temperature of use of a composite iscontrolled by the use temperature of the matrix.
- Modulus and strength are controlled by the process-thermaldecomposition of the organic precursor under well controlledconditions of temperature and stress.
- Heterogeneous microstructure consisting of numerouslamellar ribbons.
- Thus, carbon fibers are anisotropic in nature.

c) Organic

d) Ceramic

2. Natural Fibers:

a) Animal fibers b) Vegetable fibers c) Mineral fiber

1.4.4 Types of Matrix Materials Polymers:

1. Thermoplastic Matrix Material

During processing, a thermoplastic polymer does not undergoa chemical transformation and does not form cross linkedbonds. A thermoplastic is softened in order to be processed then hardens back to a solid after processing is complete.Thermoplastics are harder to process than thermosets due to a higher viscosity. The high viscosity hinders impregnation of the resin into the reinforcement fibers. Damage to a thermoplastic can be repaired since the polymer bonds are reversible by applying heat. Due to the difficulties in manufacture which lead to a higher manufacturing cost, thermoplastic types were not explored for the use in the integral frame.

Examples: Polypropylene, Polyvinyl Chloride (PVC), Nylon, Polyurethane, Poly-ether-ether Ketone (PEEK),Polyphenylene sulfide (PPS), Polysulpone.

2. Thermoset Matrix Materials

During the curing of a thermoset matrix the resin system undergoes an irreversible chemical transformation forming a cross-linked polymer. Thermoset matrices are the most popular type of polymer matrices since they are available in a large range of properties, have high processing speeds and achieve high fiber impregnation due to the fact that they typically possess a low Viscosity. Thermoset resins have a limited handling time, referred to as pot life, before they become too viscose to use. Pot life and curing time varies for each resin system depending on the catalyst used and the chemical composition of the resin. Furthermore, the curing reaction can either be exothermic or endothermic. During curing thermoset resin shrinks volumetrically and considering that reinforcement materials show negligible shrinkage, this phenomenon can cause internal stresses if not considered (Barbero, 2010). Table 2-3 shows a comparison of characteristics for some common thermoset polymers.

Examples and Characteristics

Type	Characteristics
Polyester Resin	-Have a high performance-to-cost ratio making them popular -Medium mechanical strength -Fillers may be added to achieve favorable properties
Vinyl Ester Resin	-Higher elongation and corrosion properties than polyester -Highly resistant to acids, alkalis, solvents, and peroxides -Costs are between polyesters and epoxies
Epoxy Resin	-Versatile in processing -High mechanical properties -High corrosion resistance -Less shrinkage than other thermosets -Electrically insulates -More expensive than polyesters and vinyl esters
Phenolic Resin	-Have low flammability and smoke production making them attractive for use in planes and vehicle interior panels -Have a good dimensional stability under temperature fluctuations -Have good adhesive properties -Brittle -Large shrinkage -Difficult to process

Table 1-1 Thermoset Matrix Material Examples

Parameters affecting the properties of fibrous composites:

1. Length of the fiber
2. Orientation of the fiber (with respect to the loading direction)
3. Shape of the fiber
4. Distribution of the fibers in matrix material
5. Properties of the fibers
6. Properties of the matrix material
7. Proportion of fiber and matrix material

1.5 Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multiplatform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

The 3D CAD system CATIA V5 was introduced in 1999 by Dassault Systems. Replacing CATIA V4, it stood for a completely new design tool showing fundamental differences to its predecessor. The user

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interface, now featuring MS Windows layout, allows for the easy integration of common software packages such as MS Office, several graphic programs or SAPR3 products (depending on the IT environment).

The concept of CATIA V5 is to digitally include the complete process of product development, forming the first draft, the Design, the layout and at last the production and the assembly. The workbench Mechanical Design is to be addressed in the Context of this CAE training course. Sets of workbenches can be composed according to the user's preferences.

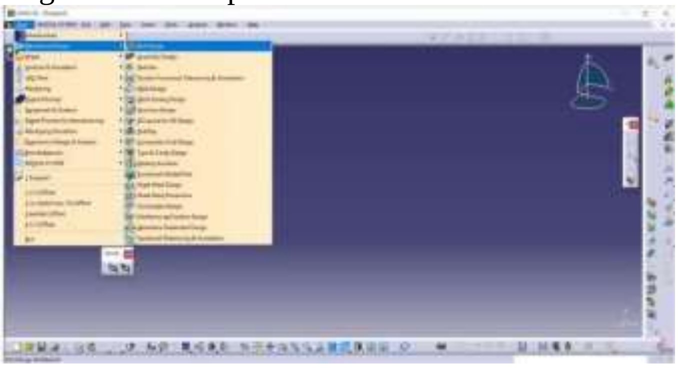

Figure 1.7 CATIA V5 Work Bench

Sets of workbenches can be composed according to the user's preferences. Therefore, Dassault Systems offers three different software installation versions. The platform P1 has the basic features and is used for training courses or when reduced functionality is needed. For process orientated work the platform P2 is the right one. It enables, apart from the basic design features, analysis tools and production related functions. P3 comprises specific advanced scopes such as the implementation of external software packages.

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and Solid Works are the dominant systems.

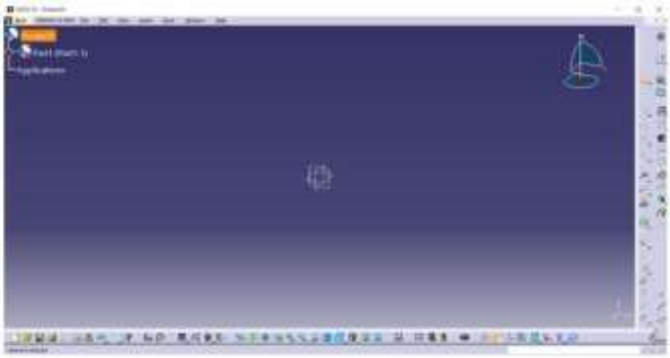

Figure 1.8 Home Product Page of CATIA V5

II. Literature

2 History

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM CAD software to develop Dassault's Mirage fighter jet, and then was adopted in the aerospace, automotive, shipbuilding, and other industries. Initially named CATIA (Conception Assisted Tridimensional Interactive - French for Interactive Aided Three-dimensional Design) it was renamed CATIA in 1981, when Dassault created a subsidiary to develop and sell the software and signed a non-exclusive distribution agreement with IBM.

- In 1984, the Boeing Company had chosen CATIA V3 as its main 3D CAD tool, becoming its largest customer.

- In 1990, General Dynamics Electric Boat Corp chose CATIA as its main 3D CAD tool, to design the U.S. Navy's Virginia class submarine. Boeing had been also selling worldwide its CADAM CAD system through the channel of IBM since 1978.
- In 1992, CADAM had been bought from IBM, and the next year CATIA CADAM V4 was published.
- In 1996, it was ported from one to four UNIX operating systems, including IBM AIX, Silicon Graphics IRIX, Sun Microsystems SunOS, and Hewlett-Packard HP-UX.
- In 1998, V5 was released, which was an entirely rewritten version of CATIA, with support for UNIX, Windows NT and Windows XP since 2001.
- In 2008, Dassault announced and released CATIA V6. While the server can run on Microsoft Windows, Linux or AIX, client support for any operating system other than Microsoft Windows is dropped.
- In November 2010, Dassault launched CATIA V6R2011x, the latest release of its PLM2.0 platform while continuing to support and improve its CATIA V5 software.

a) Scope of Application

Commonly referred to as 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development (CAX), from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE). CATIA facilitates collaborative engineering across disciplines, including surfacing & shape design, mechanical engineering, equipment and systems engineering.

CATIA supplies a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complexinnovative shapes. From subdivision, styling, and Class Asurfaces to mechanical functional surfaces.

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling partsup to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances,as well as kinematics definition.

CATIA facilitates the design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation.

b) Systems engineering

CATIA offers a solution to model complex and intelligent products through the systems engineering approach. It covers the requirements definition, the systems architecture, the behavior modeling and the virtual product or embedded software generation. CATIA can be customized viaapplication programming interfaces (API).

CATIA V5 & V6 can be adapted using Visual Basic and C++ programming languages via CAA (Component ApplicationArchitecture); a part object model (COM)-like interface. Although later versions of CATIA V4 implemented NURBS, V4 principally used piecewise polynomial surfaces. CATIA V4 uses a non-manifold solid engine.

CATIA V5 features a parametric solid/surface-based package which uses NURBS as the core surface representation and has several workbenches that provide KBE support.

c) Industries

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and Solid Works are the dominant systems.

d) Aerospace

The Boeing Company used CATIA V3 to develop its 777airliner and used CATIA V5 for the 787 series aircraft. Theyhave employed the full range of Dassault Systems' 3D PLM Products — CATIA, DELMIA, and ENOVIA LCA — supplemented by Boeing developed applications.

The development of the Indian Light Combat Aircraft has been using CATIA V5. Chinese Xian JH-7A is the first aircraft developed by CATIA V5, when the design was completed on September 26, 2000.European aerospace giant Airbus has been using CATIA since 2001.Canadian aircraft maker Bombardier Aerospace has done all of its aircraft design on CATIA.

The Brazilian aircraft company, EMBRAER, use CATIA V4 and V5 to build all airplanes. Vought Aircraft Industries use CATIA V4 and V5 to produce its parts. The Anglo/Italian Helicopter Company, Agusta Westland, use CATIA V4 and V5 to design their full range of aircraft. The Euro fighter Typhoon has been designed using both CATIA V4 and V5. The main supplier of helicopters to the U.S Military forces, Sikorsky Aircraft Corp., uses CATIA as well. Bell Helicopter, the creator of the Bell Boeing V-22 Osprey, has used CATIA V4, V5, and now V6

e) Shipbuilding's

Dassault Systems has begun serving shipbuilders with CATIAV5 release 8, which includes special features useful to shipbuilders. GD Electric Boat used CATIA to design the latest fast attack submarine class for the United States Navy, the Virginia class. Newport News Shipbuilding also used CATIA to design the Gerald R. Ford class of super carriers forthe US Navy.

f) Industrial equipment's

CATIA has a strong presence in the Industrial Equipmentindustry. Industrial Manufacturing machinery companies like Schuler and Met so use CATIA, as well as Heavy mobile machinery and equipment companies like Class, and also various industrial equipment product companies like Alstom Power and ABB Group.

g) Other

Architect FrankGehry has used the software, through the C- Cubed Virtual Architecture Company, now Virtual Build Team, to design his award-winning curvilinear buildings His technology arm, Gehry Technologies, has been developingsoftware based on CATIA V5 named Digital Project Digital Project competes for market share with Revit, Micro station and other Building Information Modeling applications.

a) Introduction to ANSYS

ANSYS, Inc. is an American company based in Canonsburg, Pennsylvania. It develops and markets CAE/multiphysics engineering simulation software for product design, testing and operation and offers its products and services to customersworldwide.

h) FAE/FEM

Finite- Any continuous object has infinite degrees of freedom, and it is not possible to solve the problem in this format. The Finite Element Method reduces the degrees of freedom from infinite to finite with the help of discretization or meshing (nodes and elements)

Element - All of the calculations are made at a limited numberof points known as nodes. The entity of joining nodes and forming a specific shape such as quadrilateral or triangles is known as Element. To get the value of a variable (say displacement) anywhere in between the calculation points, an interpolation function (as per the shape of the element) is used.Method- There are 3 methods to solve any engineering problem. Finite Element Analysis belongs to numerical method category. Finite Element Method (FEM) and Finite Analysis (FEA) both are one and the same. The term "FEA" isthe more popular in industries while "FEM" is more popular atuniversities.

Example:

Figure 1.9 Sheet

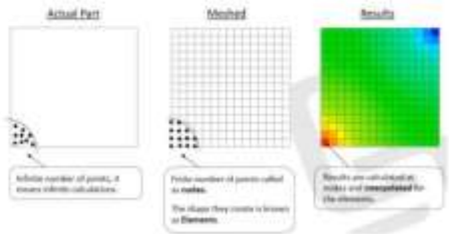

Figure 1.10 Finite Element Analysis

Advantages of FEA / FEM

1. Better Visualization of Failure Location
2. Lower down the Design cycle time
3. Decrease the Number of prototypes
4. Cut the Testing cost
5. Optimum design can be achieved faster

i) Meshing

The basic idea of FEA is to male calculations at only limited (Finite) number of points and the interpolate the results for theentire domain (surface or volume0. Any continuous object hasinfinite degrees of freedom and it's just not possible to solve the problem in this format. Finite Element Method reduces thedegrees of freedom from infinite to finite with the help of discretization or meshing (nodes and elements)

The Finite Element Method only makes calculations at a limited (Finite) number of points and then interpolates the results for the entire domain (surface or volumes).

j) DOF (Degree Freedom) of

The minimum number of parameters (motion, coordinates, andtemp. Etc.) needed to define the position of any entity completely in the space is known as a degree of freedom.

Example:

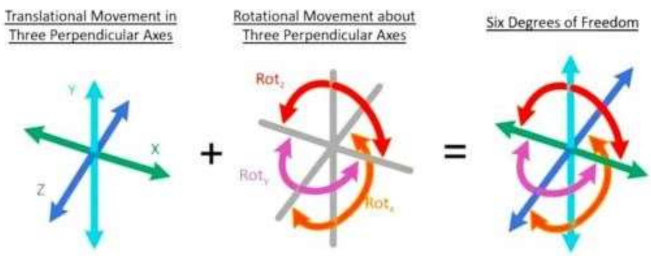

Figure 1.11 Degree of Freedom

k) Element Shapes and its Characteristics

In general, four shapes are possible: point, line, area, orvolume:

1. A point element is typically defined by one node, such as amass element.
2. A line element is typically represented by a line connectingtwo or three nodes. Examples are beams, spars, pipes, etc.

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- We use 1D element when one of the Dimensional of the object /component is very large as compared other two dimensions.

3. An area element has a triangle or quadrilateral shape. Examples are Quard and Tria

- We use 2D Elements when Two of the dimensions of the object/components is very large as compared to the Third Dimension (Generally Thickness)

4. A volume element has a tetrahedral or brick shape is usually a 3-D solid element.

- We use 3D element when all the three dimensions of the object / components are comparable

Type	Actual Model	Element Shape (Geometric properties defined by Nodes)	Additional Requirement (Actual Volume Calculation)
1D Element	Steel Rod	Beam element with 2 nodes (Length Only)	Cross – Sectional Parameters (Area) V = L x A
2D Element	Sheet Metal Component	Quard Element with 4 nodes (Area Only)	Thickness (T) V = A x T
3D Element	Metal Cube	Hexa Element with 8 Nodes (Volume)	None Element itself has volume.

Figure 1.12 Element Shapes and Characteristics

l) Theory of 1-D Meshing

We use 1D Meshing or 1D Elements, when one of the dimensions of any component / object is very large in comparison to the other two dimensions.

Element Shape – Line

Additional data from user - The remaining two dimensions, the cross-sectional area.

Element type – Rod, bar, beam, pipe, etc.

Practical Applications: Long shafts, Beams, pin joints, connection elements.

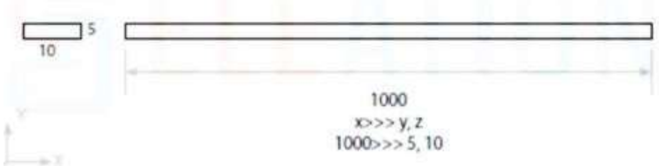

Figure 1.13 1-D Meshing

m) Deformation

Physical deformations are calculated on and inside a part or an assembly. Fixed supports prevent deformation; locations without a fixed support usually experience deformation compared to the original location. Deformation is calculated relative to the part or assembly global coordinates system.

ANSYS gives results of the following Deformation:

1. Component deformations (Directional Deformation)

- This option gives deformation in individual axis, like you can find deformation on either X/Y/Z axis.

2. Deformed shape (Total Deformation vector)

- This option gives total deformation, means its gives average / resultant deformation.

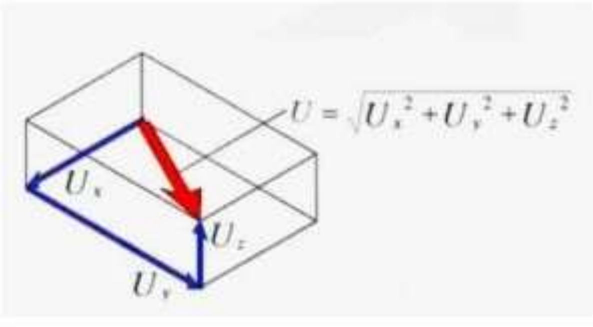

Figure 1.14 Directional and Deformation Vector

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n) Displacement – Deflection – Deformation

Displacement is the distance from which one node or element (beam, column, frame, etc.) moved from its original location. The movement could be forming a beam deflecting, but it could also be the result of the entire objectmoving, un-distorted, like a box sliding on a surface with

friction. Displacement can both be measured in terms of distance and in terms of rotation.

Deflection is the distance that an object bends, twist from its original position. I would generally assume that an objects deflection does not include rigid movement of the object.

Deformation is the actual distortion that occurs to a structural member. We most commonly discuss elastic and plastic deformations. Elastic deformations are those deformations that, when the loading is removed, will returnto the original un-deflected shape. Plastic deformations are those that will remain even after the loading is removed. Because most structures are securely attached to their foundation, there is general no rigid body motion, and displacement and deflection are particular similar concepts .We would say the outlier is deformations .Displacements and Deflections are generally measures of distances (or ratios of that distance comparedto a meaningful value, such as the member length) while the deformation is what happened to the member to cause the displacements /deflections.

b) 2-D Meshing

2-D elements are used when two of the dimensions arevery large in comparison to the third dimension. Practical Applications: Sheet metal parts, plasticcomponents like instrument panel etc.

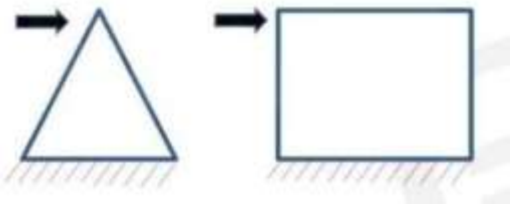

Figure 1.15 Shape Stiffness

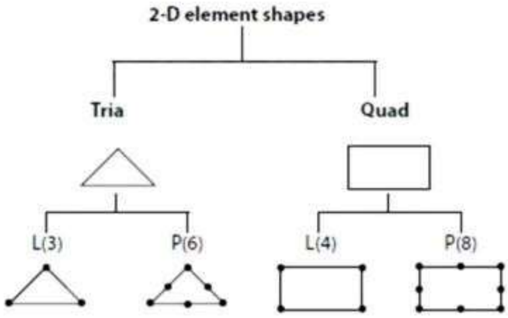

Figure 1.16-D Element Shapes

a) Elements Quality and Checks

Element Quality is a subject often talked about and never fullyunderstand. The reason for this is complex but is related to the fact that quality is relative and the solution. Check with the "local experts" regarding the appropriate values for each element type required by your element checking computerprograms.

Wrap angle: Wrap angle is the out of plane angle

Ideal Value = 0° (Acceptable < 10°) Wrap angle is notapplicable for triangle elements

It is defined as the angle between the normal to two planes formed by splitting the quad element along the diagonals. Themaximum angle of the two possible angles is reported as the wrap angle.

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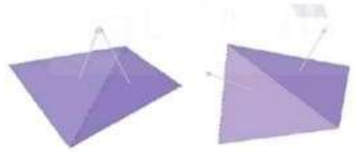

Figure 1.17 Wrap Angle

Aspect: maximum element edge length / minimum elementedge length
Ideal value = 1(Acceptable

Figure 1.18 Aspect Ratio

Jacobian: Ideal value = 1.0 (Acceptable >0.6)

In the simple terms, the Jacobian is a scale factor for arisingbecause of the transformation of the coordinates system.

Elements are transformed from the global coordinates to localcoordinates (defined at the centroid of every element), for Faster analysis times.

Figure 1.19 Jacobian

Included Angles: Included or interior angle check is appliedfor individual angles.

Quad: Ideal Value = 90° (Acceptable = 45°< θ < 135°)
Tria: Ideal Value = 60° (Acceptable = 20°< θ < 120°)

b) 3-D Meshing

3-D elements should be used when all dimensions of acomponent are comparable.
x~ y ~z
Element Shape – Tetra, Penta, Hex, Pyramid.
Element shapes: Solid
Practical Applications: Gearbox, Engine block, crankshaft,etc.

DOFs for Solid Elements

2-D Elements and 1-D Elements generally supports 6 dofs, butall solid elements have only 3 translation dofs (no rotational dof)

The energy absorbed by composite Epoxy carbon is 2.317mJ,Epoxy E-Glass 5.213mJ and for AISI 4130 is 0.2368mJ the energy absorbed by the composite is 10 times than the AISI 4130.

Increased Deformation

The deformation is low for conventional AISI 4130 when compared with composite metals. Although AISI 4130 can have high stiffness and Tensile strength the real benefits of Carbon and Glass fiber composites are its strength-to-weightratio and stiffness-to-weight ratio due to its low density

So, we can increase the thickness of the sheet of the integral frame to increase stiffness and strength with reduction in weight when compared to conventional material. Because theweight reduction is 74 % - 80%.And also, the orientation of the fibers has greatinfluence on the static and dynamic characteristics of the composite integral frame. And also, the orientation of the fibers has greatinfluence on the static and dynamic characteristics of the composite integral frame.

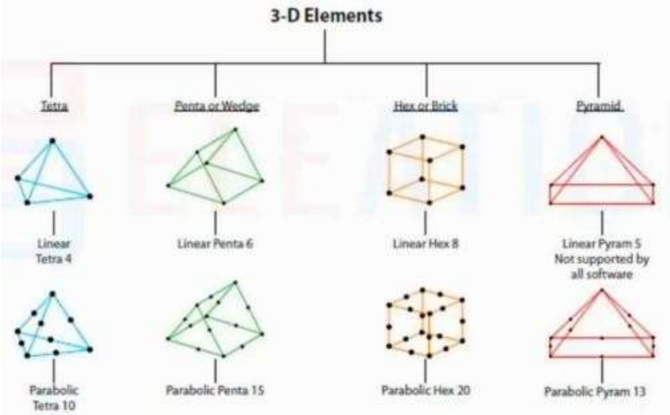

Figure 1.20 3-D elements

Result

The replacement of composite materials has resulted in considerable amount of weight reduction about 74% to 80% whencompared to conventional AISI 4130 (American Ironand Steel Institute).

Weight Reduction

The weight of composite integrated frame, when assigned with Epoxy Carbon composite weight is 314kg, for Epoxy E- Glass & S-Glass composite weight is 425kg, whereas the weight of AISI 4130 is 1669kg so there is 74% to 80% weight reduction because of less density glass fiber and carbon fiber. The density of Epoxy Carbon is 1480kg/m^3 and Epoxy E-glass and S-Glass is 2000kg/m^3, whereas the density of AISI 4130 is 7850kg/ m^3.

Impact Strength Increased

The energy absorbed by composite Epoxy carbon is 2.317mJ, Epoxy E-Glass 5.213mJ and for AISI 4130 is 0.2368mJ the energy absorbed by the composite is 10 times than the AISI 4130.

Increased Deformation

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So, we can increase the thickness of the sheet of the integral frame to increase stiffness and strength with reduction in weight when compared to conventional material. Because the weight reduction is 74 % - 80%.

And also, the orientation of the fibers has great influence on the static and dynamic characteristics of the composite integral frame.

III. Conclusion

1. From the results and discussion, the designed integral frame is analyzed with for varied materials which are AISI4130, Epoxy Carbon, Epoxy E- Glass and Epoxy SGlass.
2. Among this Epoxy Carbon has good material prosperitiesand it is suitable for integral frame.
3. Epoxy E-Glass and Epoxy S-Glass has more deformation tendency. Hence, from the results it is not suitable for integralchassis.

References

[1] Jason Denny, Sarp Adali. "Conceptual design and validation of a composite monocoque solar passenger vehiclechassis." University of Kwazulu – Natal, 2629 HS delft.
[2] Jonne Margareth R. Catibog, Andrea Mikhacla B.Lazarte.
[3] The replacement of composite materials has resulted in considerable amount of weight reduction about 74% to 80%when compared to conventional AISI 4130 (American Iron and Steel Institute).

[4] “Materials Selection Methods in the Design of Monocoque fora fuel-efficient concept vehicle.” Department of Mining, Metallurgical and Materials Engineering. University of Philippines’s.
[5] Prof, Andera TONOLI, “Design of carbon fibermonocoque for high performance car.”
[6] Aditya Rao Peabowo, Fajar Budi Laksono. “Structural Assessment of Monocoque Frame Construction using Finite Element Analysis: A study case on Designed Vehicle Chassisreferring to Ford GT40”, Department of Mechanical Engineering, Universities of Sebelas Maret, Surakarta 57126.
[7] Meghana P. Kamble. “Design and Analysis of a CompositeMonocoque for Structural Performance.” Master of Science in Mechanical, Engineering, Purdue University.
[8] Dr. PM Mohite. “Introduction, Defination, Classificationfactors influencing strength and stiffness failure modes of
[9] composites.” International Journal of Engineering ScienceInvention, 2019; Volume 8.
[10] G. Nilimam, P. Tharun, V. Vishnu, B. Pavan, Sk.Arshad.“Dynamic Analysis of chassis of Solar Powered Vehicle.” Department of Mechanical Engineering, Geethanjali Institute of Science and Technology, Nellore, Andhra Pradesh, India.
[11] Nishanth Chavan, Abhijit Salaunkhe, Chentan Dhwade, Aditya Dhanawade, Prof.Siddesh Lad. “Review on Design, Static and Dynamic Analysis of FSAE Chassis.” B.E Students and Professor, Automobile Department, Saraswathi College ofEngineering, Navi Mumbai Maharashtra, INDIA.
[12] Nancy L Johnson. “Department of a cost Competitive, Composite Intensive, Body-inwhite.” Society of AutomotiveEngineering’s. 2002-01-1905
[13] Vijayan S. N, S. Sendhilkumar, Prakash. “Effect of CrossSections Considering Material and Design Aspects in Automotive Chassis.” Assistant Professors, Department of Mechanical Engineering, Karpagam Institute of Technology,
[14] Coimbatore, Tamil Nadu, India
[15] Ismail Agus suprihadi, Rifky. “Strength Analysis of Monocoque Frame Construction in an Electric city car usingFinite Element Method.” Department of Mechanical Engineering, University of Diponegoro – Electric and Chemical Engineering (ICEVT & IMECE) 2015.
[16] Pravin, A. Renuke. “Dynamic Analysis of a car Chassis,”(IJERA) ISSN: 2248-9622 Vol-2, Issue 5, November – December 2012, PP.955-959.
[17] L. Praveen and N. Sandeep Kumar. “Crash Analysis of acomposite Car body, IOP Conference.” Series: Materials Science and Engineering – Mater, Sci, Engg-455012099.
[18] Nicholas Tjebbe Witte Veen. “Structural Analysis of a Composite Monocoque Chassis for use in a High Performanceof Electric Vehicle.” Engineering and Science, University of Kwaazulu – Natal.
[19] Prof, J. Ram Kumar. “Manufacturing of Composites,Introduction to Composites, Matrices, and Fiber reinforcements composite Properties.” Department of Mechanical Engineering. Indian Institute of Technology, Kanpur.
[20] Prof, S. Mayank Singh. “Application of Steel in Automotive Industry.” International Journal of Engineering Technology aue7nd Advanced Engineering, (ISSN 2250-2459,ISO 9001:2008 Certified Journal, Volume 6, Issue 7, July 2016.
[21] M . Ravi Chandra, S. Sreenivasulu. “Modeling and Structural Analysis of heavy vehicle chassis made of polymercomposite material by three different cross sections”. Volume2-2; September 2012.
[22] S. Nixon, G. Barnes. “Effective Crushing Simulation forComposite Structures”. SIMULIA; Ingenuity Limited
[23] Note : this all References may not be available in aboveinformation but I References this all sources of information.