DESIGN AND STRUCTURAL ANALYSIS OF A BICYCLE FRAME UNDER STATIC LOADING CONDITIONS

A Project report submitted in partial fulfilment of the requirements for the award of the Degree of

BACHELOR OF TECHNOLOGY

In

MECHANICAL ENGINEERING

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2022

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CERTIFICATE

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ACKNOWLEDGMENT

We express immensely our deep sense of gratitude to **Dr. Rajesh Ghosh**, Associate Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam Mandal, Visakhapatnam district for his valuable guidance and encouragement at every stage of work for the successful fulfilment of students.

We are very thankful to **Prof.T.V.Hanumantha Rao**, Principal and **Prof.B.Nagaraju**, Head of the Department , Mechanical Engineering , Anil Neerukonda Institute of Technology & Sciences for their valuable suggestions.

We express our sincere thanks to the non-teaching staff of Mechanical Engineering for their kind co-operation and support to carry on work.

Last but not the least, we like to convey our thanks to all who have contributed directly or indirectly for the completion of our work.

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ABSTRACT

This era of growing automobile evolution is leaving a huge impact on the environment. The bicycles provide a pollution free environment, helps in health wellness. Electric bicycles are the modern means of transport which runs on electrical power, reducing and having a least impact on the environment and also decreases the fuel consumption which results in preventing the depletion natural resources. This work involves the design of the bicycle frame and the analysis of the bicycle frame. The frame is designed by taking reference of the bicycle frames in the present market. The design of the bicycle frame is done in the Solidworks software using all the major tools, the static analysis is done in Ansys22 R1 software. The design of bicycle is done in a way that it can be adopted into an electric-bicycle. The frame is analysed for static loading conditions. Six different materials are considered for this study, such as structural steel, Al 6061 alloy, Titanium alloy, Carbon Fibre material, AISI 1025 Carbon steel, Chromoly steel. Static analysis is performed on the frame by applying a load of 588N seating on the frame. The load acting in the static analysis is considered to be the average weight of a human being .The values of Von- Mises stresses and deformations and elastic strains are obtained for different materials of frame are tabulated. Based on the results we conclude that carbon fibre material frame exhibited less values of deformation and stresses compared to other materials under static analysis.

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INTRODUCTION

1. INTRODUCTION

A bicycle is a two wheeled vehicle that is moved with pedals, which are attached to the wheels with a gear and chain. It is steered with handlebars. A bicycle, also called a pedal cycle, bike or cycle, is a human-powered or motor-powered assisted, pedal-driven, single-track vehicle, having two wheels attached to a frame, one behind the other. A bicycle rider is called a cyclist, or bicyclist.

Bicycles were introduced in the 19th century in Europe. By the early 21st century, more than 1 billion were in existence. These numbers far exceed the number of cars, both in total and ranked by the number of individual models produced. They are the principal means of transportation in many regions. They also provide a popular form of recreation, and have been adapted for use as children's toys, general fitness, military and police applications, courier services, bicycle racing, and bicycle stunts.

The basic shape and configuration of a typical upright or "safety bicycle", has changed little since the first chain-driven model was developed around 1885. However, many details have been improved, especially since the advent of modern materials and computer-aided design. These have allowed for a proliferation of specialized designs for many types of cycling.

The bicycle's invention has had an enormous effect on society, both in terms of culture and of advancing modern industrial methods. Several components that played a key role in the development of the automobile were initially invented for use in the bicycle, including ball bearings, pneumatic tires, chain-driven sprockets and tension-spoked wheels.

Although bike and cycle are used interchangeably to refer mostly to two types of two-wheelers, the terms still vary across the world. In India, for example, a cycle refers only to a two-wheeler using pedal power whereas the term bike is used to describe a two-wheeler using internal combustion engine or electric motors as a source of motive power instead of motorcycle/motorbike.

1.1 History

The "dandy horse", also called Draisienne or Laufmaschine ("running machine"), was the first human means of transport to use only two wheels in tandem and was invented by the German Baron Karl Von Drais. It is regarded as the first bicycle, but it did not have pedals; Drais introduced it to the public in Mannheim in 1817 and in Paris in 1818. Its rider sat astride a wooden frame supported by two in-line wheels and pushed the vehicle along with his or her feet while steering the front wheel.

Fig 1.1 Wooden Draisienne

The first mechanically propelled, two-wheeled vehicle may have been built by Kirkpatrick MacMillan, a Scottish blacksmith, in 1839, although the claim is often disputed.

In the early 1860s, Frenchmen Pierre Michaux and Pierre Lallement took bicycle design in a new direction by adding a mechanical crank drive with pedals on an enlarged front wheel (the velocipede). This was the first in mass production. Another French inventor named Douglas Grasso had a failed prototype of Pierre Lallement's bicycle several years earlier. Several inventions followed using rear-wheel drive, the best known being the rod-driven velocipede by Scotsman Thomas McCall in 1869. In that same year, bicycle wheels with wire spokes were patented by Eugene Meyer of Paris. The French vélocipède, made of iron and wood, developed into the "penny-farthing" (historically known as an "ordinary bicycle", a retronym, since there was then no other kind). It featured a tubular steel frame on which were mounted wire-spoked wheels with solid rubber tires. These bicycles were difficult to ride due to their high seat and poor weight distribution. In 1868 Rowley Turner, a sales agent of the Coventry Sewing Machine Company (which soon became the Coventry

Machinists Company), brought a Michaux cycle to Coventry, England. His uncle, Josiah Turner, and business partner James Starley, used this as a basis for the 'Coventry Model' in what became Britain's first cycle factory.

Fig 1.2 Michaux's son on a velocipede 1868

The dwarf ordinary addressed some of the faults by reducing the front wheel diameter and setting the seat further back. This, in turn, required gearing—effected in a variety of ways—to efficiently use pedal power. Having to both pedal and steer via the front wheel remained a problem. Englishman J.K. Starley (nephew of James Starley), J.H. Lawson, and Shergold solved this problem by introducing the chain drive (originated by the unsuccessful "bicyclette" of Englishman Henry Lawson), connecting the frame-mounted cranks to the rear wheel. These models were known as safety bicycles, dwarf safeties, or upright bicycles for their lower seat height and better weight distribution, although without pneumatic tires the ride of the smaller-wheeled bicycle would be much rougher than that of the larger-wheeled variety. Starley's 1885 Rover, manufactured in Coventry is usually described as the first recognizably modern bicycle. Soon the seat tube was added which created the modern bike's double-triangle diamond frame.

Further innovations increased comfort and ushered in a second bicycle craze, the 1890s Golden Age of Bicycles. In 1888, Scotsman John Boyd Dunlop introduced the first practical pneumatic tire, which soon became universal. Willie Hume demonstrated the supremacy of Dunlop's tyres in 1889, winning the tyre's first-ever races in Ireland and then England.[Soon after, the rear freewheel was developed, enabling the rider to coast. This refinement led to the 1890s invention of coaster brakes. Dérailleur gears and hand-operated Bowden cable-pull brakes were also developed during these years, but were only slowly adopted by casual riders.

Fig 1.3 John Boyd Dunlop on a bicycle

The Svea Velocipede with vertical pedal arrangement and locking hubs was introduced in 1892 by the Swedish engineers Fredrik Ljungström and Birger Ljungström. It attracted attention at the World Fair and was produced in a few thousand units.

In the 1870s many cycling clubs flourished. They were popular in a time when there were no cars on the market and the principal mode of transportation was horse-drawn vehicles, such the horse and buggy or the horsecar. Among the earliest clubs was The Bicycle Touring Club, which has operated since 1878. By the turn of the century, cycling clubs flourished on both sides of the Atlantic, and touring and racing became widely popular. The Raleigh Bicycle Company was founded in Nottingham, England in 1888. It became the biggest bicycle manufacturing company in the world, making over two million bikes per year.

Bicycles and horse buggies were the two mainstays of private transportation just prior to the automobile, and the grading of smooth roads in the late 19th century was stimulated by the widespread advertising, production, and use of these devices. More than 1 billion bicycles have been manufactured worldwide as of the early 21st century.

1.2 Uses of Bicycle

From the beginning, bicycles have been and continue to be employed for many uses. In a utilitarian way, bicycles are used for transportation, bicycle commuting, and utility cycling. It can be used as a 'work horse' by mail carriers, paramedics, and police, messengers, and general delivery services. Military uses of bicycles include communications, reconnaissance, troop movement, supply of provisions, and patrol.

The bicycle is also used for recreational purposes, such as bicycle touring, mountain biking, physical fitness, and play. Bicycle competition includes racing, BMX racing, track racing, criterium, roller racing, sportives and time trials. Major multi-stage professional events are the Giro d'Italia, the Tour de France, the Vuelta a Espana, the Tour de Pologne, and the Volta a Portugal.

The bicycle has undergone continual adaptation and improvement since its inception. These innovations have continued with the advent of modern materials and computer-aided design, allowing for a proliferation of specialized bicycle types, improved bicycle safety, and riding comfort.

1.3 Types

Bicycles can be categorized in many different ways: by function, by number of riders, by general construction, by gearing or by means of propulsion. The more common types include utility bicycles, mountain bicycles, racing bicycles, touring bicycles, hybrid bicycles, cruiser bicycles, and BMX bikes. Less common are tandems, low riders, tall bikes, fixed gear, folding models, amphibious bicycles, cargo bikes, recumbents and electric bicycles.

Unicycles, tricycles and quadracycles are not strictly bicycles, as they have respectively one, three and four wheels, but are often referred to informally as "bikes" or "cycles".

1.4 Dynamics

A bicycle stays upright while moving forward by being steered so as to keep its centre of mass over the wheels. This steering is usually provided by the rider, but under certain conditions may be provided by the bicycle itself.

The combined centre of mass of a bicycle and its rider must lean into a turn to successfully navigate it. This lean is induced by a method known as counter steering, which can be performed by the rider turning the handlebars directly with the hands or indirectly by leaning the bicycle.

Short-wheelbase or tall bicycles, when braking, can generate enough stopping force at the front wheel to flip longitudinally. The act of purposefully using this force to lift the rear wheel and balance on the front without tipping over is a trick known as a stoppie, endo, or front wheelie.

1.5 Performance

The bicycle is extraordinarily efficient in both biological and mechanical terms. The bicycle is the most efficient human-powered means of transportation in terms of energy a person must expend to travel a given distance. From a mechanical viewpoint, up to 99% of the energy delivered by the rider into the pedals is transmitted to the wheels, although the use of gearing mechanisms may reduce this by 10–15%. In terms of the ratio of cargo weight a bicycle can carry to total weight, it is also an efficient means of cargo transportation.

A human traveling on a bicycle at low to medium speeds of around 16–24 km/h (10–15 mph) uses only the power required to walk. Air drag, which is proportional to the square of speed, requires dramatically higher power outputs as speeds increase. If the rider is sitting upright, the rider's body creates about 75% of the total drag of the bicycle/rider combination. Drag can be reduced by seating the rider in a more aerodynamically streamlined position. Drag can also be reduced by covering the bicycle with an aerodynamic fairing.

1.6 Parts

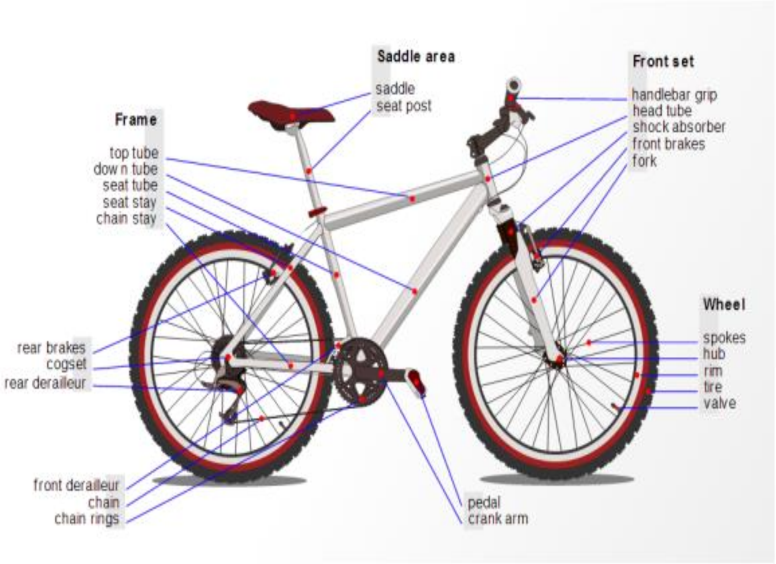

Fig 1.4 Components of a bicycle

1.6.1 Bicycle frame

The great majority of modern bicycles have a frame with upright seating that looks much like the first chain-driven bike. These upright bicycles almost always feature the diamond frame, a truss consisting of two triangles: the front triangle and the rear triangle. The front triangle consists of the head tube, top tube, down tube, and seat tube. The head tube contains the headset, the set of bearings that allows the fork to turn smoothly for steering and balance. The top tube connects the head tube to the seat tube at the top, and the down tube connects the head tube to the bottom bracket. The rear triangle consists of the seat tube and paired chain stays and seat stays. The chain stays run parallel to the chain, connecting the bottom bracket to the rear dropout, where the axle for the rear wheel is held. The seat stays connect the top of the seat tube (at or near the same point as the top tube) to the rear fork ends.

Historically, women's bicycle frames had a top tube that connected in the middle of the seat tube instead of the top, resulting in a lower stand over height at the expense of compromised structural integrity, since this places a strong bending load in the seat tube, and bicycle frame members are typically weak in bending.

Another style is the recumbent bicycle. These are inherently more aerodynamic than upright versions, as the rider may lean back onto a support and operate pedals that are on about the same level as the seat.

1.6.2 Drivetrain and gearing

The drivetrain begins with pedals which rotate the cranks, which are held in axis by the bottom bracket. Most bicycles use a chain to transmit power to the rear wheel. A very small number of bicycles use a shaft drive to transmit power, or special belts. Hydraulic bicycle transmissions have been built, but they are currently inefficient and complex.

Since cyclists' legs are most efficient over a narrow range of pedalling speeds, or cadence, a variable gear ratio helps a cyclist to maintain an optimum pedalling speed while covering varied terrain. Some, mainly utility bicycles use hub gears with between 3 and 14 ratios, but most use the generally more efficient derailleur system, by which the chain is moved between different cogs called chainrings and sprockets to select a ratio. A derailleur system normally has two derailleurs, or mechs, one at the front to select the chainring and another at the back to select the sprocket. Most bikes have two or three chainrings, and from 5 to 11 sprockets on the back, with the number of theoretical gears calculated by multiplying front by back. In reality, many gears overlap or require the chain to run diagonally, so the number of usable gears is fewer.

An alternative to chain drive is to use a synchronous belt. These are toothed and work much the same as a chain—popular with commuters and long distance cyclists they require little maintenance. They can't be shifted across a cassette of sprockets, and are used either as single speed or with a hub gear.

Different gears and ranges of gears are appropriate for different people and styles of cycling. Multi-speed bicycles allow gear selection to suit the circumstances: a cyclist could use a high gear when cycling downhill, a medium gear when cycling on a flat road, and a low gear when cycling uphill. In a lower gear every turn of the pedals leads to fewer rotations of the rear wheel. This allows the energy required to move the same distance to be distributed over more pedal turns, reducing fatigue when riding uphill, with a heavy load, or against strong winds. A higher gear allows a cyclist to make fewer pedal turns to maintain a given speed, but with more effort per turn of the pedals

1.6.3 Steering

The handlebars connect to the stem that connects to the fork that connects to the front wheel, and the whole assembly connects to the bike and rotates about the steering axis via the headset bearings. Three styles of handlebar are common. Upright handlebars, curve gently back toward the rider, offering a natural grip and comfortable upright position. Drop handlebars "drop" as they curve forward and down, offering the cyclist best braking power from a more aerodynamic "crouched" position, as well as more upright positions in which the hands grip the brake lever mounts, the forward curves, or the upper flat sections for increasingly upright postures. Mountain bikes generally feature a 'straight handlebar' or 'riser bar' with varying degrees of sweep backwards and centimetres rise upwards, as well as wider widths which can provide better handling due to increased leverage against the wheel.

1.6.4 Seating

Saddles vary with rider preference, from the cushioned ones favoured by short-distance riders to narrower saddles which allow more room for leg swings. Comfort depends on riding position. With comfort bikes and hybrids, cyclists sit high over the seat, their weight directed down onto the saddle, such that a wider and more cushioned saddle is preferable. For racing bikes where the rider is bent over, weight is more evenly distributed between the handlebars and saddle, the hips are flexed, and a narrower and harder saddle is more efficient. Differing saddle designs exist for male and female cyclists, accommodating the genders differing anatomies and sit bone width measurements, although bikes typically are sold with saddles most appropriate for men. Suspension seat posts and seat springs provide comfort by absorbing shock but can add to the overall weight of the bicycle.

A recumbent bicycle has a reclined chair-like seat that some riders find more comfortable than a saddle, especially riders who suffer from certain types of seat, back, neck, shoulder, or wrist pain. Recumbent bicycles may have either under-seat or over-seat steering.

1.6.5 Brakes

Bicycle brakes may be rim brakes, in which friction pads are compressed against the wheel rims; hub brakes, where the mechanism is contained within the wheel hub, or disc brakes, where pads act on a rotor attached to the hub. Most road bicycles use rim brakes, but some use disk brakes. Disc brakes are more common for mountain bikes, tandems and recumbent bicycles than on other types of bicycles, due to their increased power, coupled with an increased weight and complexity. Linear-pull brake, also known by the Shimano trademark: V-Brake, on rear wheel of a mountain bike.

Front disc brake, mounted to the fork and hub operated by hydraulic pressure to disc pads. With hand-operated brakes, force is applied to brake levers mounted on the handlebars and transmitted via Bowden cables or hydraulic lines to the friction pads, which apply pressure to the braking surface, causing friction which slows the bicycle down. A rear hub brake may be either hand-operated or pedal-actuated, as in the back pedal coaster brakes.

Track bicycles do not have brakes, because all riders ride in the same direction around a track which does not necessitate sharp deceleration. Track riders are still able to slow down because all track bicycles are fixed-gear, meaning that there is no freewheel. Without a freewheel, coasting is impossible, so when the rear wheel is moving, the cranks are moving. To slow down, the rider applies resistance to the pedals, acting as a braking system which can be as effective as a conventional rear wheel brake, but not as effective as a front wheel brake.

1.6.6 Suspension

Bicycle suspension refers to the system or systems used to suspend the rider and all or part of the bicycle. This serves two purposes: to keep the wheels in continuous contact with the ground, improving control, and to isolate the rider and luggage from jarring due to rough surfaces, improving comfort.

Bicycle suspensions are used primarily on mountain bicycles, but are also common on hybrid bicycles, as they can help deal with problematic vibration from poor surfaces. Suspension is especially important on recumbent bicycles, since while an upright bicycle rider can stand on the pedals to achieve some of the benefits of suspension, a recumbent rider cannot.

Basic mountain bicycles and hybrids usually have front suspension only, whilst more sophisticated ones also have rear suspension. Road bicycles tend to have no suspension.

1.6.7 Wheels and tyres

The wheel axle fits into fork ends in the frame and fork. A pair of wheels may be called a wheel set, especially in the context of ready-built "off the shelf", performance-oriented wheels.

Tires vary enormously depending on their intended purpose. Road bicycles use tyres 18 to 25 millimetres wide, most often completely smooth, or slick, and inflated to high pressure to roll fast on smooth surfaces. Off-road tires are usually between 38 and 64 mm (1.5 and 2.5 in) wide, and have treads for gripping in muddy conditions or metal studs for ice.

1.6.8 Groupset

Groupset generally refers to all of the components that make up a bicycle excluding the bicycle frame, fork, stem, wheels, tires, and rider contact points, such as the saddle and handlebars.

1.6.9 Accessories

Touring bicycle equipped with front and rear racks, fenders (called mud-guards), water bottles in cages, four panniers and a handlebar bag.

Some components, which are often optional accessories on sports bicycles, are standard features on utility bicycles to enhance their usefulness, comfort, safety and visibility. Fenders with spoilers protect the cyclist and moving parts from spray when riding through wet areas. In some countries (e.g. Germany, UK), fenders are called mudguards. The chain guards protect clothes from oil on the chain while preventing clothing from being caught between the chain and crank set teeth. Kick stands keep bicycles upright when parked, and bike locks deter theft. Front-mounted baskets, front or rear luggage carriers or racks, and panniers mounted above either or both wheels can be used to carry equipment or cargo. Pegs can be fastened to one, or both of the wheel hubs to either help the rider perform certain tricks, or allow a place for extra riders to stand, or rest. Parents sometimes add rear-mounted child seats, an auxiliary saddle fitted to the crossbar, or both to transport children. Bicycles can also be fitted with a hitch to tow a trailer for carrying cargo, a child, or both.

Toe-clips and toe straps and clip less pedals help keep the foot locked in the proper pedal position and enable cyclists to pull and push the pedals. Technical accessories include cyclo computers for measuring speed, distance, heart rate, GPS data etc. Other accessories include lights, reflectors, mirrors, racks, trailers, bags, water bottles and cages, and bell. Bicycle lights, reflectors, and helmets are required by law in some geographic regions depending on the legal code. It is more common to see bicycles with bottle generators, dynamos, lights, fenders, racks and bells in Europe. Bicyclists also have specialized form fitting and high visibility clothing.

Children's bicycles may be outfitted with cosmetic enhancements such as bike horns, streamers, and spoke beads. Training wheels are sometimes used when learning to ride.

Bicycle helmets can reduce injury in the event of a collision or accident, and a suitable helmet is legally required of riders in many jurisdictions. Helmets may be classified as an accessory or as an item of clothing.

Bike trainers are used to enable cyclists to cycle while the bike remains stationary. They are frequently used to warm up before races or indoors when riding conditions are unfavourable.

1.7 Environmental impact

One of the profound economic implications of bicycle use is that it liberates the user from motor fuel consumption. The bicycle is an inexpensive, fast, healthy and environmentally friendly mode of transport. The bicycle use extends the usable physical environment for people, while alternatives such as cars and motorways degraded and confined people's environment and mobility. Currently, two billion bicycles are in use around the world. Children, students, professionals, labourers, civil servants and seniors are pedalling around their communities. They all experience the freedom and the natural opportunity for exercise that the bicycle easily provides. Bicycle also has lowest carbon intensity of travel.

1.8 Computer-aided design

Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design. This software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. Designs made through CAD software are helpful in protecting products and inventions when used in patent applications. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

1.8.1 Design

Product design as a verb is to create a new product to be sold by a business to its customers. Product design process: the set of strategic and tactical activities, from idea generation to commercialization, used to create a product design. In a systematic approach, product designers conceptualize and evaluate ideas, turning them into tangible inventions and products. The product designer's role is to combine art, science, and technology to create new products that people can use. Their evolving role has been facilitated by digital tools that now allow designers to do things that include communicate, visualize, analyse, 3D modelling and actually produce tangible ideas in a way that would have taken greater human resources in the past. Product design is important to an organization or a brand as it differentiates the brands from others. It was just a product design change which involved a different technology.

When compared with a competition, if you have the better product design, your product will be chosen above competition in the market. Product design is a major crowd pull especially in technology markets like Laptops or Smartphones. Even in heavy machinery or services, design plays a major role because it can be the difference between efficiency and chaos.

Design can be in various forms, and better the acceptability of the product design over time, the better the brand built for the organization.

1.8.2 Analysis

Analysis is a very important field in product optimisation and in conjunction with Finite element methods, solving complex structures is relatively quicker. In this study stress analysis of a Bicycle frame is carried out using ANSYS Workbench using various boundary conditions and compared it with theoretical results. All the stresses were found well below the yield stress of the material used and hence are in the safer zone.

Ansys develops and markets engineering simulation software for use across the product life cycle. Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analysing the strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

1.9 Frame

The most popular frame design is known as the diamond or double- triangle. This design has changed very little since the advent of the safety bicycle in the 1880s. It's proven to be a great use of materials, great for bracing angles, great for strength; it lends itself to being beat up pretty hard and still being ride able. The strength of the design comes from the triangle shapes that make up the diamond design. "Structurally, it's quite impressive. If you look at engineers playing with structures, they tend to come back to triangles and since the bike is basically three triangles, it works out to be a pretty strong structure."

While the diamond design is the core of most bicycles built today, some frame builders are experimenting with new variations on this classic design. For example, some carbon-fibre frames are being made with oval tubing, making the bicycle more aerodynamic. New full-suspension bikes have altered the diamond design to allow for a large shock to be mounted on the seat stem. However, most changes to the design are more subtle and have to do with maximizing performance for different types of terrain or uses.

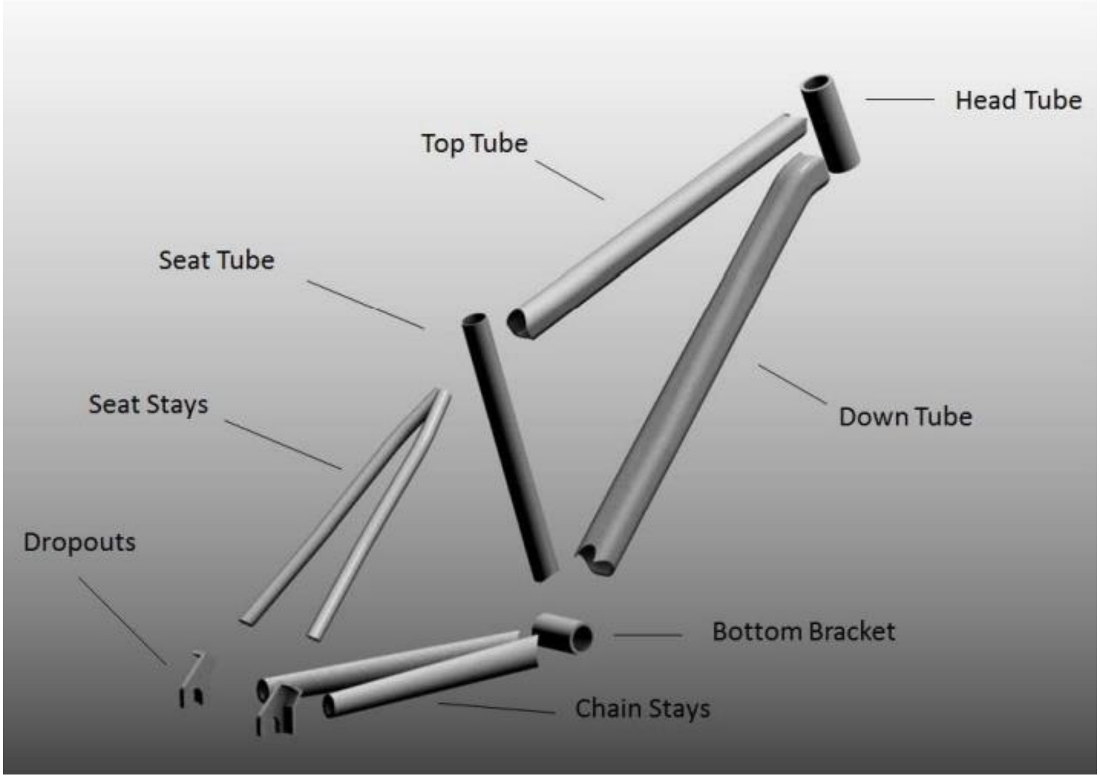

Fig 1.5 Tubing diagram of a diamond bicycle frame

1.9.1 Stress on the Frame

Bicycle frames have to be built to handle a variety of loads. First, the frame needs to support itself and other components of the bicycle. These are considered static loads. In addition, the frame needs to be able to handle the cyclist's weight, the forces of pedalling and braking, and the effects of the road's surface. These are dynamic loads; they are the most problematic for a frame builder since, as the name implies, they move and vary in intensity.

CHAPTER-II

LITERATURE REVIEW

2. LITERATURE REVIEW

Before going with the project, a brief study on papers related to DESIGN AND STRUCTURAL ANALYSIS OF A BICYCLE FRAME UNDER STATIC LOADING CONDITIONS was done. Many authors portrayed different ideas related to their works on the design of bicycle frames and analysis on different frames. The different papers reviewed are listed below:

Vignesh.M et al 2019 modelled optimum design for an electric bike and analysed for stress and failure rate for commercial purpose. The main objective was to design and fabricate a light weight still strong, safe, and economical than the conventional ones. The materials used in analysis Steel Alloys, Aluminium and its alloys, Titanium, Carbon Fibre. The analysis comprised of static simulations and torsional analysis for sudden impacts and harmonic analysis for dynamic behaviour of all the components in the frame. The carbon fibre and titanium alloy restricts the design as it is costly but it is compared to be much stronger than the material AISI 4130. AISI 4130, the loading conditions have been restricted, so if any other stronger material has been chosen the loading conditions can be expanded. The study concluded that after the analysis AISI 4130 shown to be the optimum material for the frame considering cost.

Derek Covill et al proposed use of a finite element model to simulate the behaviour for a standard steel bicycle frames under a range of measured load cases. These load cases include those measured both in the laboratory setting and also in the field, and include loads transmitted at key areas such as the dropouts and hub, the bottom bracket and drive, the headset and handlebars, and the seat post and saddle. The load cases analysed include static representations of dynamic bump situations which occur sporadically and also those which occur constantly or regularly such as those generated at the drive and handlebars during climbing or cruising. The resulting stresses within the bicycle are analysed in the context of frame performance relating to static and fatigue strengths and are also compared to similar load cases presented in the literature.

W H Tan et al 2021 studied that how the changing of material of the bicycle frame and the insertion of the suspension system can reduce vibration. This study was conducted using aluminium alloy as the material for bicycle frame to reduce the vibration and the weight of the bike. The suspension system has also been customized into the bicycle frame as the main vibration absorber. The CAD model was developed and been analysed using static and dynamic analysis based on the specific boundary condition. The static and dynamic analysis of bicycle frame was analysed based on the specific boundary condition of adult's weight of 76 kg. Both static and dynamic analysis of bicycle frame were done using aluminium alloy as the material for the frame. The vibration analysis was conducted using dynamic analysis to obtain the six modes of frequency. The result showed a small deformation occurs on the frame that causes the frame to deflect from the original shape as depicted in modal analysis. Overall, it is concluded that a suspension system adopted on the bicycle frame can have a significant enhancement in vibration reduction on the rider. Although the deformation occurs, the bicycle frame can still absorb the tested vibration without the large deformation on the frame structure. The results are still acceptable and can be improved by future researchers to increase the thickness of the frame.

Zhang Long et al 2015 found the best position of human-bike system, simulation experiments. On riding comfort under different riding postures are done with the life mode software employed to facilitate the cycling process as well as to obtain the best position and the size function of it. With BP neural network and GA, analysing simulation data, conducting regression analysis of parameters on different heights and bike frames, the equation of best position of human-bike system is gained at last. In addition, after selecting testers, customized bikes based on testers’ height dimensions are produced according to the size function. By analysing and comparing the experimental data that are collected from testers when riding common bicycles and customized bicycles, it is conducted that customized bicycles are four times even six times as comfortable as common ones. The equation of best position of human-bike system is applied to improve bikes’ function, and the new direction on future design of bicycle frame parameters is presented.

Y. Champoux et al 2004 optimized their choice of geometry and tube thickness, bicycle frame manufactures need to use an approach for a modern design on a finite-element model. They presented new measurement techniques and an overview of the different approaches. Knowledge about the loads carried by off-road bicycles provides crucial information to bicycle frame manufacturers, allowing them to develop and propose new and optimized versions of their product.

Arun Abishek.T et al 2021 analysed the single main frame electric bike chassis using material AISI 1018 low carbon steel. The Design and Analysis of Single Main Frame Electric Bike Chassis was done successfully by using Ansys workbench software. From the Ansys workbench Total Deformation, Equivalent Shear stress, Maximum Shear Stress, Equivalent Shear Strain, Maximum Shear Strain are obtained. The material AISI-1018 Low carbon steel gives positive results.

Krishan Kumar Mishra et al 2021 designed bicycle frame which is done in solid works and is analysed in Ansys software. The frame is imported into Ansys and the analysis is done which includes Stress, Strain and Total deformation of some condition are analysed. Conditions of analysis are static, rear wheel braking, steady state pedalling, vertical impact, horizontal impact. Al 6061 is used for the analysis for this study as it has greater weldability characteristics and above analysis is performed. From the results of Finite element analysis, it is showed that the stress induced in bicycle frame is minimal and factor of safety is greater than the limit. Ultimate strength for the material is also greater than equivalent stress (Von Mises).

Nair Ajit et al 2018 replaced bicycle frame material with magnesium alloy (AZ91D) and performed the analysis such as FEM, structural, static analysis, dynamic analysis and report the deformation under different loading conditions, and ensured the implementation of modified mountain bike frame with magnesium AZ91D alloy. The bicycle frame is designed by using CREO PARAMETRIC 3.0 and the analysis of the bicycle frame is done by using ANSYS software tool. A modified mountain bike frame model was created to simulate the behaviour of the frame under a range of measured load cases. The various analysis are performed under different loading conditions, structural analysis in both static and dynamic conditions are taken, highly stressed areas correlate reasonably well in terms of being similarly located with those simulations presented in the literature for similar load cases, although our values tend to be somewhat lower than the existing model. This model is suited for off road conditions and best in on road conditions. By this model the frame weight is reduced and the other structural properties remains the same. The mountain bike frame in magnesium alloy is designed, and analyses under different parameters and the results are noted, and this shows lesser deformation than the traditional mode

Chien-Cheng Lin, Song-Jeng Huang Chi-Chia Liu analysed the stress and optimized the design of a customized bicycle frame using Pro/ENGINEER digital solid modelling computer-aided design software. It also attempts to verify the stress and displacement response of several bicycle frames using a wireframe model and then analyse the solid structure. It was found that, for a shell-entity frame, the diamond-type frame (diamond-shaped) has the highest rigidity, and the mechanical properties of $AZ60/Al_2O_{3p}$ magnesium metal matrix nano composites by equal channel angular extrusion almost acquire the level of Al6061 aluminium. For the mountain bike (MTB) frame simulated with ECAEed AZ61/Al2O3 MMCs, the calculation results show that not only is the rigidity similar to that of Al6061 but also compared to Al6061 aluminium alloy, the weight can be reduced from 4.0123 to 2.5764 kg (a weight reduction percentage of 36%). It is a bicycle frame of optimum size with lightweight in compliance with structural rigidity requirements.

Akhyar et al discussed the stress analysis and displacement of the bike frame (T-I profiles) through the Finite Element Analysis (FEA). Five scenarios loading conditions have been applied which are expected to represent various situations that happen in the actual performance of the bicycle frame. Loading conditions are a static start-up, steady-state pedalling, vertical-horizontal loading, and rear-wheel braking. The cross-section of the bike frame comprises two forms. There is a “T” profile on the mainframe and an “I” profile on stay. The simulation results in this paper showed that von-Mises stress ranges from 7.18 - 36.83 MPa which are spreading over several areas of this bike frame such as seat beam, chain stay-seat stay, top beam, and drop out, depending on the position of the loading applied. Subsequently, the maximum deflection that the bike frame from this design is obtained is 0.018 - 0.23 mm.

Amareswari Reddy et al found that in design, it should be considered many factors such as product design must be satisfied by the customer, the material used the ability of the product to work, and others. All part of the design is to fulfill customer need. Besides, that design will have an effect on the Company such as profit, loss, and reputation of the company. In this paper, they have modelled a diamond frame of the bicycle by using SOLIDWORKS and performed finite element analysis on it by using ANSYS 14.5. A conceptual design of a bicycle is proposed for reducing the effort kept by the cycler while he rides on an inclined plane. The project idea is the implementation of a four-bar mechanism on the bicycle. The increased Centre of mass of the bicycle is restricting the objective of the project.

CHAPTER-III

SELECTION OF MATERIALS

3. SELECTION OF MATERIALS

The material selection of an automobile or a bicycle frame plays a vital role for giving strength to the automobile or bicycle. The load with standing capability also depends on the materials selected for a particular bicycle. Generally, the tubes of the frame are made of steel. Steel frames can be very inexpensive carbon steel to highly specialise using high performance alloys. Frames can also be made from aluminium alloys, titanium, and carbon fibre. Density is a measure of how light or heavy the material per unit volume. Stiffness (or elastic modulus) can in theory affect the ride comfort and power transmission efficiency. In practice, because even a very flexible frame is much stiffer than the tires and saddle, ride comfort is in the end more a factor of saddle choice, frame geometry, tire choice, and bicycle fit. Yield strength determines how much force is needed to permanently deform the material (for crash-worthiness). Elongation determines how much deformity the material allows before cracking (for crash-worthiness). In this study different materials are considered for analysing the behaviour of a particular bicycle frame. The properties of all the materials considered are given below.

3.1 Structural steel

Structural steel is a category of steel construction material that is produced with a particular cross section or shape, and some specified values of strength and chemical composition. Structural steel composition, strength, size, shape, and storage are controlled in most advanced countries. The word structural steel includes a broad variety of low carbon and manganese steels that are used in great numbers for civil and marine engineering applications. Numerous structural steels also include minor quantities of significant additions of other elements like Nb, V, Ti and Al. These are called High Strength Low Alloy or micro-alloyed steels. Structural steels are manufactured in section and plate shapes and are normally used in bridges, buildings, ships, and pipelines.

Properties	**Values**
Density(kg/mm^3)	7.85E-06
Poisson's Ratio	0.3
Elastic Modulus(MPa)	2.00E+05
Ultimate Tensile strength(MPa)	460
Bulk Modulus(MPa)	1.66E+05
Shear Modulus(Mpa)	76923
Coefficient of Thermal expansion(10^-5/°C)	1.20E+00
Reference Temperature (°C)	22

Table 3.1 Properties of Structural steel

3.2 Al 6061

Aluminium metal and its alloys are implemented in most of modern industrial processes due to its wide availability and the vast number of uses. An alloy is a metal made by combining two or more metallic elements to achieve improved material properties. Type 6061 aluminium is of the 6xxx aluminium alloys, which entails those mixtures which use magnesium and silicon as the primary alloying elements. The second digit indicates the degree of impurity control for the base aluminium. When this second digit is a “0”, it indicates that the bulk of the alloy is commercial aluminium containing its existing impurity levels, and no special care is needed to tighten controls. The third and fourth digits are simply designators for individual alloys (note that this is not the case with 1xxx aluminium alloys). The nominal composition of type 6061 aluminium is 97.9% Al, 0.6% Si, 1.0%Mg, 0.2%Cr, and 0.28% Cu. 6061 aluminium alloy is heat treatable, easily formed, weld-able, and is good at resisting corrosion. Its weld-ability and formability make it suitable for many general-purpose applications. Its high strength and corrosion resistance lend type 6061 alloy particularly useful in architectural, structural, and motor vehicle, marine frames, electronic parts, and heat exchanger applications.

Properties	**Values**
Density(kg/m^3)	2700
Poisson’s Ratio	0.33
Elastic Modulus(MPa)	6.89E+04
Ultimate Tensile strength(MPa)	2.76E+02
Bulk Modulus(MPa)	6.7549E+04
Shear Modulus(Mpa)	2.5902E+04
Coefficient of Thermal expansion(10^-5/°C)	2.3
Reference Temperature (°C)	22

Table 3.2 Properties of Al606

3.3 Titanium Alloy

Titanium alloys are metals that contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and toughness (even at extreme temperatures). They are light in weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. Materials are frequently chosen for various applications because they have desirable combinations of mechanical characteristics. For structural applications, material properties are crucial and engineers must take them into account. They are light in weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. However the high cost of raw materials and processing limits to the use in military applications, aircrafts, bicycles, medical devices, sports cars, jewellery and etc.

Properties	**Values**
Density(kg/m^3)	4620
Poisson's Ratio	0.36
Elastic Modulus(MPa)	9.60E+04
Ultimate Tensile strength(MPa)	1070
Bulk Modulus(MPa)	1.14E+05
Shear Modulus(Mpa)	35294
Coefficient of Thermal expansion(10^-5 /°C)	9.40E-01
Reference Temperature (°C)	22

Table 3.3 Properties of Titanium alloy

3.4 Carbon Fibre

Carbon Fibre Reinforced Composites are lightweight, strong materials used in the manufacturing of numerous products used in our daily life. It is a term used to describe a fibre-reinforced composite material that uses carbon fibre as the primary structural component. These strong, stiff and lightweight materials are an ideal choice for applications where lightweight and superior performance are important, for components for aircrafts, automotive , sail boats, and notably in modern bicycles and motor cycles, where high strength-to-weight ratios are required. These materials have wide applications such as in the manufacturing of hybrid smart memory composites, aeronautical applications, wind power generation, marine applications, medical equipment and prosthetic devices, thermoplastic applications, for engineering constructions (bearings, gears, cams, fan, and turbine blades), in telecom applications, in automobile sectors, textile industries, in high-end sports equipment, for high-quality audio components and musical instruments, etc. The properties of Carbon Fibre Material are given in the table.

Properties	**Values**
Density(kg/m^3)	1750
Poisson's Ratio	0.2
Elastic Modulus(Pa)	2.3E+11
Ultimate Tensile strength(Pa)	2.23E+09
Bulk Modulus(Pa)	1.27E+011
Shear Modulus(pa)	9.58E+10
Coefficient of Thermal expansion(10^-6/°C)	2.1
Reference Temperature (°C)	22

Table 3.4 properties of Carbon Fibre

3.5 Chromoly Steel

Chromoly steel is a type of low alloy steel that gets its name from a combination of the words “chromium” and “molybdenum” – two of the major alloying elements. Chromoly steel is often used when more strength is required than that of mild carbon steel, though it often comes at an increase in cost. Chromoly falls under the AISI 41xx designations. Chromoly steel is actually alloy steel grade 4130. The “30” at the end of the grade number designates that it has approximately 0.30% carbon by weight. The added chromium helps to increase the steels hardenability and also the corrosion resistance. The added molybdenum helps to increase the toughness. Other important benefits of AISI 4130 include the ability to be easily hardened by heat treating or work hardening, and the ability to be case hardened using a process called carburizing. The applications of chromoly steels can be found in a variety of industries. They are very commonly used in automotive, bicycle, and heavy equipment parts, the oil and gas industry, metal production and forming equipment, and many other industries. Here are some more specific examples molds, pins, bicycle tubing, furnace equipment, crank shaft, chain links, drill collars, machine shafts, conveyors, tie rods, miscellaneous tooling.

Properties	**Values**
Density(kg/m^3)	7850
Poisson’s Ratio	0.28
Elastic Modulus(GPa)	205
Ultimate Tensile strength(Pa)	6.35E+08
Bulk Modulus(Pa)	1.553E+011
Shear Modulus(pa)	8.0078E+10
Coefficient of Thermal expansion(10^-6/°C)	11.2
Reference Temperature (°C)	22

Table 3.5 Properties of chromoly steel

3.6 AISI 1025 Carbon Steel

Carbon steel is a steel with carbon content from about 0.05 up to 2.1 percent by weight. AISI 1025 is a low- to medium-carbon alloy appropriate for general engineering and construction applications. Offering good machinability, AISI 1025 can be normalized, hot- and cold-worked, or water quenched and tempered. 1025 carbon steel is a high-quality carbon structural steel with certain strength, hardness, plasticity and toughness. Generally used in the manufacture of cold stampings, small forgings and in the processing of small and medium-sized parts for heavy and medium machinery, such as washers, pins, bolts, nuts, etc. AISI 1025 carbon steel, containing only carbon as its main alloying element. These steels also contain 0.4% silicon and 1.2% manganese. Small amounts of copper, nickel, molybdenum, aluminium and chromium can also be detected in carbon steel.

AISI 1025 is a standard grade of carbon steel. It consists of (by weight percent) 0.22-0.28% carbon (C), 0.30-0.60% manganese (Mn), 0.04% (max) phosphorus (P), 0.05% (max) sulphur (S) and The base metal iron (Fe) composition. The use of these steels are in structures in buildings, bridges, railways, fabrication of pipeline components, construction of automobile bodies, shipping containers, commercial appliances, etc.

Properties	**Values**
Density(kg/m^3)	7858
Poisson’s Ratio	0.3
Elastic Modulus(Pa)	2.1E+11
Ultimate Tensile strength(Pa)	4.40E+08
Bulk Modulus(Pa)	1.75E+011
Shear Modulus(pa)	8.076E+10
Coefficient of Thermal expansion(10^-6/°C)	12.1
Reference Temperature (°C)	22

Table 3.6 Properties of AISI 1025 Carbon Steel

CHAPTER-IV

DESIGN

4. DESIGN

A design is a plan or specification for the construction of an object or system or for the implementation of an activity or process, or the specification in the form of a prototype, product or process.

SolidWorks is a solid modeller, and utilizes a parametric feature-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create models and assemblies. The Solidworks software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside the sketch.

In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. SolidWorks also includes additional advanced mating features such as gear and cam follower mates, which allow modelled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and SAC).

Solidworks uses a 3D design approach. As a part is designed, from the initial sketch to the final result, 3D model is created. From this model, 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies can be done. 2D drawings of 3D assemblies can also be created. When designing a model using Solidworks, it can be visualized in three dimensions, the way the model exists once it is manufactured. One of the most powerful features in the Solidworks application is that any change made to a part is reflected in all associated drawings or assemblies.

Designing of a bicycle is been carried out in solidworks using all the required design tools. The bicycle was designed by taking reference of various by-cycles in the market and a model was designed using Solidworks. The parts of the bicycle were designed separately in part drawings and then assembled in assembly drawing into a single unit to make a bicycle.

4.1 Design of frame

The body of the bicycle is designed using tools such as sketch tools as of line, circle, spline, arc in different planes. The features tools in the solidworks were used to get the 3-dimensional or the body such as boss extrude, extrude cut and many other features.
Some of the important tools and commands used in the design of the bicycle are:

Line tools in sketch is used in drawing the sketch that includes straight lines.

Circle is used to draw the circles with required dimension.

Spline tool is used for drawing curved lines between certain points.

There are other tools such as rectangle, polygon, ellipse, and many other sketching tools in the sketch toolbar.

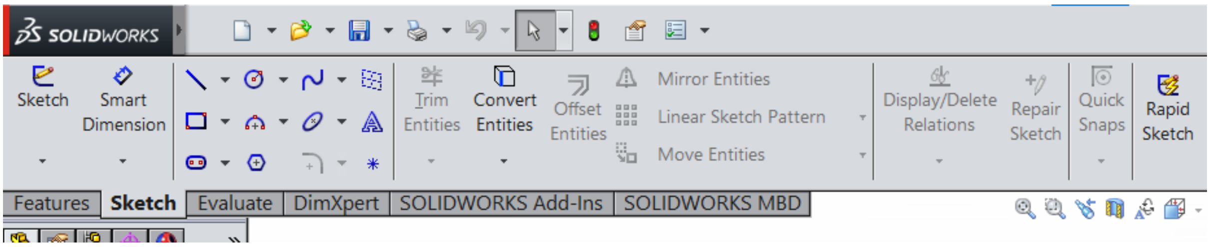

Fig 4.1 Sketch Toolbar

After the complete sketching of the component of the part the features commands were used in obtaining the body of the component for the part. The whole body of the part is completed using the features tools with reference to the sketch with respect to their respective planes.

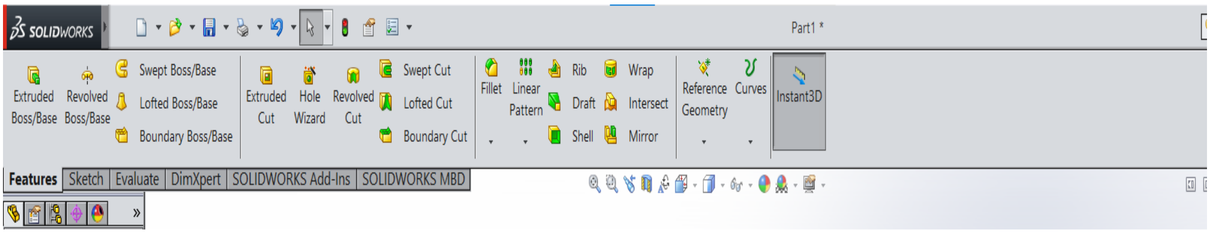

Fig 4.2 Features Tool Bar

4.1.1 Major feature tools used in the bicycle frame design are:

Boss/base Extrude: Extrude Boss/Base is one of the important and very useful tool in Soildworks CAD software to create solid 3D models. It extrudes a sketch or selected sketch contours in one or two directions to create solid feature. That means, for a closed contour sketch drawing, materials can be added to that contour and convert it into 3D model.

Revolved Boss/Base: Revolved Boss or Base is a SolidWorks feature tool which is used to create solid 3D model around an axis. The sketch can be revolved around an axis to add materials to it.

Extruded Cut: Extrude cut is another cool feature which helps to remove materials from the 3D model. It is just opposite to extrude boss/base feature, because it cuts a sketch profile while extruding. Cut can be done in both directions and mainly used for creating holes, channels, slots etc.

Swept Boss/Base: Swept Boss or base feature is very useful tool, which helps to create 3D product design parts. Some of the application examples are create spring model, complex hollow pipes, air conditioning ducts, curved rods, tubes, twisted parts etc.

Lofted Boss/Base: Loft Boss or base is SolidWorks Features tool (like Extrude Boss, Revolved Boss, Sweep Boss etc.), which mainly helps to add materials between two or more profiles with ease. The profile should be closed and it can be used for profiles different (e.g. between circle and rectangle) or similar (e.g. between two rectangles or circles) in shape.

Swept Cut: Solidworks swept cut is features tool, mainly used to cut a solid model or part by sweeping a completely closed profile along an open or closed path. To use swept cut, you should need a closed profile and open or closed path, which may be line, helix, and circle, rectangular or arc etc.

There are other tools used such as convert entities, trim entities which is used to trim the parts in the sketching, fillet tools which is used in giving the fillet to desired parts in the drawing.

Smart Dimensioning: It helps to correct or modify the dimension for sketched part according to given idea or paper drawing. The Smart Dimension tool can be found at the sketch toolbar manager.

The parts which are designed are made to bring together using assembly drawing in Solidworks using insert components tool. All the files which are saved as part drawings are drawn and are assembled using mate tool.

Mate: Mates create geometric relationships between assembly components. As you add mates, you define the allowable directions of linear or rotational motion of the components. A component can be moved within its degrees of freedom, visualizing the assembly's behaviour.

Mating is done between parts with reference to the surfaces of the two mating parts and the collinearity and tangents and parallel is checked and locked between the parts.

Design of frame is done in Solidworks 2015 software, part modelling is done for the bicycle frame.

4.1.2 Head tube and Down tube

The head tube is drawn in the top plane, a circle of 35 mm diameter is drawn in the top plane. Extrude Boss/Base feature is selected on the circle and the length of the head tube is given in the extrude boss feature. Another circle is drawn with 32 mm diameter, selecting the circle Extrude cut feature is selected and the given through all, the hollow desired head tube of the frame is obtained.

The down tube is formed by selecting the front plane, sketch is drawn using spline command and a spline curve is drawn with one point on the head tube by forming a plane where a circle is drawn and another plane at the other point with a curve length of 415 mm and distance between two points is 390mm, a circle is drawn on the plane. The two circles are selected on the two planes are selected and lofted boss feature is applied, the down tube of the frame is obtained.

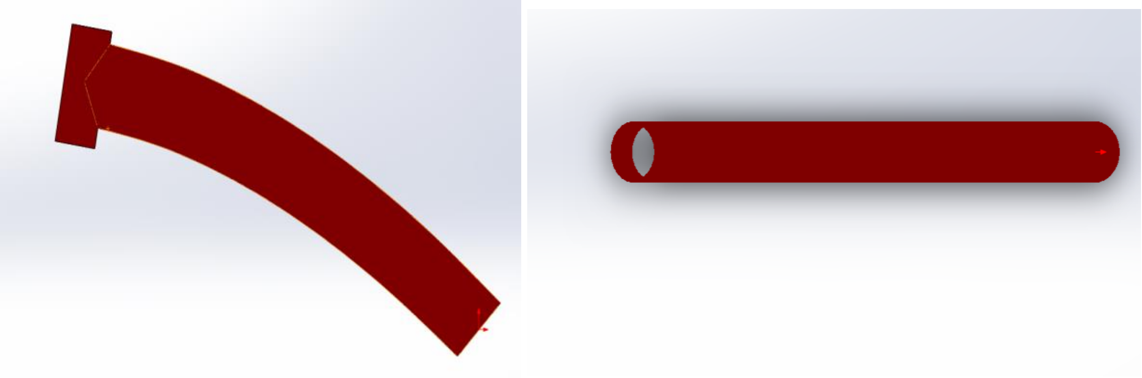

Fig 4.3 Modelling of head tube and down tube

4.1.3 Bottom Bracket and Seat tube

The front plane is selected and sketch is selected, with the use of circle command with centre at the point of the down tube a circle is drawn of 55mm diameter in the front plane. Now using Extrude boss a feature with constrain as mid plane with length of 75mm, a solid bottom bracket is formed in the form of a shaft. Another circle is drawn in the front plane with the same centre a circle is drawn with 52mm diameter, selecting the circle using extrude cut feature with through all, the bottom tube of the frame is obtained with 75mm length.

Choosing the top plane a centre line is drawn from a circle drawn from the bottom racket, the circle is drawn at the top and selecting the circle using Extrude Boss/Base and Extruded Cut features the seat tube is obtained.

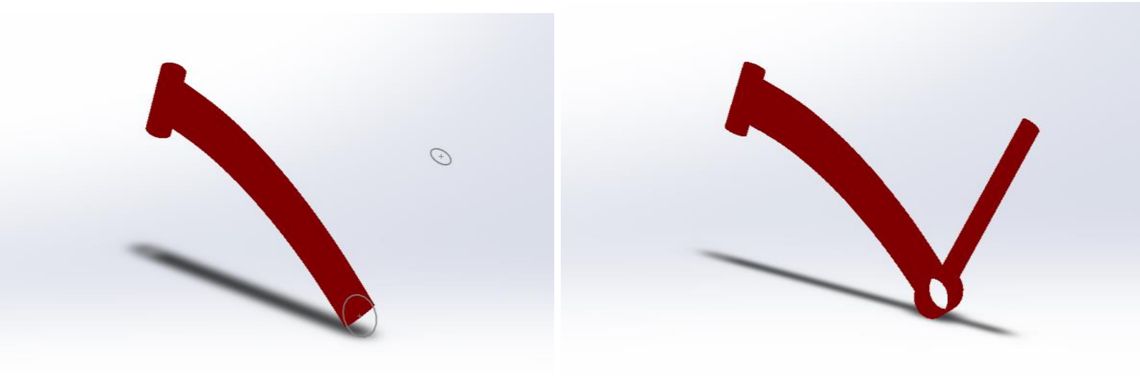

Fig 4.4 Modelling of the bottom bracket and seat tube

4.1.4 Chain Stays and Seat Stays

In the front plane a centre line triangle is drawn with the starting corneer at circle of the bottom bracket. Choosing the right plane, sketch a circle with refercence of the point of circle for drawing the backward part of the frame. Sketch a line draw a line for the chain stays, making it relating parallel to the centreline triangle. Draw the chain stay points and join the lines and also draw the seat stay points, join them with line commands and connect to the last line of the triangle or the centre line of the seat tube. The chain stay and the seat stay line near dropout regions are selected and fillet feature is applied to get the required shape. Using the Swept boss/base feature given to the drawn portion, one side of the chain stays and seat stays are obtained. Choosing the front plane, and using the mirror command, the chain and seat stays are selected and the centre line triangle is given as a reference line, the other side of chain and seat stays are obtained. The centreline triangle in the sketch is hidden using hide command. The chain and seat stays are obtained.

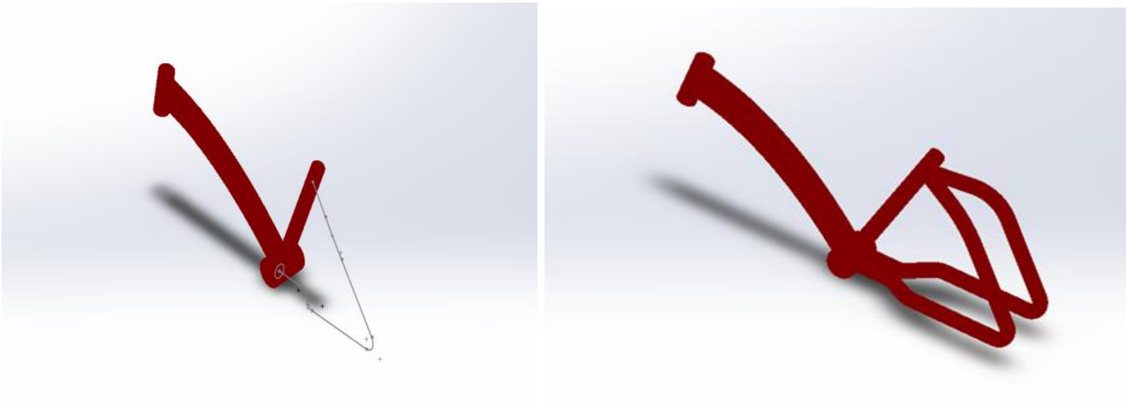

Fig 4.5 Modelling of chain stays and seat stays

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4.1.5 Top tube

In the front plane , a spline is drawn from the seat tube to the down tube with required dimensions. Choosing spline and select a plane draw circles at the seat tube. Selecting the sketch the Swept base/boss feature is used to get the 3D model of the top tube.

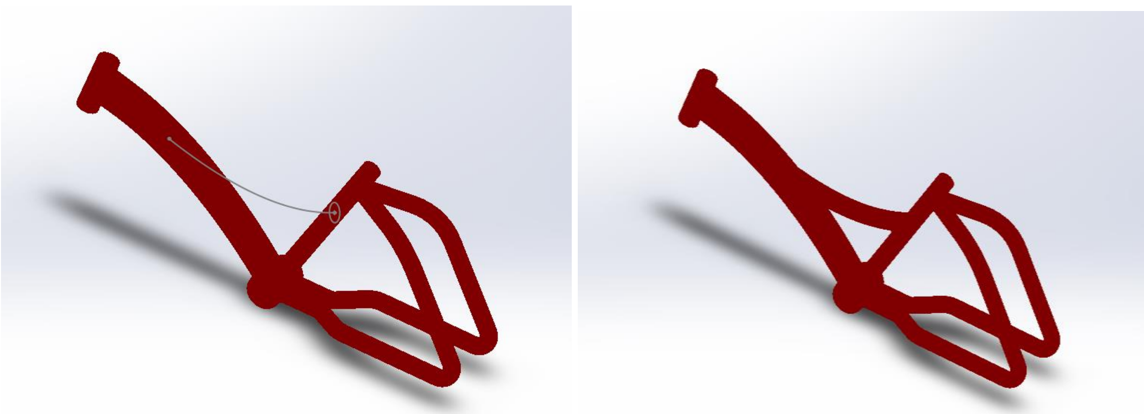


Fig 4.6 Modeling of top tube of the frame

4.1.6 Dropouts

Dropouts of required shape are drawn in the front plane, using extrude Boss/Base feature with required thickness and dimensions dropouts are obtained. Using mirror in the front plane and selecting the dropout, the dropout on the other side of the frame is also obtained.

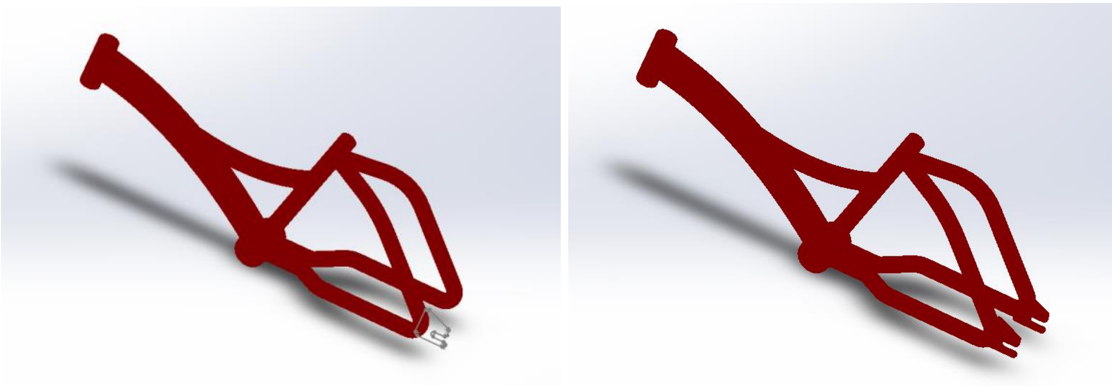


Fig 4.7 Modelling of the dropouts of the frame

The undesired portions on the frame are removed using extruded cut feature. Using the fillet feature the fillet is applied to all the joints of the parts of the frame.

Fig 4.8 Frame of the bicycle

Fig 4.4 Final design of the bicycle is with all parts assembled

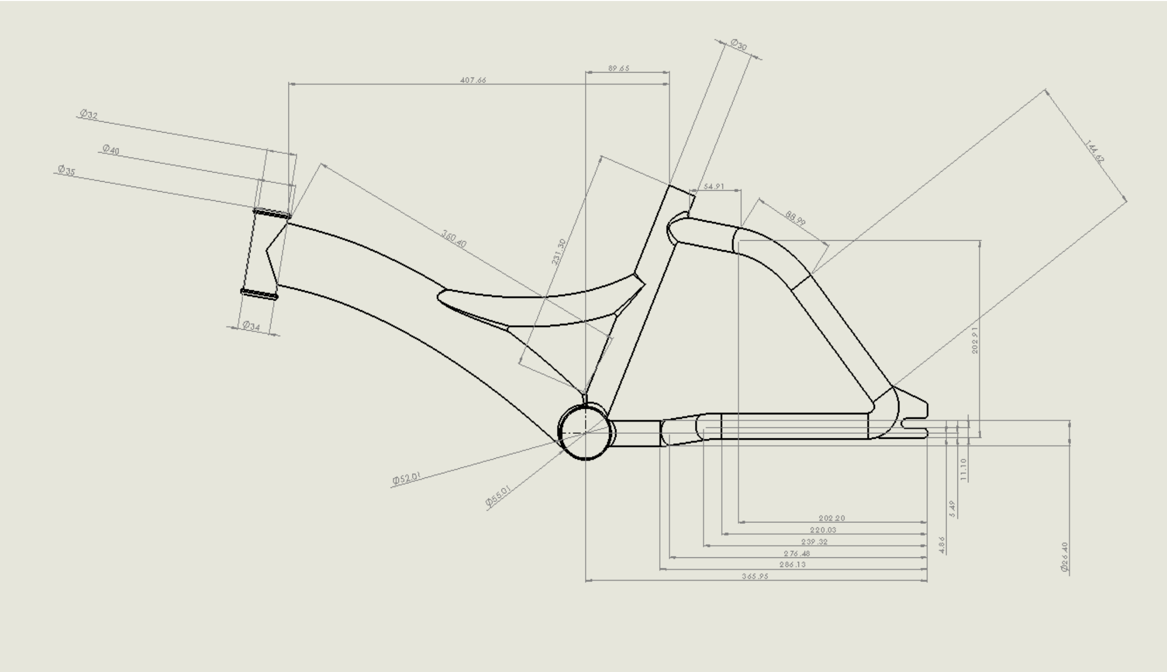


Fig 4.5 Dimensions of the frame in front view (all dimensions in mm)

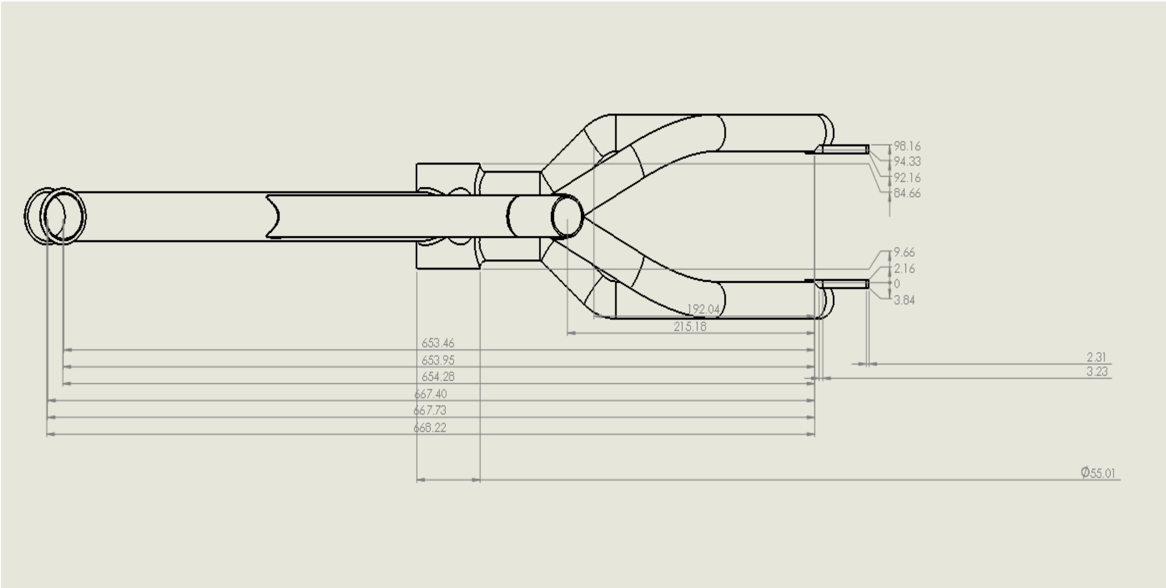


Fig 4.6 Dimensions of the frame in top view (all dimensions in mm)

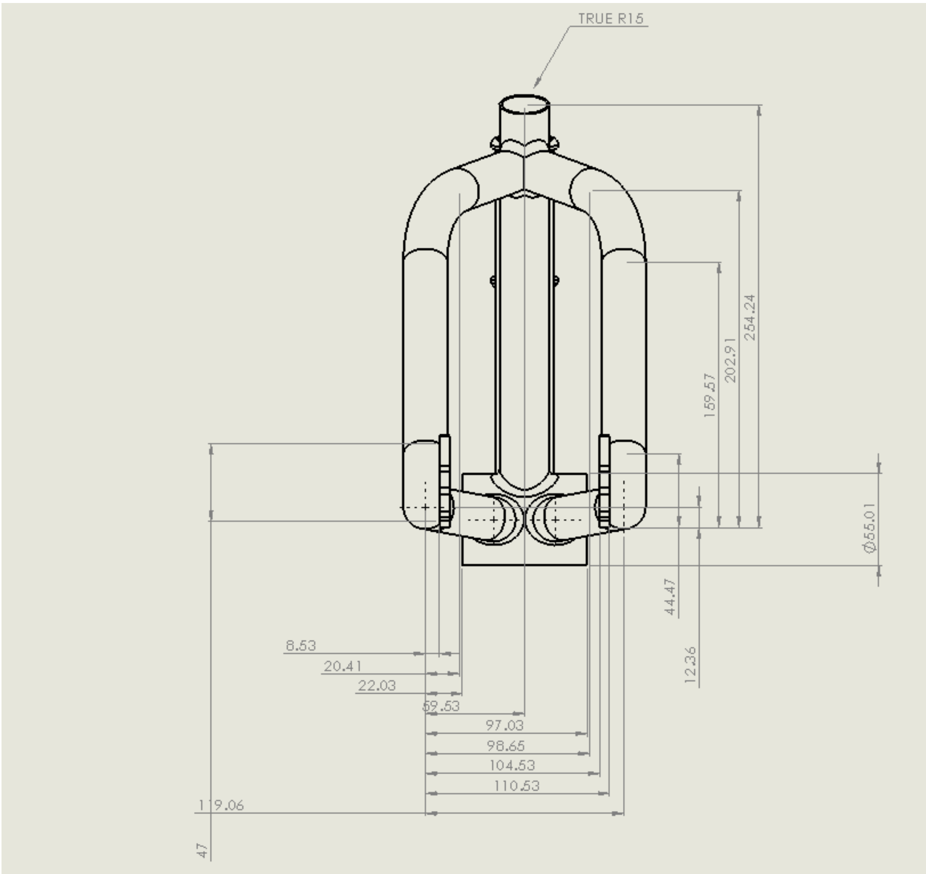


Fig 4.7 Dimensions of the frame in the back view (all dimensions in mm)

CHAPTER-V

ANALYSIS

5. ANALYSIS

An analysis model defines a coherent set of required properties of the system under development. Many of the design criteria are the quality of service constraints from the analysis. There may be others as well, such as reliability and safety level, reusability, maintainability, simplicity, time to market, and so on. Design analysis is the systematic process of developing a design including all information discovery, planning and communications. This can be applied to any type of design including the design of physical things such as buildings and intangible things such as software, information and process.

5.1 Structural analysis under static loading conditions

The frame that is designed in Solidworks is saved as an IGES. file or STEP. file and imported into Ansys 22R1. Here we saved the frame as a step and the STEP. File is imported into Ansys software.

Static structural is selected for the analysis.

5.1.1 Engineering data:

The materials used for the analysis is being selected in engineering data with some inbuilt properties and we can define materials with properties that can be used for the analysis purpose.

5.1.2 Geometry:

The design. STEP file is imported in the geometry selection.

5.1.3 Meshing:

Meshing is defined as the process of dividing the whole component into a number of elements so that whenever the load is applied on the component, it distributes the load uniformly to all the portions of the part or area which is selected for meshing. ANSYS meshing capabilities helps reduce the amount of time and effort spent to get the accurate results. More precisely meshing is the process of turning irregular shapes into more recognizable volumes called elements. Usually smaller mesh gives more accurate results.

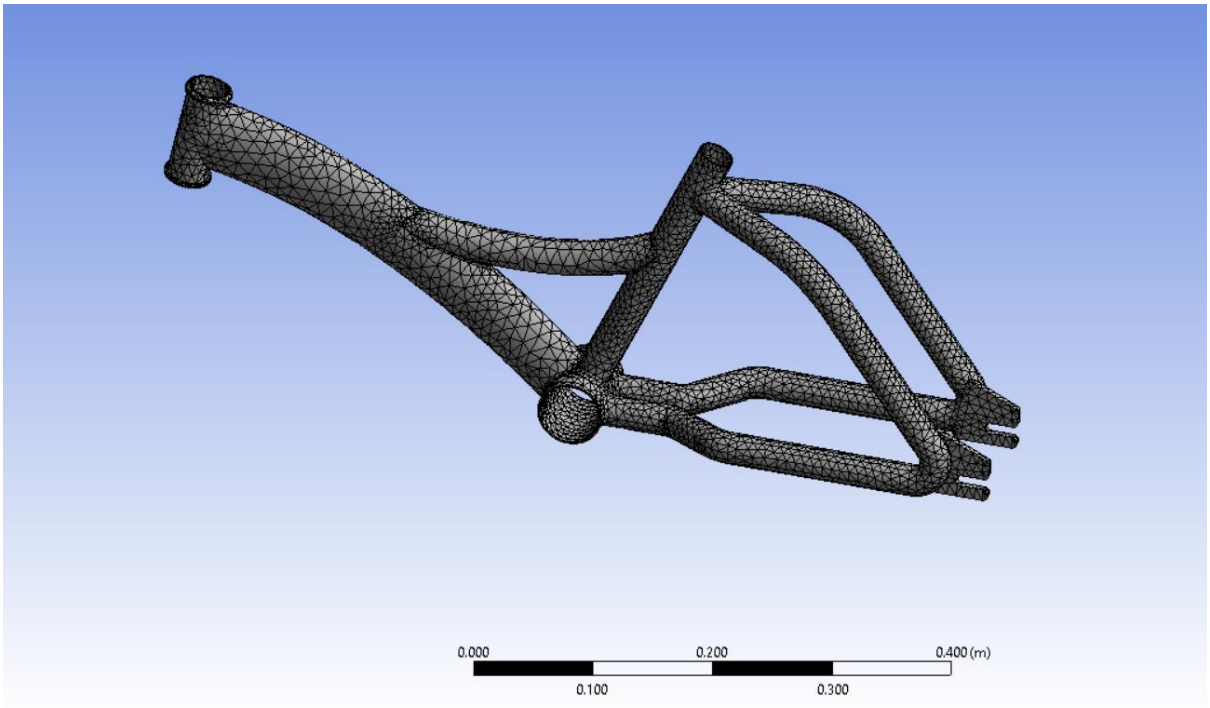


Fig 5.1 Mesh generated on the bicycle frame

Details of "Mesh"	
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Di...	0.80058 m
Average Surface ...	2.2776e-003 m^2
Minimum Edge L...	1.7133e-004 m
+ Quality	
+ Inflation	
+ Advanced	
− Statistics	
Nodes	46962
Elements	25553

Fig 5.2 Details of generated mesh

5.1.4 Constrains

The static structural analysis is made by applying loads and constraints to the frame at several points and the positions and analysis is done for the frame.

In the figure point A is the fixed support where the bottom front part of the frame goes and rests on the fork of the steering. Point B is the fixed support where the frame rests on the hub of the rear wheel of the bicycle near the dropouts. Point C is load acting on the frame that is at the area of the saddle location. The load considered is 588N on the frame which is 60kg..

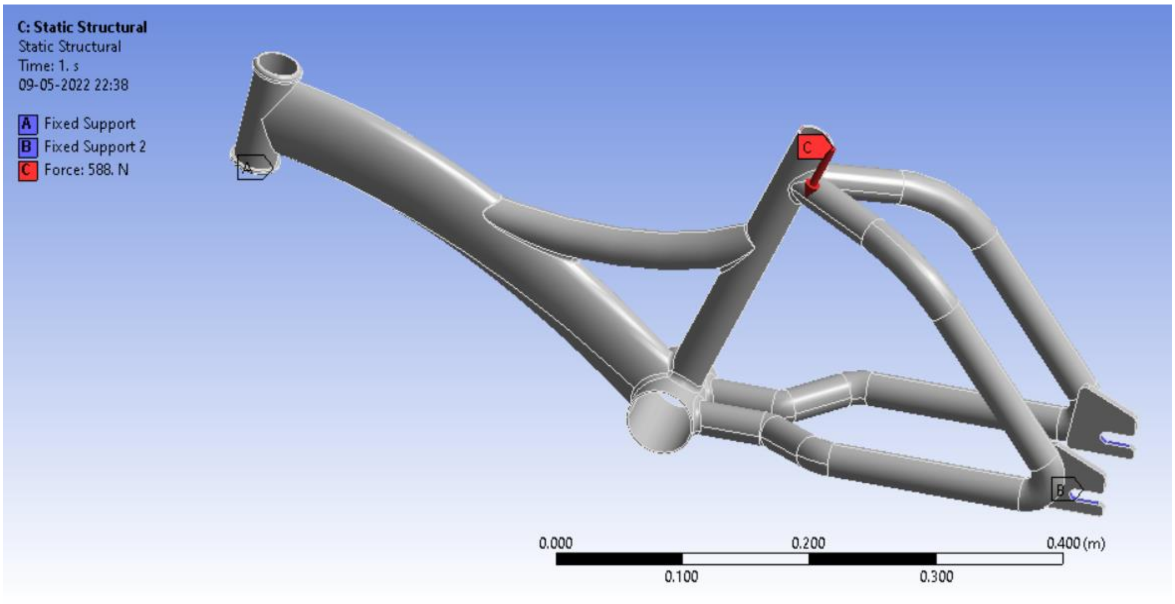


Fig 5.3 Constrains and loads acting on the frame

After all the forces are applied on the frame and the structural constrains given after the meshing the deformation results, stresses on the frame for each material are obtained and the conclusions are made based on the amount of deformation each material is undergoing.

CHAPTER-VI

RESULTS AND DISCUSSIONS

6. RESULTS AND DISCUSSIONS

The static structural analysis of the designed frame which is designed in solidworks is done. Analysis is done on different materials such as structural steel, Al 6061, titanium alloy, carbon fibre, Chromoly steel, AISI 1025 Carbon Steel which exhibit different stresses and deformations.

Static analysis is performed on the bicycle frame by applying a load of 588N which is considered to be the average human weight. The results of static analysis of frame using different materials were noted.

The weight of the frame for different materials are also obtained from the analysis along with stresses, deformations and strains on the frame for different materials.

6.1 Deformations, Stresses & Strain in Structural Steel

The maximum deformation generated on the frame is 5.8004e-005 m.
The minimum deformation generated on the frame is 0 m.

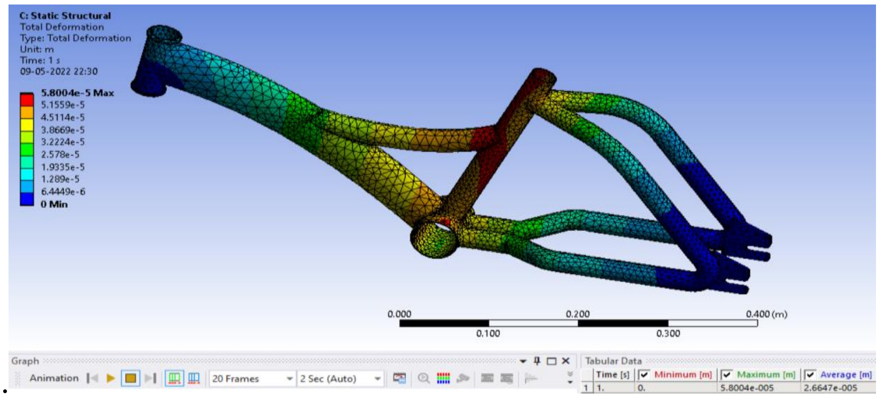


Fig 6.1 Deformation in Structural Steel frame

The maximum Von-Mises stress generated in the frame is 4.2698e+007 Pa.
The minimum Von-Mises stress generated in the frame is 37157 Pa.

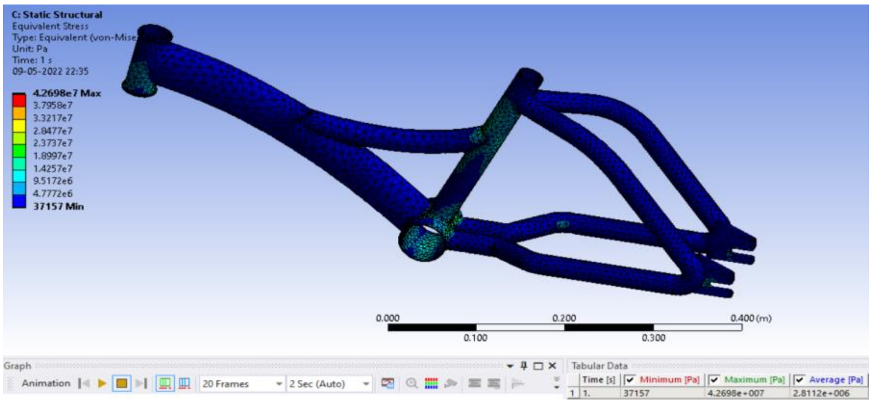


Fig 6.2 Stresses in Structural Steel frame

Maximum equivalent elastic strain generated is 2.1395e-004 m/m.
Minimum equivalent elastic strain generated is 2.2077e-007 m/m.

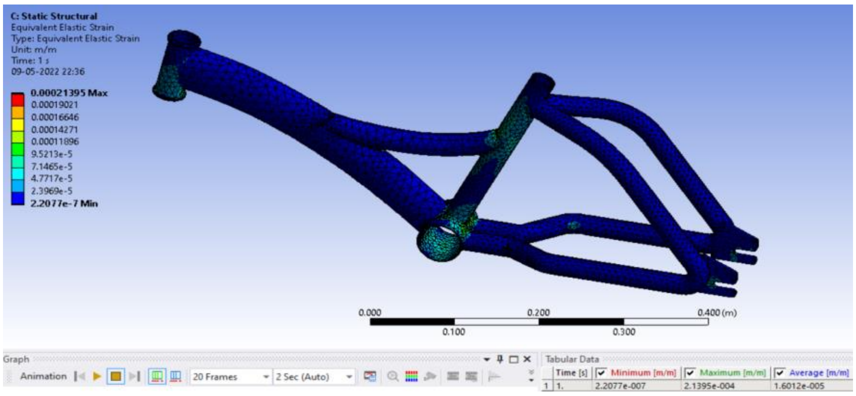


Fig 6.3 Elastic Strain in Structural Steel frame

The obtained mass of the frame under the structural steel material is 11.639 kg

6.2 Deformations, Stresses & Strain in Al 6061

The maximum deformation generated on the frame is 1.6702E-4 m.
The minimum deformation generated on the frame is 0 m.

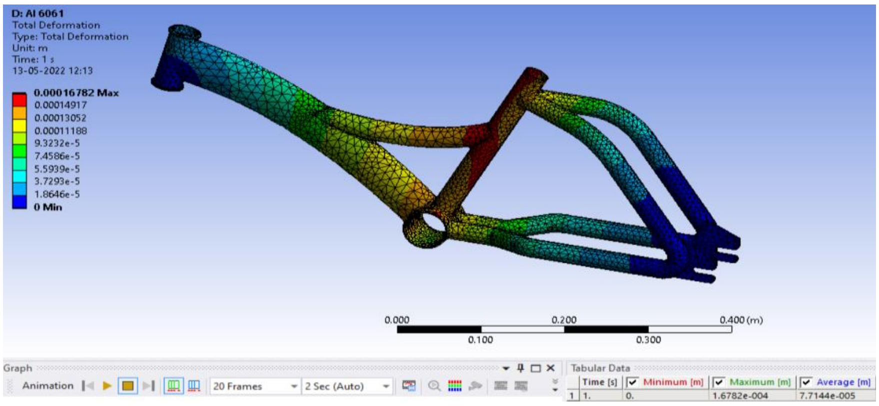


Fig 6.4 Deformation in Al 6061 frame

The maximum Von-Mises stress generated in the frame is 3479 Pa.
The minimum Von-Mises stress generated in the frame is 4.309E+007 Pa.

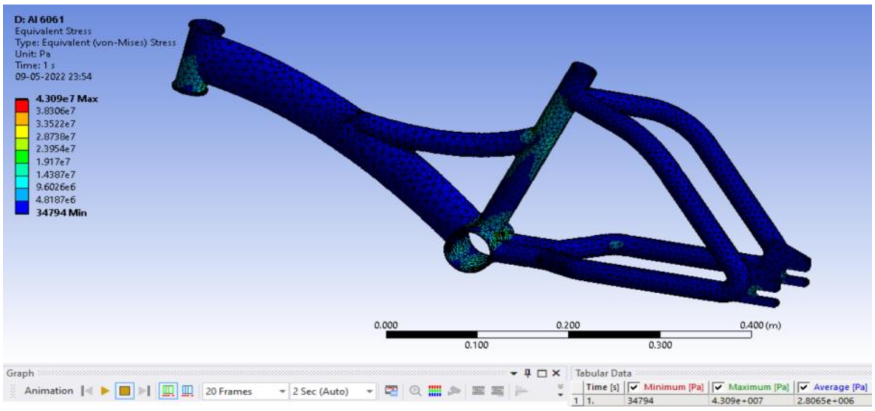


Fig 6.5 Stresses in Al 6061 frame

Maximum equivalent elastic strain generated is 6.2663E-04 m/m.
Minimum equivalent elastic strain generated is 6.2622E-07 m/m.

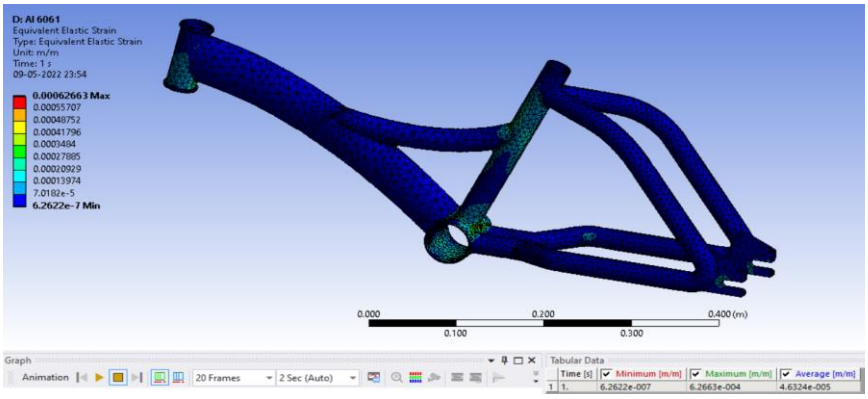


Fig 6.6 Elastic strain in Al 6061 frame

The obtained mass of the frame under the Al 6061 material is 4.0034 kg

6.3 Deformations, Stresses & Strain in Titanium Alloy

The maximum deformation generated on the frame is 1.993E-004m.
The minimum deformation generated on the frame is 0 m.

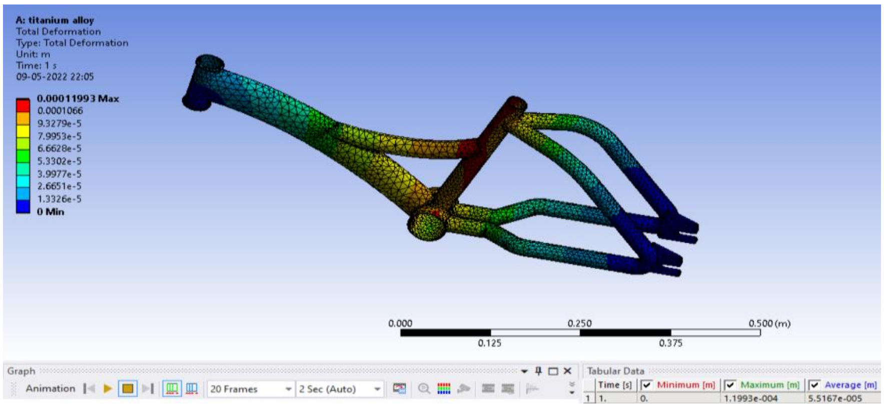


Fig 6.7 Deformation in Titanium alloy frame

The maximum Von-Mises stress generated in the frame is 4.3498E+007 Pa.
The minimum Von-Mises stress generated in the frame is 32102 Pa.

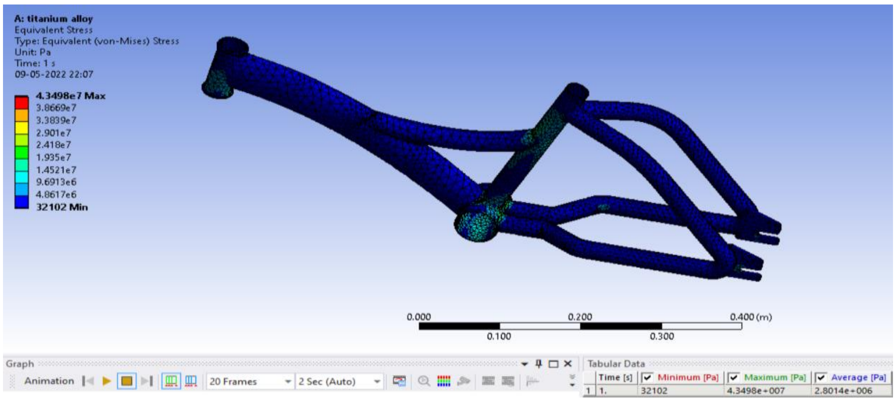


Fig 6.8 Stresses in Titanium alloy frame

Maximum equivalent elastic strain generated is 4.539E-4 m/m.
Minimum equivalent elastic strain generated is 4.3958E-07 m/m.

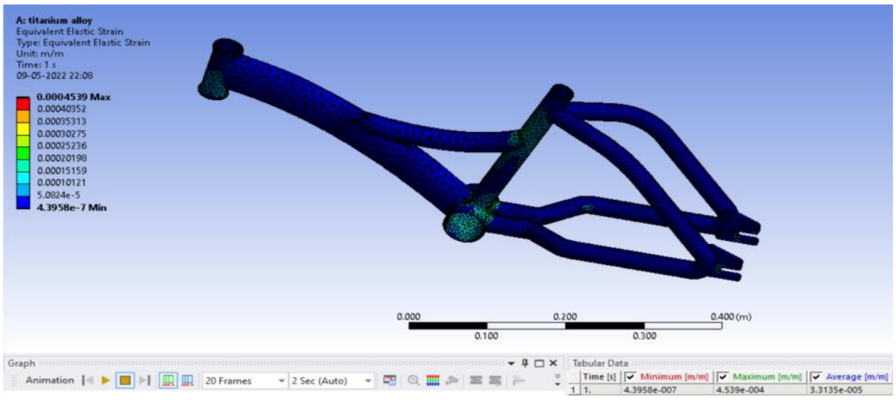


Fig 6.9 Elastic Strain in Titanium alloy frame

The obtained mass of the frame under the titanium alloy material is 6.8502 kg

6.4 Deformations, Stresses & Strain in Carbon Fibre

The maximum deformation generated on the frame is 5.0736e-005 m.
The minimum deformation generated on the frame is 0 m.

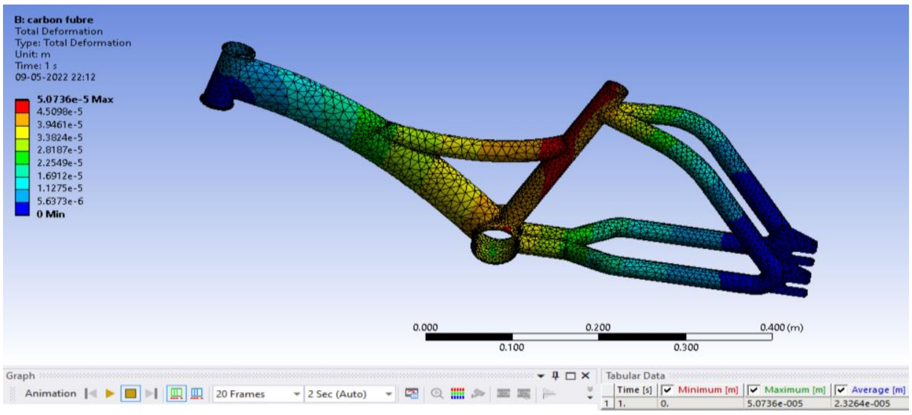


Fig 6.10 Deformation in Carbon Fibre frame

The maximum Von-Mises stress generated in the frame is 4.2432e+007 Pa.
The minimum Von-Mises stress generated in the frame is 37040 Pa.

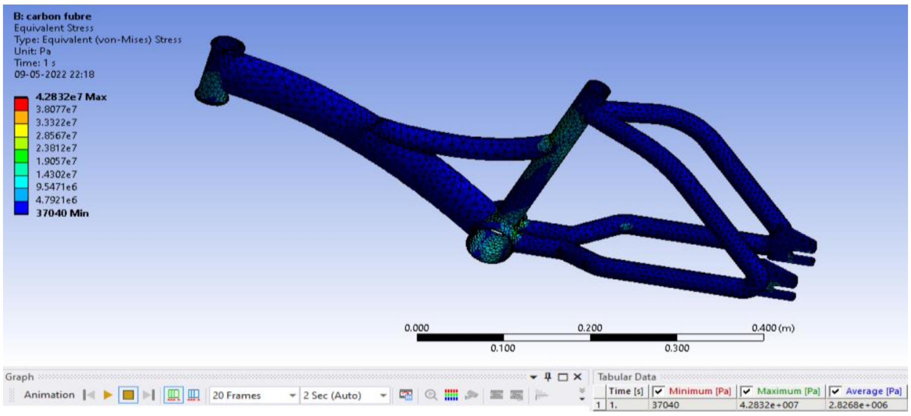


Fig 6.11 Stresses in Carbon Fibre Frame

Maximum equivalent elastic strain generated is 1.8797e-004 m/m.
Minimum equivalent elastic strain generated is 2.0769e-007 m/m.

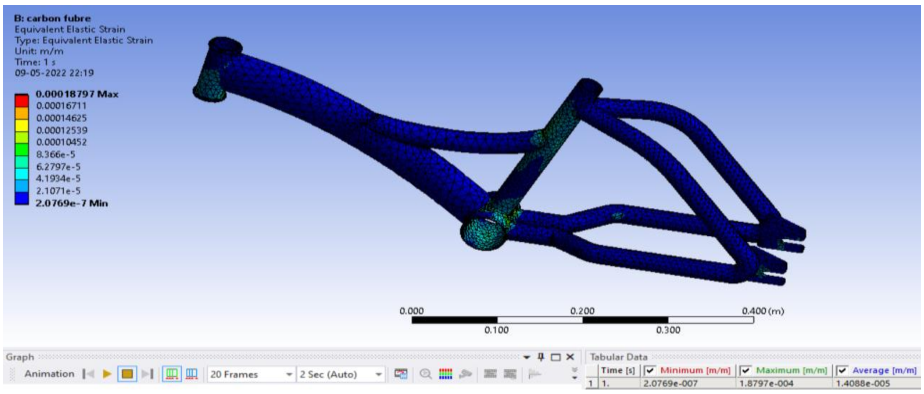


Fig 6.12 Elastic Strain in Carbon fibre frame

The obtained mass of the frame under the carbon fibre material is 2.5948 kg

6.5 Deformations, Stresses & Strain in Chromoly Steel

The maximum deformation generated on the frame is 5.6688e-005 m.
The minimum deformation generated on the frame is 0 m.

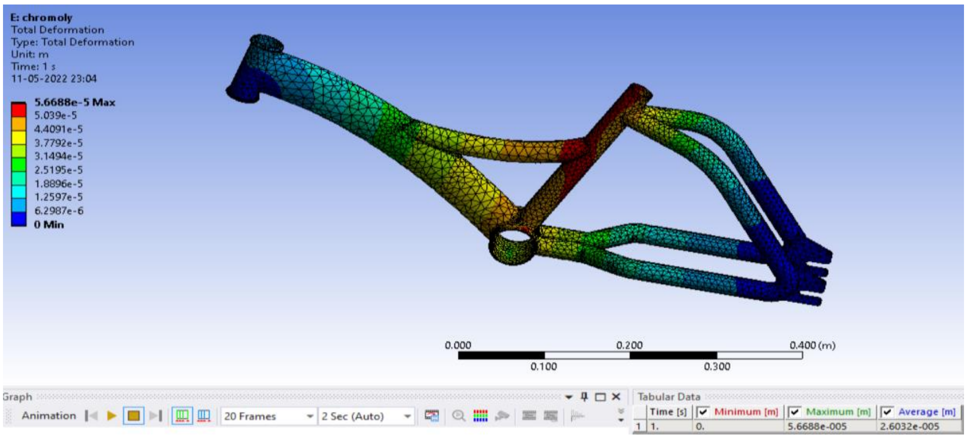


Fig 6.13 Deformation in Chromoly steel frame

The maximum Von-Mises stress generated in the frame is 4.2448e+007 Pa.
The minimum Von-Mises stress generated in the frame is 37129 Pa.

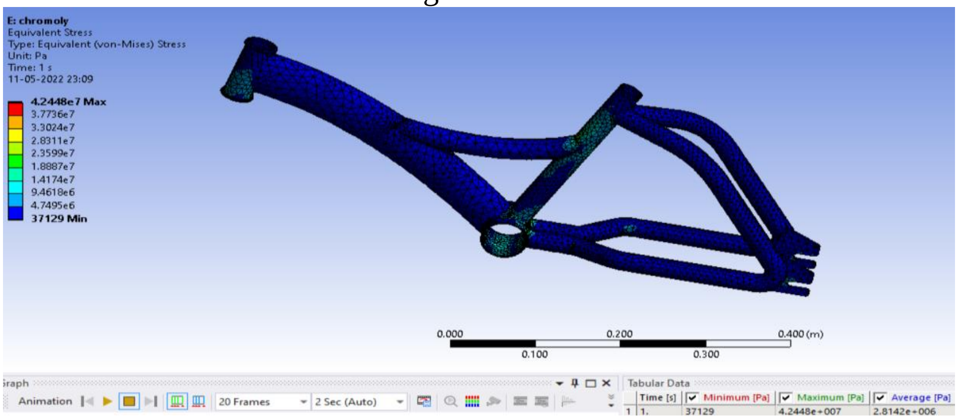


Fig 6.14 Stresses in Chromoly steel frame

Maximum equivalent elastic strain generated is 2.0755e-004 m/m.
Minimum equivalent elastic strain generated is 2.1879e-007 m/m.

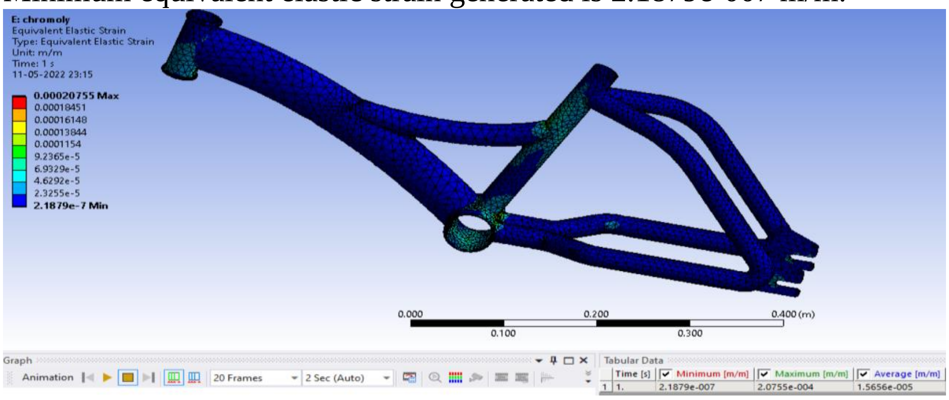


Fig 6.15 Elastic Strain in Chromoly Steel frame

The obtained mass of the frame under the chromoly steel material is 11.639 kg.

6.6 Deformations, Stresses & Strain AISI 1025 Carbon Steel

The maximum deformation generated on the frame is 5.5242e-005 m.
The minimum deformation generated on the frame is 0 m.

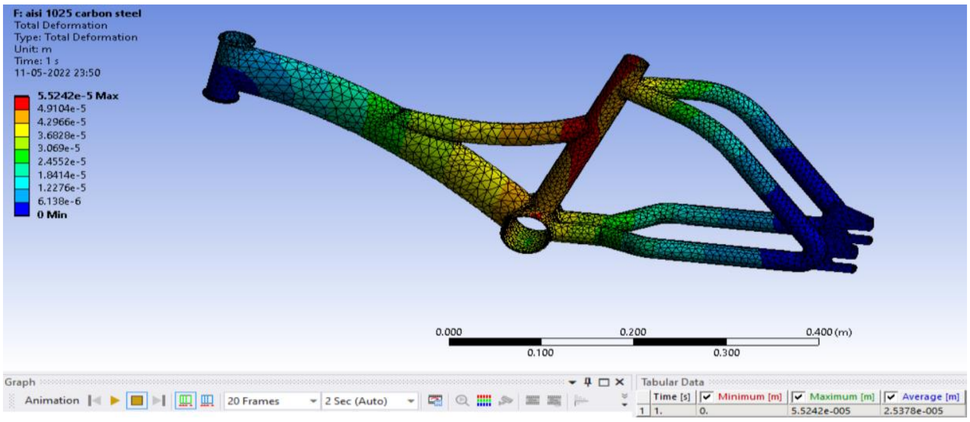


Fig 6.16 Deformation in AISI 1025 Carbon Steel frame

The maximum Von-Mises stress generated in the frame is 4.2698e+007 Pa.
The minimum Von-Mises stress generated in the frame is 37157 Pa.

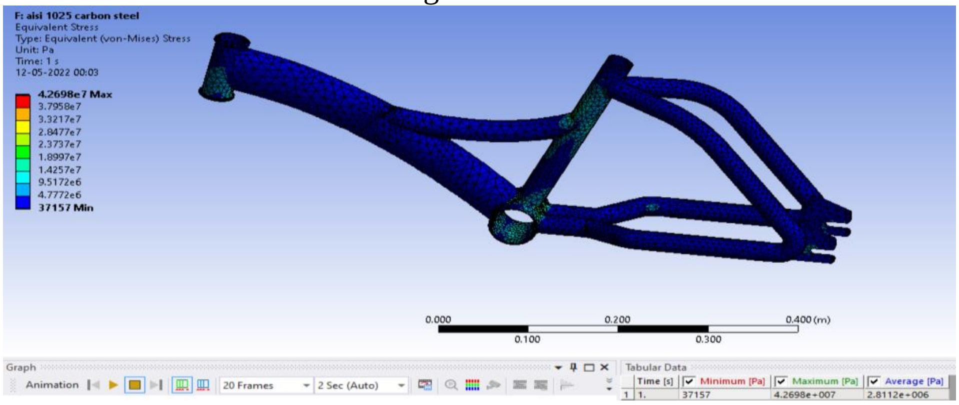


Fig 6.17 Stresses in AISI 1025 Carbon Steel frame

Maximum equivalent elastic strain generated is 2.0377e-004 m/m.
Minimum equivalent elastic strain generated is 2.1026e-007 m/m.

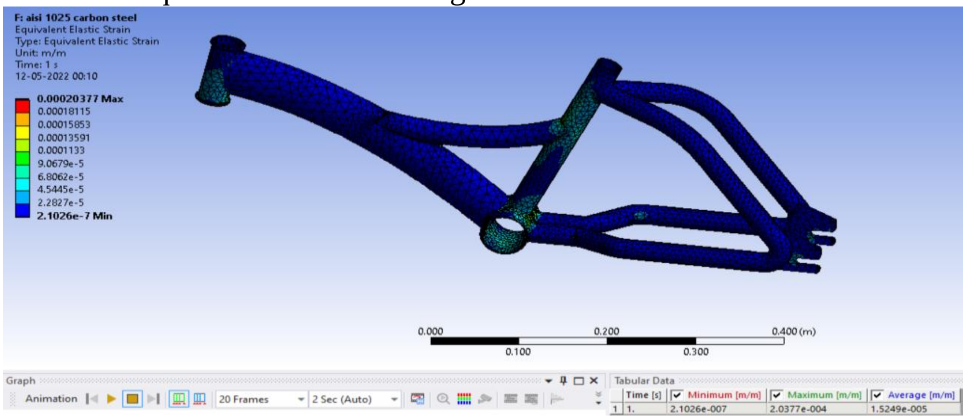
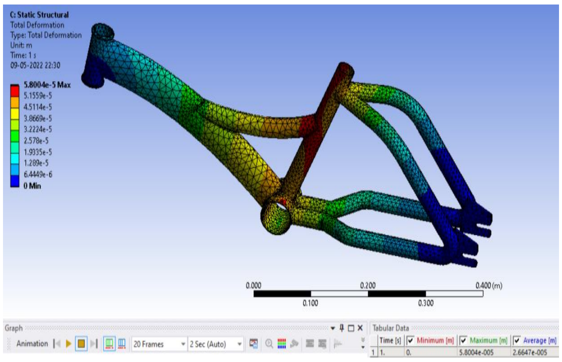
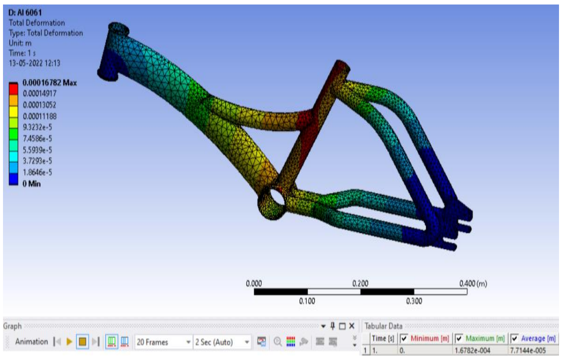


Fig 6.18 Elastic Strain in AISI 1025 Carbon Steel frame

The obtained mass of the frame under the AISI 1025 Carbon Steel material is 11.639 kg.

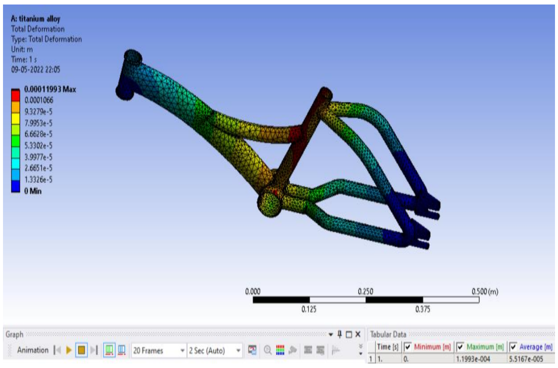
6.7 Deformations in Frame

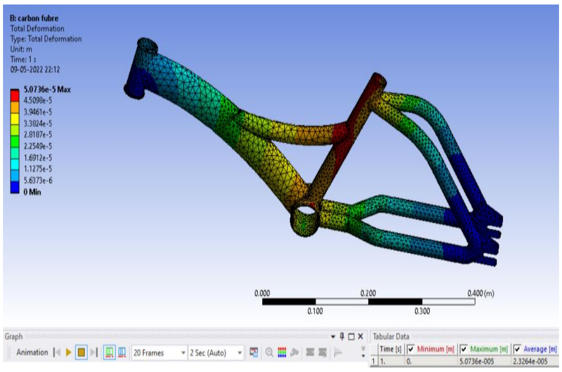




Structural Steel:
Max deformation :- 5.8004E-002 mm

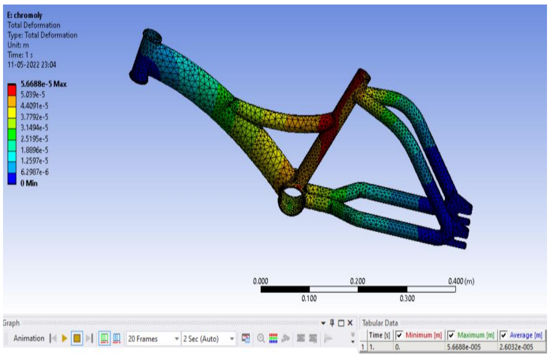
Al 6061:
Max deformation:- 1.6782E-001 mm

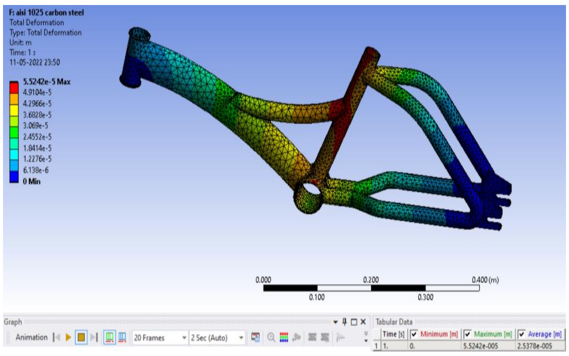




Titanium Alloy:
Max deformation :- 1.993E-001 mm

Carbon Fibre:
Max deformation:- 5.0736E-002 mm



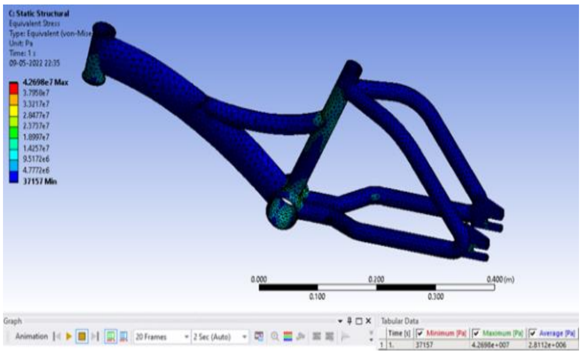


Chromoly steel:
Max deformation :- 5.6688E-002 mm

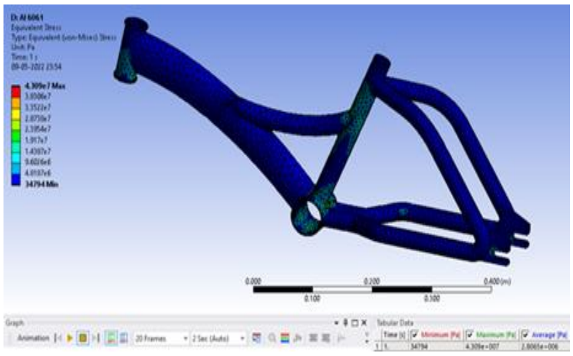
AISI 1025 Carbon Steel:
Max deformation:- 5.5242E-002 mm

Fig 6.19 Maximum Deformations in all materials

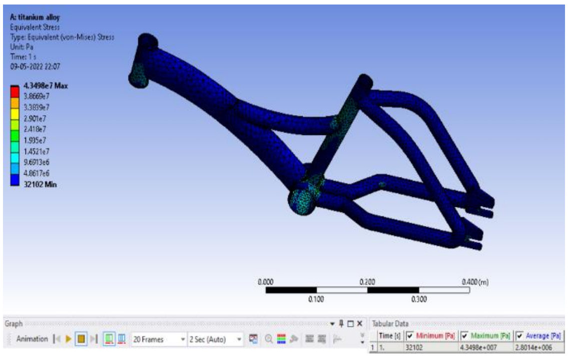
6.8 Maximum Von-Mises stress on Frame



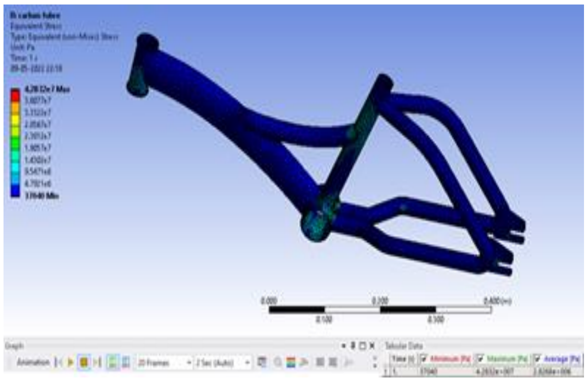
Structural steel:-
Max Stress:- 5.2698E+007 Pa



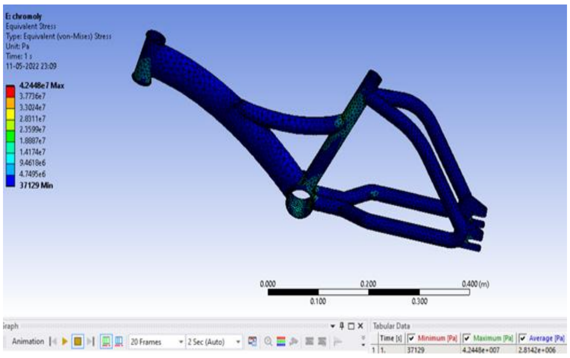
Al 6061:-
Max Stress:- 4.309E+007 Pa



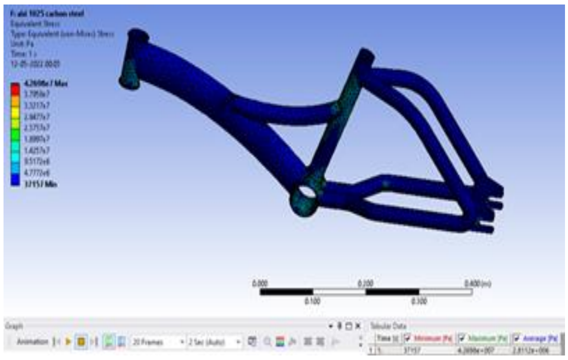
Titanium Alloy:-
Max Stress:- 4.3498E+007 Pa



Carbon Fibre:-
Max Stress:- 4.2432E+007 Pa



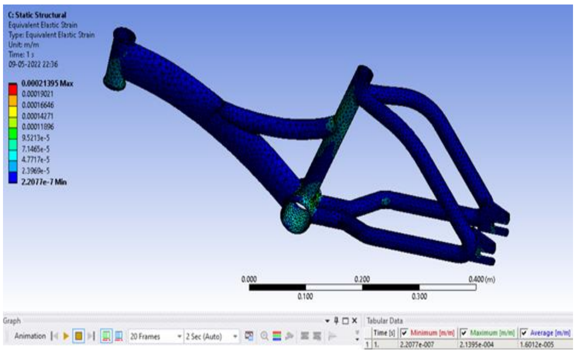
Chromoly Steel:-
Max Stress:- 4.244E+007 Pa



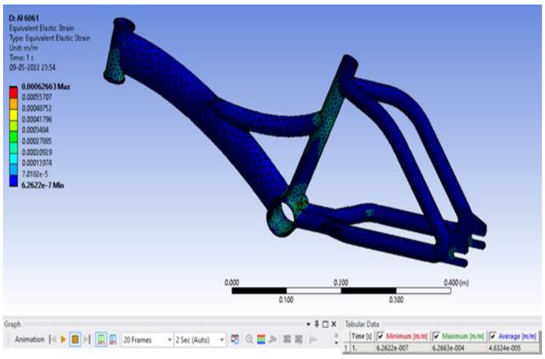
AISI 1025 Carbon Steel:-
Max Stress:- 4.2698E+007 Pa

Fig 6.20 Maximum stress in all materials

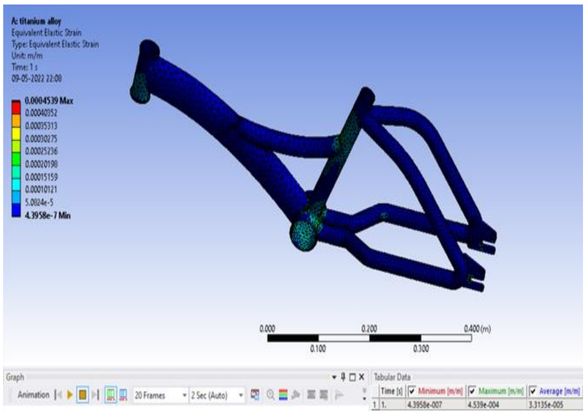
6.9 Maximum Elastic Strain in Frame



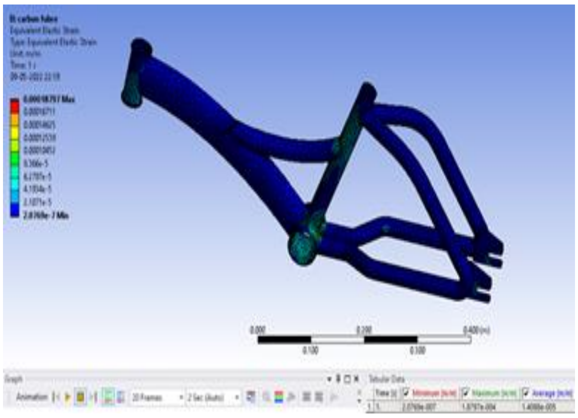
Structural Steel:-
Max Strain:- 2.199E-004 m/m



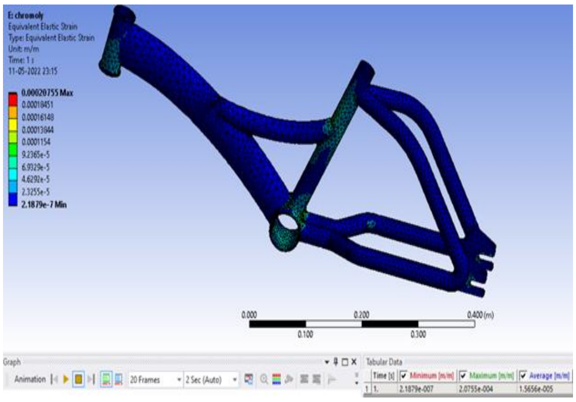
Al 6061:-
Max Strain:- 1.879E-004 m/m



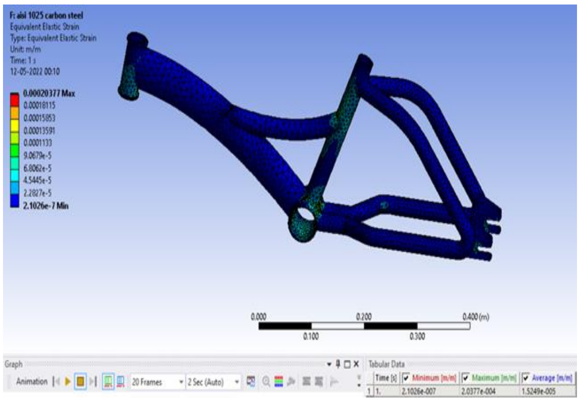
Titanium Alloy:-
Max Strain:- 4.539E-004 m/m



Carbon Fibre:-
Max Strain:- 1.8797E-004 m/m



Chromoly Steel:-
Max Strain:- 2.0755E-004 m/m



AISI 1025 Carbon Steel:-
Max Strain:- 4.0377E-004 m/m

Fig 6.21 Maximum Strain in all materilas

The graphs were plotted according to the recorded data:

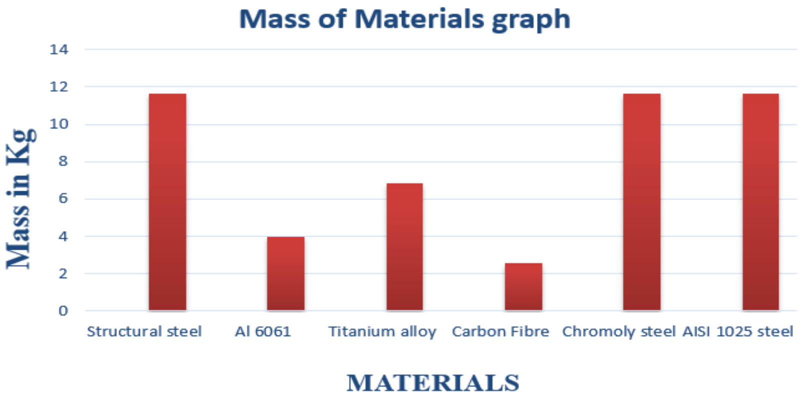


Fig 6.22 Mass vs Materials

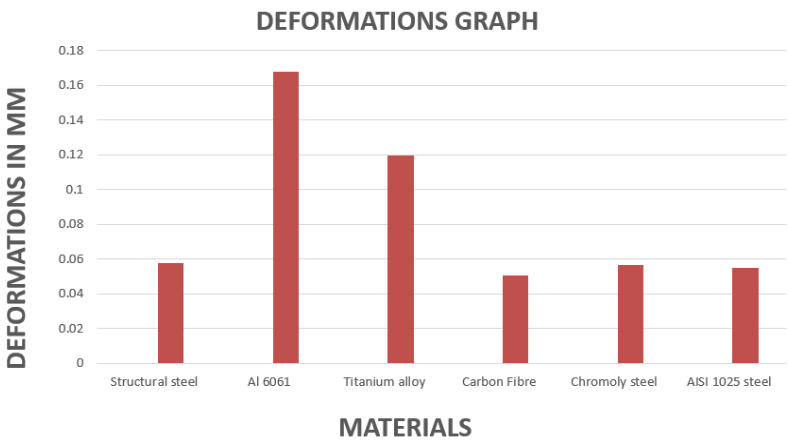


Fig 6.23 Deformations vs Materials

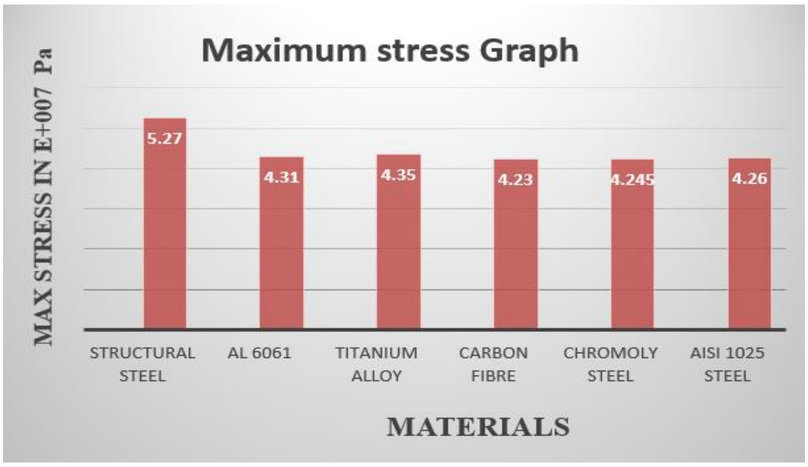


Fig 6.24 Maximum Stress vs Materials

CHAPTER-VII

CONCLUSION

7. CONCLUSION

- The total deformations and Von-Mises stress and elastic strain in static structural analysis were obtained for all the six materials.
- The graphs were plotted from the values of total deformation and Von-Mises stress with different selected materials under static loading conditions.
- The graph for mass obtained of the frame for all the materials is plotted.
- After studying the graphs we can conclude that carbon fibre shows less deformations and less Von-Mises stresses when compared with other materials in static loading conditions.
- Carbon Fibre material frame has less mass when compared with other materials according to the results.
- So, according to our study we can conclude that carbon fibre is the best material for the fabrication of the bicycle frame.

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CERTIFICATE

This is to certify that the Project Report entitled "**DESIGN AND STRUCTURAL ANALYSIS OF A BICYCLE FRAME UNDER STATIC LOADING CONDITIONS**" being submitted by Gudipati Dinesh(319126520L18), Lakkoju Deepak(318126520093), Bavirisetti Sujeeth (318126520065), Bheesetti Mohan Srinivas(318126520066), Karrothu Lokesh Kumar(318126520088) in partial fulfillment for the award of degree of BACHELOR OF TECHNOLOGY in MECHANICAL ENGINEERING. It is the work of bonafide, carried out under the guidance and supervision of, Dr Rajesh Ghosh, Associate Professor, Department of Mechanical Engineering during the academic year of 2018-2022.

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