# STUDY ON DESIGN AND ANALYSIS OF IN-WHEEL SUSPENSION SYSTEM

*A project report submitted in partial fulfilment of the requirement for the award of the degree of*

**BACHELOR OF TECHNOLOGY**
**IN**
**MECHANICAL ENGINEERING**

BY


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# CERTIFICATE

This is to certify that the Project Report entitled **"STUDY ON DESIGN AND ANALYSIS OF IN-WHEEL SUSPENSION SYSTEM"** being submitted by K N V S S AVINASH (317126520197), AYILA VENKATA NAGASAI (317126520183), MOHAMMAD ARSHAD HUSSAIN (318126520L43), NELIPUDI BHANU PRASAD (317126520211), PRITHVI ATTADA (317126520215) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING, ANITS**. It is the work of bona-fide, carried out under the guidance and supervision of **DR.B.NAGARAJU**, Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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# ABSTRACT

In today's world, Bicycles are the most favourite choice when it comes to causes like health, pollution, and environment. Several researches have been done in order to make the ride comfortable. Different types of cycles have been developed for various applications like Commuter Bikes, Mountain Bike, and Racing bike. This paper presents the Loop wheel which is designed such that the suspension system is integrated within wheel for higher shock-absorbing performance and better comfort. Loop wheels offer you a smoother ride. Loop wheel springs are usually made up of a composite material carefully developed to offer optimum compression and lateral stability as well as strength and durability. The three loops in every wheel work along as a self-correcting system. This spring system between the hub and the rim of the wheel provides suspension that continuously adjusts to uneven terrain cushioning the rider from abnormalities in the road wheel. The spring configuration permits the torque to be transferred smoothly between the hub and the rim. In this paper loop wheel manufactured using C20 material and the analysis is done on ANSYS Workbench 14.5 to determine the forces acting on wheel, maximum deflection, principle stresses.

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# CHAPTER 1

# INTRODUCTION

**1.1 Automobile.** An automobile is a self-propelled vehicle which is used for transportation of passengers and goods through road ways; a representation of a automotive vehicle evolving with time is shown in fig.1.1 and fig. 1.2.

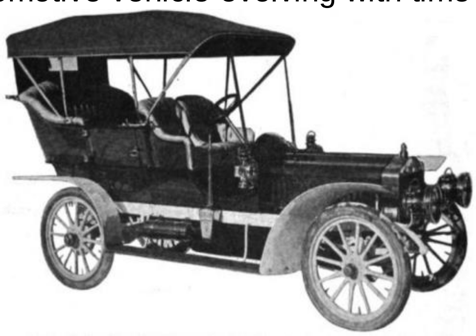

Fig.1.1 Ford Model T 1908

Fig. 1.2 Ford GT 2017

## 1.2 History

1.2.1 The early history of the automobile can be divided into a number of eras, based on the prevalent means of propulsion. Later periods were defined by trends in exterior styling, size and utility preferences.

1.2.1.1 In 1769 the first steam powered automobile capable of human transportation was built by Nicolas Joseph Cugnot.

1.2.1.2 In 1807, Francois Isaac de Rivaz designed the first car powered by an internal combustion engine fuelled by hydrogen.

1.2.1.3 In 1886 the first petrol or gasoline powered automobile the Benz Patent Motor wagon was invented by Karl Benz.

1.2.1.4 In 1828, Anyos Jedlik, a Hungarian who invented an early type of electric motor, created a tiny model car powered by his new motor.

1.2.1.5 In 1834, Vermont blacksmith Thomas Davenport, the inventor of the first American DC electrical motor, installed his motor in a small model car, which he operated on a short circular electrified track.

1.2.1.6 At the turn of the 20th century electrically powered automobiles appeared but only occupied a niche market until the turn of 21st century

1.2.2 The modern era is defined as 25 years preceding from the current year .

## 1.3 Components of Automobile

### 1.3.1 **Engine**.

1.3.1.1 The engine is the source of motive power to an automobile. and its basic function of transporting passengers or goods would be defeated. The power of the engine determines the working of the automobile. In the same manner, the efficiency of the engine determines the efficiency of an automobile.

1.3.1.2 The engines used are multi-cylinder engines. In a multi-cylinder engine, each cylinder handling a smaller amount of power may keep the engine light in weight. In an internal combustion engine, total heat produced by the burning of fuel is not converted into work. An example of such engine that provide higher power is given in fig. 1.3.

1.3.1.3 So an engine can be air-cooled or water-cooled. These days some chemicals have been developed which have a cooling property, and these remain unaffected for a longer period of time. These chemicals are being used as coolants, and these do not require frequent replacement. Apart from their long life, they are more efficient also. The moving parts in an engine need regular lubrication to reduce unwanted friction.

Fig 1.3 V12 Engine

1.3.2 **Brakes** A brake is a mechanical device that inhibits motion by absorbing energy from a moving system. It is used to slow or stop a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction. The friction of your tires against the road is what slows down and stops your car. In an automobile vehicle, a braking system is an arrangement of various linkages and components that are arranged in such a fashion that it converts the vehicle kinetic energy into the heat energy which in turn stops or de-accelerates the vehicle. The conversion of kinetic energy into heat energy is a function of frictional force generated by the frictional contact between brake shoes and moving drum or disc of a braking system as shown in fig.1.4.

Fig. 1.4 Disc Brake

### 1.3.3 **The Chassis**

1.3.3.1 The chassis of an automobile incorporates all the major assemblies consisting of an engine, components of the transmission system. In other words, it is the vehicle without its body.

1.3.3.2 The chassis of an automobile has the frame, suspension system, axles, and wheel as the main components as in fig.1.5. The frame could be in the form of conventional chassis. In a conventional chassis frame, the frame forms the main skeleton of the vehicle. It supports engine, power transmission, and car body. The frame is supported on wheels and axles through springs. The frame carries the weight of the vehicle and passengers, withstands engine, transmission, accelerating, and braking torques. The other parts of the chassis are suspension system, axles, and wheel. The suspension system absorbs the vibrations due to up and down movement of wheels.

Fig 1.5 Chassis

1.3.4 **The Transmission System**

1.3.4.1 The transmission system transmits power developed by the engine to the road wheels as in fig.1.6. This movement is to be transferred to the road wheels to cause their rotary motion. Their rotary motion makes possible the movement of the vehicle.

1.3.4.2 The transmission system consists of different parts :-

1.3.4.2.1 Clutch
1.3.4.2.2 Gear box
1.3.4.2.3 Differential
1.3.4.2.4 Axle

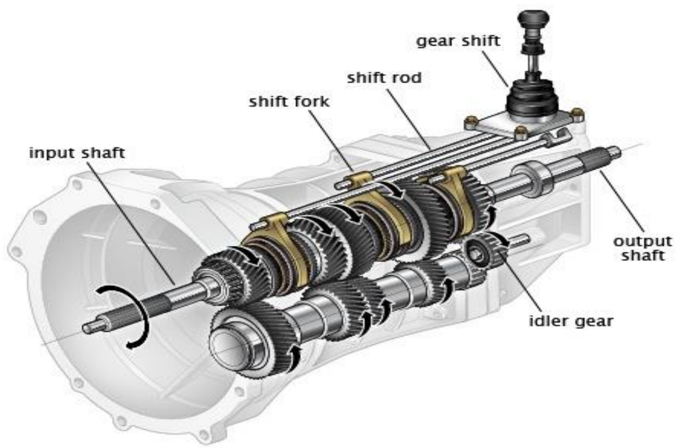


Fig 1.6 Transmission System

1.3.5 **Suspension**

1.3.5.1 Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between them. The function is to keep the tyres on the road by controlling spring and suspension movements and by maintaining a vertical load on the tyres.

1.3.5.2 Two types of suspension systems :-

(aa) Dependent suspension system
(ab) Independent suspension system

1.3.6 **The Body**

1.3.6.1 The use of a separate frame to which the body structure is attached is now almost obsolete except for some applications for heavy-duty commercial vehicles as in fig.1.7. Many heavy vehicles now use 'sub-frames' of simple construction to which the engine and gearbox are attached.

1.36.2 The `control systems are used to control the motion of an automobile and therefore are essential in an automobile. These include :-

(aa) The steering system
(ab) Braking system or brakes.

Fig. 1.7 Body of a Car

1.3.7 **Wheel**

1.3.7.1 In its primitive form, a wheel is a circular block of a hard and durable material at whose center has been bored a hole through which is placed an axle bearing about which the wheel rotates when torque is applied to the wheel about its axis.

1.3.7.2 A wheel comprises a rim, a hub, and a suspension unit as shown in fig.1.8. The wheel incorporates or is connectable to a torque source capable of producing torques up to a maximal torque for rotating the wheel around a rotation-axis.

Fig1.8 Wheel

1.3.8 **Rim** The rim is the “outer edge of a wheel, holding the tire”. It makes up the outer circular design of the wheel on which the inside edge of the tire is mounted on vehicles such as automobiles as shown in fig 1.9. For example, on a bicycle wheel the rim is a large hoop attached to the outer ends of the spokes of the wheel that holds the tire and tube. In cross-section, the rim is deep in the center and shallow at the outer edges, thus forming a "U" shape that supports the bead of the tire casing.


Fig.1.9 Rim

1.3.8.1 **Functions of Rims.** Main function of the rim is supporting and sealing the tire to the wheel. The rim ensures proper fitting between tire and rim and retaining the air inside the tubeless tire.

1.3.8.2 **Types of Rims**

(aa) Steel Rims
(ab) Alloy Rims
(ac) Chrome Rims
(ad) Spinner

1.3.8.3 **Advantages.** The larger the wheel, the shorter the tire's sidewall and the wider its tread must be to maintain the same outside tire diameter and prevent reducing the tire's load-carrying capacity. The shorter and wider the tire, the better the handling and cornering grip. Some plus-size wheels and tires live up to their image.

1.3.8.4 **Disadvantages.** When it comes to wheels or rims, size matters -- and adding larger wheels could affect a vehicle in a number of ways. Larger and heavier rims will also cause the engine to work harder, which could hamper fuel economy and dull acceleration.

## 1.4 Suspension System

### 1.4.1 History

1.4.1.1 Henry Ford's Model T used a torque tube to restrain this force, for his differential was attached to the chassis by a lateral leaf spring and two narrow rods. The torque tube surrounded the true driveshaft and exerted the force to its ball joint at the extreme rear of the transmission, which was attached to the engine. A similar method was used in the late 1930s by Buick and by Hudson's bathtub car in 1948, which used helical springs that could not take fore-and-aft thrust.

1.4.1.2 The Hotchkiss drive, invented by Albert Hotchkiss, was the most popular rear suspension system used in American cars from the 1930s to the 1970s. The system uses longitudinal leaf springs attached both forward and behind the differential of the live axle. These springs transmit torque to the frame. Although scorned by many European car makers of the time, it was accepted by American car makers, because it was inexpensive to manufacture. Also, the dynamic defects of this design were suppressed by the enormous weight of U.S. passenger vehicles before the implementation of the Corporate Average Fuel Economy (CAFE) standard.

1.4.1.3 Another Frenchman invented the De Dion tube, which is sometimes called "semi-independent". Like true independent rear suspension, this employs two universal joints, or their equivalent from the centre of the differential to each wheel. But the wheels cannot entirely rise and fall independently of each other; they are tied by a yoke that goes around the differential, below and behind it. This method has had little use in the United States. Its use around 1900 was probably due to the poor quality of tires, which wore out quickly. By removing a good deal of unsprung weight, as independent rear suspensions do, it made them last longer.

1.4.1.4 Rear-wheel drive vehicles today frequently use a fairly complex fully-independent, multi-link suspension to locate the rear wheels securely, while providing decent ride quality.

### 1.4.2 Classification

1.4.2.1 Suspension systems can be broadly classified into two subgroups:

(i) Dependent
(ii) Independent.

1.4.2.2 Independent suspension allows wheels to rise and fall on their own without affecting the opposite wheel. Suspensions with other devices, such as sway bars that link the wheels in some way, are still classed as independent.

1.4.2.3 Semi-dependent suspension is a third type. In this case, the motion of one wheel does affect the position of the other, but they are not rigidly attached to each other. Twist-beam rear suspension is such a system.

1.4.2.4 Dependent suspension systems may be differentiated by the system of linkages used to locate them, both longitudinally and transversely. Often, both functions are combined in a set of linkages.

### 1.4.3 Types

1.4.3.1 **Beam Axle** This is a type of suspension that is a strong, sturdy and maintains good tire contact with the road under all load conditions as represented in fig.1.10. It is a “dependent” type meaning the wheels are mechanical connected such that when one hits an obstruction on the road, it is felt across the entire width of the vehicle. This suspension is good for trucks.

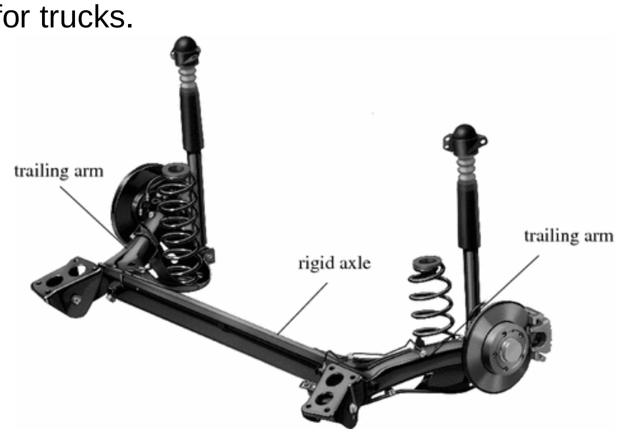


Fig1.10 Beam Axle Suspension

1.4.3.2 **Dual Beam Axle** This is a strong, sturdy suspension that does not maintain as good contact with the road as the beam axle suspension. It is an "independent" type of suspension meaning that the wheels are not mechanical connected such that when one hits an obstruction on the road, it is not felt across the entire width of the vehicle. It is used on light truck front.

1.4.3.3 **Double Wishbone** This is a lighter, more costly suspension than the beam type but adds more room for packaging other components. It is an independent type of suspension that keeps good tire contact with the road under full suspension travel. Camber, caster, and toe can be closely controlled. Good for passenger car. It is shown in fig.1.11.

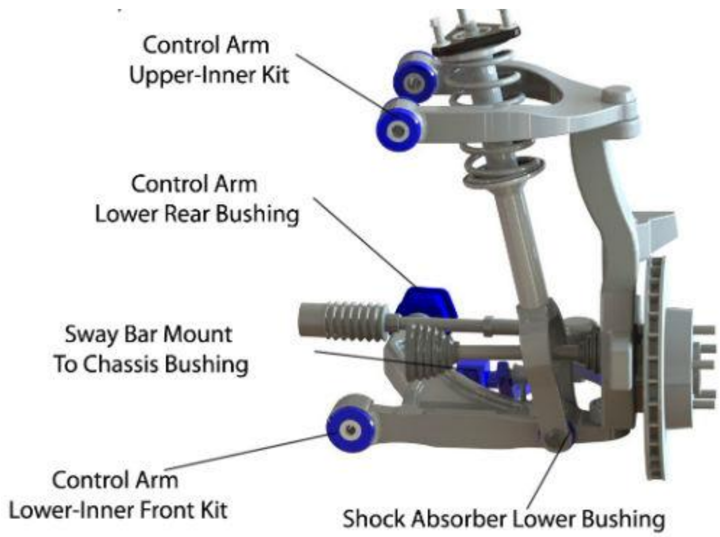


Fig.1.11 Double Wishbone Suspension

1.4.3.4 **Short/Long Arm** This type of suspension is similar to the double wishbone except that the upper arm is made shorter than the lower arm. This design feature maintains good tire contact with the road under all cornering conditions. It is good for performance vehicles.

1.4.3.5 **MacPherson Strut** This type of suspension is similar to the double wishbone except that the upper arm is rotated up and replaced with a long member called the "strut". The strut incorporates the spring and shock in a concentric package and attaches to mounts high on the vehicle. This design adds more room for packaging front engine/transmission modules and adjoining drive shafts as shown in fig.1.12.

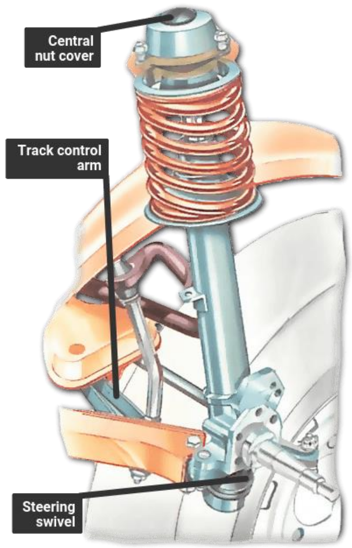


fig.1.12 Macpherson Strut Suspension

1.5 **Bicycle** A bicycle, also called a bike or cycle, is a human-powered or motor-powered, 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, and 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 eventually 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.

### 1.5.1 Uses

1.5.1.1 From the beginning and still today, bicycles have been and are 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', used by mail carriers, paramedics, police, messengers, and general delivery services. Military uses of bicycles include communications, reconnaissance, troop movement, supply of provisions, and patrol.

1.5.1.2 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, sportive and time trials.

1.5.1.3 Bikes can be used for entertainment and pleasure, such as in organised mass rides, artistic cycling and freestyle BMX.

### 1.5.2 Technical aspects

1.5.2.1 **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, freight bicycles, recumbent and electric bicycles.

1.5.2.2 **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. The fastest recorded unpaced speed on a flat surface is 144.18 km/h (89.59 mph).

1.5.2.3 **Dynamics** A bicycle stays upright while moving forward by being steered so as to keep its center 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 center 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[40] 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.

### 1.5.3 Parts

- Frame
- Drive train and Gearing
- Steering
- Seating
- Brakes
- Suspension
- Wheels and Tires
- Accessories
- Standards

### 1.5.4 Maintenance and Repair

1.5.4.1 The most basic maintenance item is keeping the tires correctly inflated; this can make a noticeable difference as to how the bike feels to ride. Bicycle tires usually have a marking on the side wall indicating the pressure appropriate for that tire. Note that bicycles use much higher pressures than cars: car tires are normally in the range 30 to 40 pounds per square inch while bicycle tires are normally in the range 60 to 100 pounds per square inch.

1.5.4.2 Another basic maintenance item is regular lubrication of the chain and pivot points for derailleur and brakes. Most of the bearings on a modern bike are sealed and grease-filled and require little or no attention; such bearings will usually last for 10,000 miles or more.

1.5.4.3 Very few bicycle components can actually be repaired; replacement of the failing component is the normal practice.

1.5.4.4 The most common roadside problem is a puncture. After removing the offending nail/tack/thorn/glass shard/etc. there are two approaches: either mend the puncture by the roadside, or replace the inner tube and then mend the puncture in the comfort of home. Some brands of tires are much more puncture resistant than others, often incorporating one or more layers of Kevlar; the downside of such tires is that they may be heavier and/or more difficult to fit and remove.

## 1.6 Suspension for Bicycles

1.6.1 Bicycle suspension is when the system accustomed comfort or sophisticates the rider and bicycle in order to insulate them from the roughness of the terrain.

1.6.2 Bicycle suspension can be implemented in a variety of ways, and any combination thereof:

- Front suspension(fig.1.13)
- Rear suspension(fig.1.14)
- Suspension seat post(fig.1.15)
- Suspension saddle
- Suspension stem (now uncommon) (fig.1.16)
- Suspension hub


Fig.1.13 Front Suspension

Fig.1.14 Rear Suspension

Fig.1.15 Suspension Seat Post

Fig.1.16 Suspension Stem

### 1.7 In-Wheel Suspension

1.7.1 The in-wheel suspension is one sort of suspension which has shock absorbers inside the wheel rim at an angle to every other. The in-wheel suspension provides a suspension effect much greater than the traditional telescopic suspension in bicycles. The spring permits the suspension to maneuvre up once the wheel encounters a bump, and to quickly draw back down once the wheel passes the bump. The spring is often a coil of steel like most springs we're acquainted with, or it may well be a cylinder containing pressurized air.

1.7.2 In either case, the more the spring it's compressed, a lot of force it takes to compress it, that is precisely what we'd like for a mountain-bike suspension. You do not wish the spring bottoming out after you land a giant jump. If the suspension were equipped with simply a spring, it might bounce up and down many times once every bump. Once compressed by a bump, a suspension needs how to dissipate the energy that's kept within the spring. The damper dissipates the energy and prevents the suspension from bouncing out of management.

1.7.3 The comparison of movement flow of the in-wheel suspension with conventional suspension is shown in fig.1.17 and fig 1.18 with full representation of bicycle in fig.1.19.

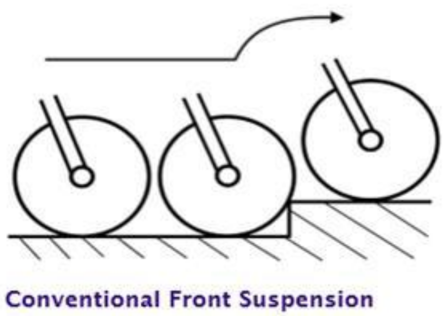


Fig.1.17 Conventional Suspension

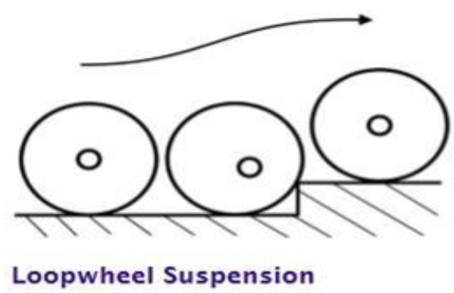


Fig.1.18 In-wheel Suspension

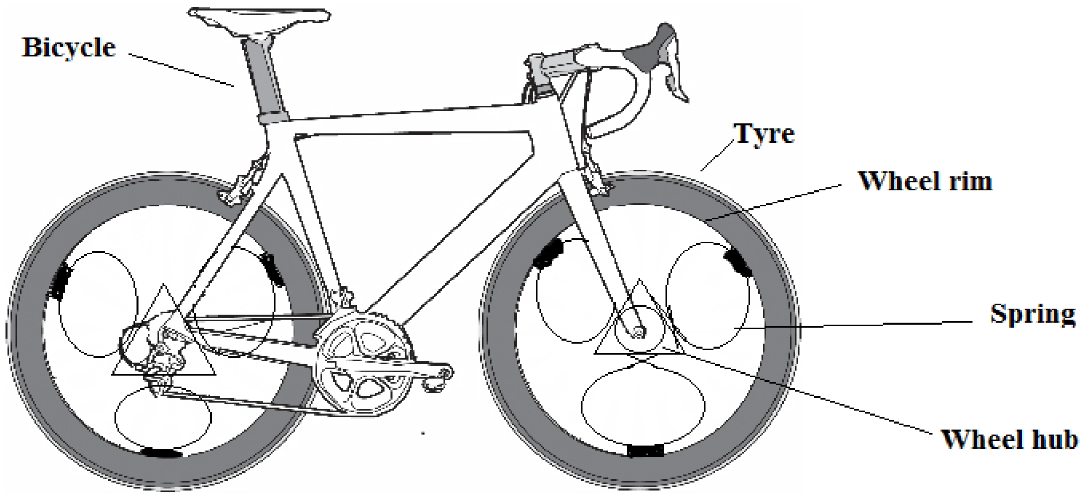

Fig.1.19 Representation of Bicycle with In-Wheel Suspension

## 1.8 How it Works?

1.8.1 The spring system between the hub and the rim of the wheel provides suspension that constantly adjusts to uneven terrain – cushioning the rider from bumps and potholes in the road. In effect, the hub floats within the rim, adjusting constantly as shocks from an uneven road hit the rim of the wheel as shown in fig.1.20. The spring configuration allows the torque to be transferred smoothly between the hub and the rim. We have developed loop wheels with consideration that the weight of the rider and cycle body to be equally distributed over the wheels of the bicycle. Every loop wheel is designed for same compression rate.

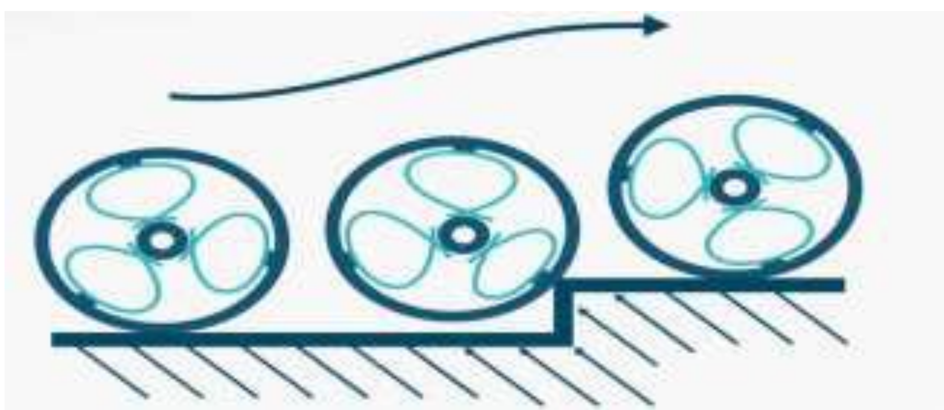
Fig.1.20 Loopwheel Spring System

**1.9 Mechanical Properties** The ability to classify and identify materials is crucial in the manufacturing industry. It helps you quickly choose the best materials for your design based on various factors including: load capacity, elasticity, hardness, strength and much more. The purpose of this article is to break down the mechanical properties that make each material unique. By becoming familiar with these terms, you'll be able to differentiate between materials and assess their usefulness for your design project.

1.9.1 **Different Types of Materials** Most materials can be categorized into two types of materials: metals and non-metals. What are the two main types of metals? Ferrous and Non-ferrous metals The difference between ferrous and Non-ferrous metals is simple. Ferrous metals typically contain iron and other small materials and is often used in the mechanical industry, while non-ferrous contains no iron and is made up of other materials like copper, zinc, aluminium and magnesium.

1.9.2 **Mechanical Properties**

1.9.2.1 **Strength** The measurement of how much load a material can withstand before failure. The more load a material can bear, the more strength it has. There are 3 different types of strength based on loading types, which are

1.9.2.1.1 **Compressive Strength** Maximum stress a material can withstand before compressive failure (MPa)

1.9.2.1.2 **Shear Strength** Maximum shear stress a material can withstand

1.9.2.1.3 **Tensile Strength** Maximum tensile stress of a material can withstand before failure (MPa)

In regards to deformation before fracture, the 3 types of strength are:

1.9.2.1.4 **Elastic Strength** Ability of a body to resist a distorting influence or stress and to return to its original size and shape when the stress is removed.

1.9.2.1.5 **Ultimate Strength** Maximum **stress** that a **material** can withstand before it breaks or weakens.

1.9.2.1.6 **Yield Strength:** The stress at which a material starts to yield plastically (MPa)

1.9.2.2 **Fluctuating Stress (cyclic loading) Upon Reaching Failure. fatigue refers to the fatigue strength** The amount of cycles a material can withstand under failure of a material under cyclic loading prior to reaching its ultimate limit

1.9.2.3 **Brittleness** Brittleness is when a material breaks suddenly under stress, without exhibiting much elastic deformation or changes in dimension.

1.9.2.4 **Stiffness** A material's ability to resist significant elastic deformation while loading. The less deformation a material exhibits during loading, the stiffer it is.

1.9.2.5. **Hardness** Hardness is defined by a material's ability to resist various forms of deformation, indentation and penetration. Also refers to its resistance to scratching, scraping, drilling, chipping and wear and tear.

1.9.2.6 **Toughness** Toughness is defined by the material's capacity to withstand elastic and plastic deformation without failure. Typically measured by the amount of energy a material can absorb before fracturing.

1.9.2.7 **Embrittlement** The result of metal losings its ductility and becoming brittle due to chemical or physical changes.

1.9.2.8 **Homogeneity** Any material that has the same properties throughout its entire geometry. A homogeneous material cannot be mechanically separated or identified individually. Certain types of homogeneous material includes plastics, metals, glass, paper, resins and coatings.

1.9.2.9 **Isotropy** Often confused with homogeneity, isotropic materials exhibit the same properties in any direction or orientation, whereas homogeneous materials have the same properties regardless of direction.

1.9.2.10 **Anisotropy** A material that exhibits different properties based on its direction or orientation. For example, in computer graphics, an anisotropic surface changes in appearance depending on the angle it's being displayed at.

1.9.2.11 **Elasticity** Materials that rebound back to their original dimensions after deformation, or being removed from its load. Every material has a certain elastic limit before becoming deformed permanently, otherwise known as plasticity deformation.

1.9.2.12 **Plasticity** A type of permanent deformation that occurs under stress before resulting in failure. Commonly used in metal shaping to achieve certain shapes and forms.

1.9.2.13 **Ductility** Ductility is the result of solid material becoming stretched due to tensile stress. A common application of this process is turning metal into wiring.

1.9.2.14 **Malleability** The ability to plastically deform a material or significantly change its shape without becoming fractured.

1.9.2.15 **Machinability** The ease of which a metal part can be cut without sacrificing the quality of the finish.

1.9.2.16 **Creep** slow and gradual deformation (or change in dimensions) of materials under a certain applied load. Measured by the influence of time and temperature. Typically occurs at high temperatures, but can also occur at room temperature, albeit much more slowly.

1.9.2.17 **Resilience** The ability to absorb energy while being elastically deformed, and releasing that energy after being unloaded. Proof resilience is the maximum amount of energy a material can absorb before permanent deformation.

1.9.2.18 **Damping** Damping refers to dissipating the amount of energy used to create vibration, oscillation or stress. A material with a good damping property, such as cast iron, is capable of absorbing high amounts of vibration.

1.9.2.19 **Thermal Expansion** A change in shape, volume or area caused by changes in temperature. The coefficient of thermal expansion refers to the amount a material’s shape or size will change during exposure to a change in temperature.

1.9.2.20 **Slip** A tendency of a material's particles to undergo plastic deformation due to a dislocation motion within the material. Common in Crystals.

### 1.9.3 Material Properties for the Suspension System

1.9.3.1 Steel alloys are the most commonly used spring materials. The most popular alloys include high-carbon (such as the music wire used for guitar strings), oil-tempered low-carbon, chrome **silicon,** chrome vanadium, and stainless steel.

1.9.3.2 High strength steels for automotive applications like suspension coil springs and engine valve springs are alloyed with high amounts of silicon because it confers increased strength and hardness (solid solution hardening), higher sag resistance (resistance to load loss, resistance to stress relaxation) and temper resistance (resistance to softening during tempering and stress relieving). Contemporary spring steels are quenched and tempered to very high strength (1900-2150 MPa, 53-57 HRC, 560-640 HV).

## 1.10 Materials Studied

### 1.10.1 **Aluminium Alloys**

1.10.1.1 Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.
The advantages of using aluminium are associated with its remarkable properties as follows:

- Resistance to corrosion
- Thermal and electrical conductivity
- Nontoxic features
- Recyclability
- Finishability
- High strength to weight ratio
- Ease of fabrication
- Great shock absorption

1.10.1.2 Aluminium alloys with a wide range of properties are used in engineering structures. Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents (DIN and ISO). Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weldability, and corrosion resistance, to name a few. A brief historical overview of alloys and manufacturing technologies is given in Ref.[4] Aluminium alloys are used extensively in aircraft due to their high strength-to-weight ratio. On the other hand, pure aluminium metal is much too soft for such uses, and it does not have the high tensile strength that is needed for airplanes and helicopters.

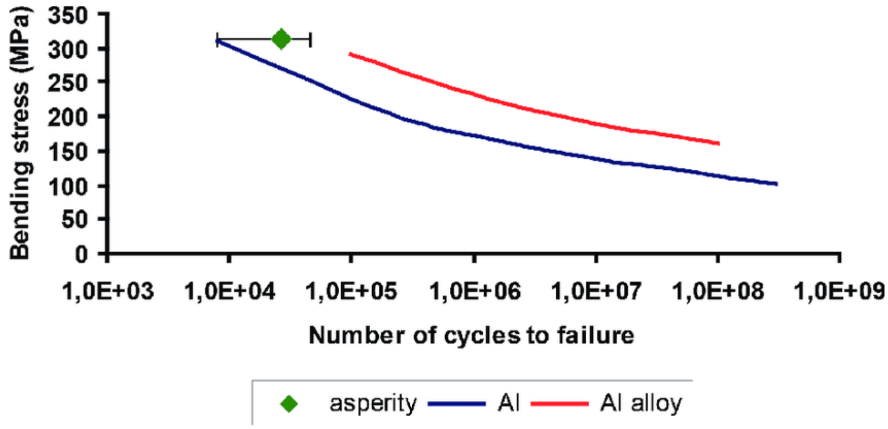


Fig.1.21 S-N Curve for Al and Al Alloy

### 1.10.2 **Mild Steel**

1.10.2.1 Mild steel is a type of low carbon steel. Carbon steels are metals that contain a small percentage of carbon (max 2.1%) which enhances the properties of pure iron. The carbon content varies depending on the requirements for the steel. Low carbon steels contain carbon in the range of 0.05 to 0.25 percent.

- High tensile strength
- High impact strength
- Good ductility and weldability
- A magnetic metal due to its ferrite content
- Good malleability with cold-forming possibilities
- It is light
- It is affordable

1.10.2.2 All types of carbon steels are usually categorised based on the amount of carbon that they contain. The three main categories of carbon steel have various different carbon content levels, and therefore can be used for various different purposes.

1.10.2.3 Low carbon steel (up to 0.30% plain carbon) is mainly used for flat-rolled steel products such as sheets, strips or light and rolled sections such as equal angle or unequal angle steel beams.
Medium carbon steel (between 0.30%-0.60% carbon content) is favoured in the engineering industry, being mainly used for wheels, rails, gears and vehicle components.

1.10.2.4 High carbon steel (0.60% to 1% carbon) is the strongest of the three carbon steels. Common uses include compression springs and wires.

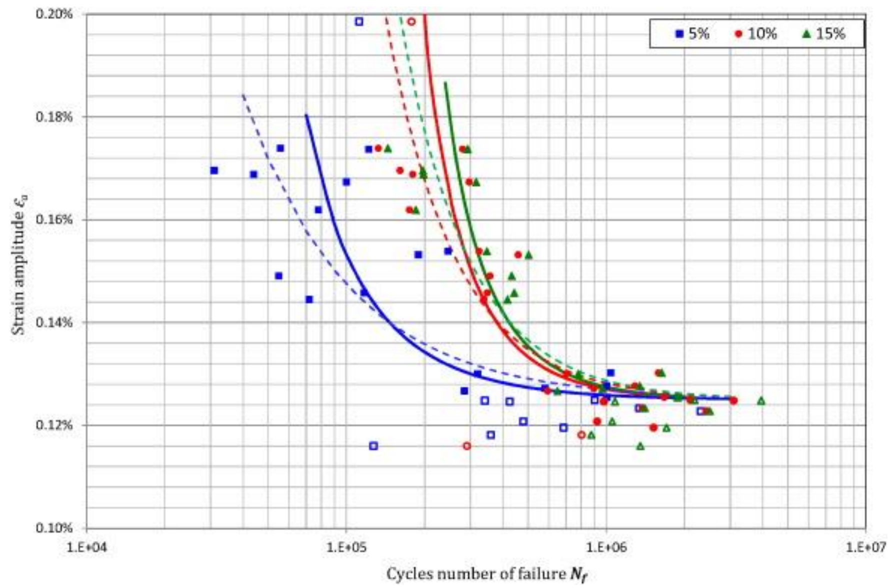


Fig.1.22 S-N Curve for Mild Steel

1.10.3 **Composite Materials** A composite material is a combination of two materials with different physical and chemical properties. When they are combined they create a material which is specialised to do a certain job, for instance to become stronger, lighter or resistant to electricity. They can also improve strength and stiffness. The reason for their use over traditional materials is because they improve the properties of their base materials and are applicable in many situations.

1.10.3.1 **Composites Advantages:**

1.10.3.1.1**Design Flexibility** – Thermoset Composites give designers nearly unlimited flexibility in designing shapes and forms. They be molded into the most intricate components and can be made a wide range of densities and chemical formulations to have precise performance properties.

1.10.3.1.2**Low cost per cubic inch** – When comparing costs based on volume, thermoset composites have lower material costs than traditional materials such as wood, engineered thermoplastics and metals. In addition, because thermoset composites have a low petroleum-based content, they are not subjected to the price fluctuations experienced in petroleum-based products.

1.10.3.1.3**Lower material costs** – Because thermoset composites can be precisely molded, there is little waste and therefore significantly lower overall material costs than metals products.
1.10.3.1.4**Improved productivity** – Industrial Designers and Engineers are able to reduce assembly costs by combining several previously assembles parts into a single component. Also, inserts can be molded directly into the part during the molding process thereby eliminating the need for a post-process. In addition, composites do not usually require additional machining, thereby reducing work-in-process and time to market.

1.10.3.1.5Other advantages are:

- Chemical Resistance
- Consolidated Parts and Function
- Corrosion Resistance
- Design Flexibility
- Durable
- High Flexural Modulus to Carry Demanding Loads
- High Performance at Elevated Temperatures
- Lighter Weight than Metal
- Lower Costs vs. Die Cast
- Low Petrochemical content

## 1.11 **Fatigue Loading Curves:**

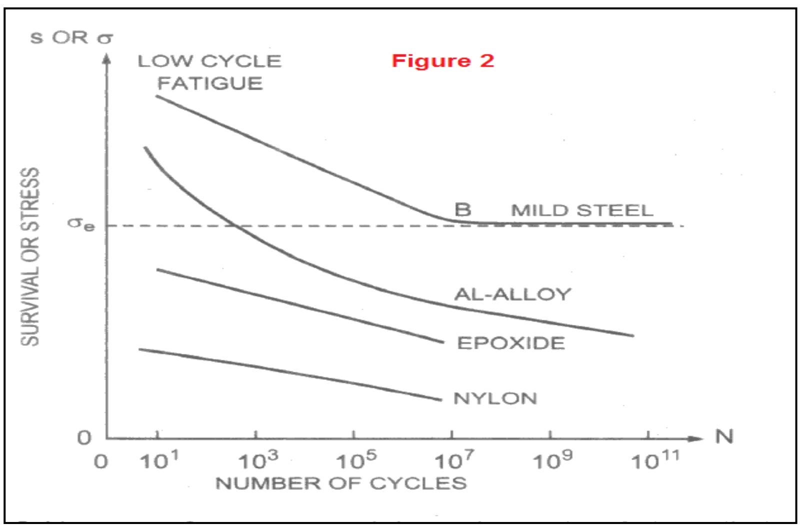


Fig.1.23 (a) S-N Curve of Some Material to Determine Fatigue Limit

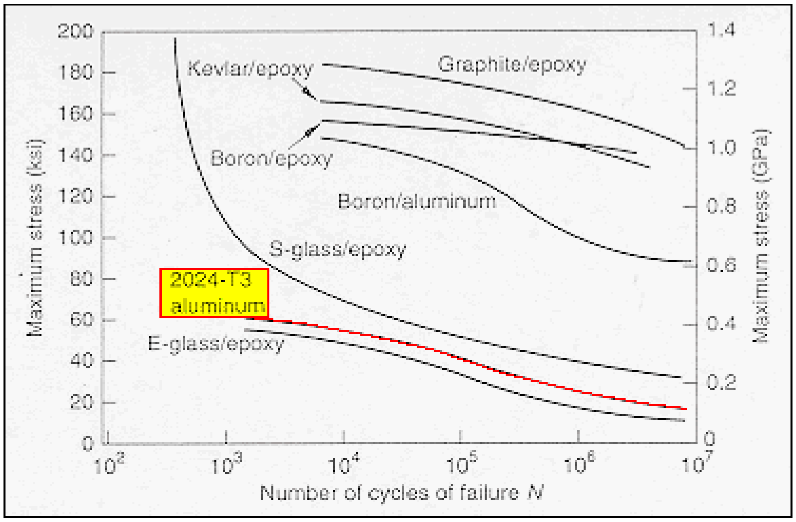


Fig.1.23(b) Comparing S-N Curves of Different Materials

## 1.12 Tensile Loading Curve

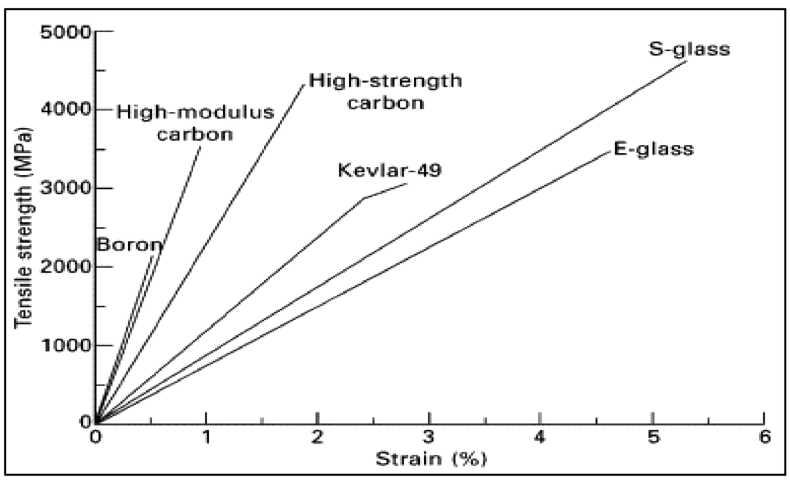


Fig.1.24 Comparing Stress-Strain Curve of Different Materials

# CHAPTER 2

# LITERATURE SURVEY

**Pankaj Saini et al.[1]** Focusing on design and analysis of composite leaf spring by comparing the stresses and weight of composite to steel leaf spring. The design constraint is stiffness. The materials selected were glass fibre reinforced polymer, carbon epoxy and graphite epoxy against conventional steel. Selection of cross section by varying between thickness and width design. Material selected for leaf spring was carbon fibre and graphite fibre for their advantages include high specific strength, low coefficient of thermal expansion, high fatigue strength, low impact resistance. Specific design data were considered for vehicle weight (sprung and unsprung), FOS, acceleration due to gravity, force applied. Specifications like length, camber, thickness, width, max load, Young's modulus, Poisson's ratio were considered for Steel, Carbon epoxy, E-Glass epoxy and Graphite epoxy leaf springs for the static analysis on ANSYS. From the load factors and graphs percent weight saving was estimated. And it was concluded that composite materials have better application over the conventional materials as the composite E-Glass, Graphite epoxy, Carbon epoxy reduced the weight by 81.22%, 91.95% and 90.51% respectively.

**Gulur Siddaramanna et al.[2],** the aim of this paper was to present a low cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints. Also, general study on the analysis and design. A single leaf with variable thickness and width for constant cross sectional area of unidirectional glass fibre reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf spring, was designed, fabricated (hand-lay up technique) and tested.
The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. The design constraints were stresses (Tsai-Wu failure criterion) and displacement. Design parameters, design and fabrication of steel and composite(E-Glass) leaf spring were considered selectively. Testing of Steel and Composite Mono Leaf Spring was done on leaf spring test rig to observe for cracks, abnormalities at max deflection.
3D Finite Element Analysis on displacement pattern, stress distribution,contact pressure distribution,boundary conditions and meshing model for steel leaf spring, composite leaf spring(E-Glass epoxy) with and without bonded end joints.
This concluded that the development of a composite mono leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective.

**Pinku Patil et al.[3],** loop wheel is designed with integral suspension which provides great shock absorbing performance and greater comfort . Loop wheels give a smoother ride.They are more comfortable than standard wheels. Loop wheels springs are made up of composite material offered to develop optimum compression and lateral stability. Specially designed connectors attach the spring to the hub and rim.The springs used to reduce vibrations as well as bumps and shocks. The loop wheels help people push over rough tracks and gravel paths , with less effort, the springs give you extra power to get up or down kerbs. The three loops in each wheel work together as a self correcting system. The spring system provides suspension . The spring configuration allows the torque to be transferred between the hub and rim. In today's world bicycles are the most favourite choice when it comes to causes like health, pollution. The normal cycle creates the noise during a massive jerk or else while going to track it increases the risk of getting damage to the rim which supports the wheel which is in rotating motion. During off road situations a normal cycle creates a large force that creates a back pain of human beings. After studying the different research papers and automobile general we came to know the concept of loop wheel. How a loop wheel is used in automobile component design and working. The loop wheel concept is inbuilt suspension or handicapped vehicles. We design the loop wheel suspension by calculating its length, width and thickness and also to calculate bending strength and material is selected which is having high compressive load. The calculated values are used to draw an imaginary drawing in solid works which provide an easy way to design . Material and rim are purchased from the market and we assemble all these design components using welding, grinding, cutting, turning, fitting.

**Divyanshu Arya et al.[4]**, the purpose of this project is to improvise the prevailing mechanical system by exchange the current shock absorbers with electromagnets. However, the mechanism needed to form this conversion introduces vital complications to the system. These complications embrace backlash and multiplied mass of the moving half thanks to connecting transducers or gears that convert motility to linear motion (enabling active suspension).
Compared with hydraulic actuators, the advantages of magnetic force actuators are as follows:

- Enlarged efficiency
- Improved dynamic behaviour
- Stability improvement
- Correct force control
- Twin operation of the mechanism.

The disadvantages are as follows:

- Enlarged volume of the suspension
- Electromagnetic deed
- Could be less
- Comparatively high current for a 12- to 14-V system
- Typical styles that require excitation to supply endless force
- Higher system prices.

In conclusion we can say that active magnetic force suspension systems will maintain the desired stability and luxury owing to the power of adaptation in correspondence with the state of the vehicle. Specifications are a unit drawn from on-road and cross-country measurements on a passive mechanical system, associate degreed it will be complete that for active role management a peak force of four kN and an RMS force of 700 N area unit necessary for the front actuators. What is more, the required peak damping power is around a pair of kW, but the RMS damping power is just sixteen W throughout traditional town driving. magnetic force feat, and an awfully smart following response proves the dynamic performance of the magnetic force mechanical system.

**Tharigonda Niranjan Babu et al.[5]**, the introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction in load carrying capacity and stiffness. Leaf spring is modelled in CATIA V5R20 software and it is imported in ANSYS 12.0. The conventional composite leaf springs were analyzed under similar conditions using ANSYS software and the results are presented. Deflection of composite leaf spring is less as compared to steel leaf spring with the same loading condition. Weight and cost are also less in composite leaf spring as compared to steel leaf spring with the same parameters. Conventional steel leaf spring is also found to be 5.5 times heavier then Jute EGlass/Epoxy leaf spring. Material saving of 71.4 % is achieved by replacing Jute EGlass/epoxy in place ofsteel for fabricating the leaf spring.

**Baviskar A.C. Et al.[6]**, Composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel. Therefore, it is concluded that composite leaf spring is an effective replacement for the existing steel leaf spring in automobile. E-glass epoxy is better than using Mild-steel as though stresses are little bit higher than mild steel, E-glass epoxy is having good yield strength value. The prior cracking in the spring was extensive enough to reduce the strength of the spring to the point where normal dirt road forces were adequate to produce rupture. The weight of the leaf spring is reduced considerably about 85 % by replacing steel leaf spring with composite leaf spring.

**P. Bhaskar et al.[7]** in automobile sector tends to increasing competition and innovation in design and tends to modify the existing products by new and advanced materials. Leaf springs are special kind of springs used in automobile suspension systems. The main function of leaf spring is not only to support vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction in load carrying capacity and stiffness. Therefore the objective of this paper is to present a general study on the performance comparison of composite (E-Glass/Epoxy and Jute E-Glass) leaf spring and conventional leaf spring. Leaf spring is modelled in CATIA V5R20 software and it is imported in ANSYS 12.0. The conventional composite leaf springs were analyzed under similar conditions using ANSYS software and the results are presented. The automobile chassis is mounted on the axles, not direct but with some form of springs. The stresses and deflection of steel leaf spring and composite leaf spring are found with great difference. Deflection of composite leaf spring is less as compared to steel leaf spring with the same loading condition. Weight and cost are also less in composite leaf spring as compared to steel leaf spring with the same parameters. Conventional steel leaf spring is also found to be 5.5 times heavier then Jute EGlass/Epoxy leaf spring. Material saving of 71.4% is achieved by replacing Jute E-Glass/epoxy in place of steel for fabricating the leaf spring. Composite leafspring can be used on smooth roads with very high performance expectations.

**K Rajesh et al.[8]** studied the material properties of the composite material the glass epoxy and graphite epoxy and analysed the conventional to composite leaf spring. Developed, fabricated and tested leaf spring using composite material. Selection of composite material indicated that the glass/graphite epoxy had higher tensile and fatigue strength and lower coefficient of thermal expansion. And result declared that compared to steel leaf spring the laminated composite leaf spring weight reduction is achieved.

**Kumar Krishna et al.[9]** carried out on multi leaf spring having nine leaves used by a commercial vehicle. The finite element modelling and analysis of multi leaf spring has been carried out. It concludes two full length leaves in which one is with eyed ends and seven graduated length leaves . The material of the leaf spring is SUP9. The FE model of the leaf spring has been generated in CATIA V5 R17 and imposed in ANSYS-11 for finite element analysis , which are **most** popular CAE tools. The FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining the under defined boundary condition. Bending stress and deflection are the target results. A comparsion of experimental and FEA results have been done to conclude.

**Manas Patnaik et al.[10]** has been carried out on a parabolic leaf spring of a mini loadtruck. The spring has been analyzed by applying a load of 3800N and the corresponding values of stress and displacement are computed. In this work, design of experiments has been applied under various configurations of the spring(i.e., by varying camber & eye distance). Camber and leaf span of a Parabolic leaf spring was found for Optimized tress and displacement values using Artificial Neural Networks.

**Lakhan Agarwal et al.[11]** bicycles are the most favourite choice when it comes to causes like health, pollution, and environment. Several researches have been done in order to make the ride comfortable. Loop wheels offer you a smoother ride. The three loops in every wheel work along as a self-correcting system. This spring system between the hub and the rim of the wheel provides suspension that continuously adjusts to uneven terrain cushioning the rider from abnormalities in the road wheel. The spring configuration permits the torque to be transferred smoothly between the hub and the rim. In this paper loop wheel manufactured using C20 material.

**Shubam Banker et al.[12],** in the conventional bicycles there no any type of suspension system. The spokes attached to rim has less load bearing capacity for special purpose cycles. The aim of the project is to design new type of wheel with hub, rim and tyre to provide suspension as well as to support rim and provide better bearing capacity. we will design and fabricate a loop-wheel bicycle which will be able to have extra feature of shock absorption and also the better load bearing capacity. The project will contain a bicycle with an improved wheel. The wheel will be replaced from conventional spoked-rim system to leaf spring or loop spring. The wheel will consist Axle, Hub, Rim, Tyre and Leaf/loop springs. All parts will be mounted in wheel so as to maintain its centre of gravity.

**Tanmay Chonkar et al.[13],** suspension system is the main component of any vehicle whether it might be car, trucks, motorbike, bicycle or wheel chair. Suspension increases the comfort level and increases ride quality. Since suspension on wheel chair is not that comfortable We decided to not only do research on suspension system of wheel chair but also fabricate it. Loop wheel suspension system will increase the comfort level of passenger. In this project we are going to take standard foldable wheel chair and would replace the spoke wheels with our loop wheels.(In-wheel suspension).The survey is done regarding parts and material to be used in the project. The major costing of the project is the suspension system. The suspension used in normally are the cylinders which are very costly and to reduce the cost and well as provide the same comfort coil spring suspensions will be used. Design of wheel which includes tyre, rim, triangular hub, coil spring and clips is done. After conforming the model created in Solidwork it will be exported into Ansys software were we will do analysis. Appropriate boundary conditions and forces like stress distribution and weight distribution will be applied and examine the behaviour of the model.

**M.C Shinde et al.[14],** recently there is an increasing interest on bicycle riding for recreation or fitness purpose. Bicycles are also accepted as urban transportation due to the consciousness of environmental protection. For a more comfortable riding experience, many bicycles are equipped with a suspension system. The aim is to design, analyze and fabricate a wheel of a cycle with tangential suspension system in the wheel itself. It is done so by introducing spring like material. Thus, the spokes of the cycle are replaced by leaf spring of variable length which can be varied according to the given conditions. The leaf springs are attached to the hub which can dislocate from its center and hence can be termed as “Floating hub”. The leaf springs are attached to the rim at the other end where the length of the spring can be adjusted. For serving the purpose a 26T cycle is taken under consideration where the suspension system is introduced in its front wheel by making the required replacements. Though this system is currently applicable only in bicycles, it has a wide future scope. Also, the springs can be replaced with damper. However, introduction of this suspension system in the bicycle itself provides more comfort to the rider than a regular bicycle. The main target was to achieve the desired deflections in the suspension for a particular weight of driver. Considering the application EN45 material is selected for leaf. The thickness of the leaf is determined by assuming it to be a cantilever beam and designing it for bending failure and the design was then analyzed in Ansys software. The stiffness of the leaf can be changed by simply shifting the mounting positions of the leaf at the wheel’s end. By changing the effective length of the leaf we can change the stiffness and hence control the hub travel.The wheel was designed considering the impact forces coming from the ground and lateral forces while cornering. Iterations were done to find the number of leaves to be used by checking the stresses and nature of deformation for 3 and 4 leaves only. Using more number of leaves will lead to unnecessary increase in weight. The analysis was done on Ansys v15.0 software to check the stresses and deformation in the system. A custom hub is designed to accommodate all the leaves with the help of nut and bolts.

**Pinjaari Shaikh et al.[15]**, in his paper “**Design, Modeling and Analysis of Loop Wheel Bicycle for Enhancing the Performance**” stated as below,

***Abstract -*** *In today’s world, Bicycle are the generally much loved excellent once it comes to cause like health, pollution and environment. More than few researches own been finished in peacefulness to present the provoke comfortable. Sundry types of cycles come with been industrial for numerous applications like person along for the ride Bikes, Mountain Bike, and Racing bikes. This make inquiries daily presents the round turn which is planned such that the suspension system is integrated inside wheel for senior shock-absorbing show and surpass comfort. The three loop in every wheel design beside as a self-correcting system. This bounce system between the focal point and the border of the turn provide suspension that ad infinitum adjusts to asymmetrical ground cushioning the specification from abnormalities in the street wheel. The give configuration permit the torque to be transferred smoothly between the centre and the rim.*

In this paper they studied three design with the help of three different materials namely C10, C20 and C30. Necessary stresses like principle stress and maximum deformation have been calculated theoretically and values have been observed on ANSYS 2019 R3 Workbench. Using the dimensions recorded from the studies loopwheels of respective materials have been fabricated and experimental results are also taken in record.
In their paper they recorded the experimental values of the maximum deflection obtained after fabrication of the loopwheel for three different materials have been done among which only C10 and C20 are being studied.

| Material | Result |
|---|---|
| C10 | 7.81 |
| C20 | 14.65 |
| C30 | 24.66 |

Table 2.1 Experimental Values for Reference

These values are being used for this paper as reference and comparison for our calculated and ANSYS results.

## Summary of Literature Survey

Studying the above papers it is concluded that loopwheel suspension for bicycles have better comfort, smoother ride and more shock absorption when compared to conventional suspension system. Having the study done on this subject shall pave our path towards a innovative studying different materials appropriate for the fabrication that is cost efficient, durable, endures the load and provide comfort to the rider and discover the aspects of its wide range of this innovative technology.

# CHAPTER 3

# MODELLING

In this project we have chosen CATIA for 3D modelling

## 3.1 About CATIA

CATIA is an acronym for Computer Aided Three-dimensional Interactive Application. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products. CATIA is a multi platform 3D software suite developed by Dassault Systems, encompassing CAD, CAM as well as CAE CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools
and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bidirectionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa.

## 3.2 CATIA for various Disciplines

The products developed today are getting increasingly complex. Users are demanding better performance and quality from them. This compels manufacturers to come up with engaging technical solutions and that too at a rapid pace. The engineering solutions from CATIA answers that challenge, enabling the rapid development of high-quality mechanical products CATIA from Dassault is a diverse application that offers a complete engineering toolset for various disciplines within a single working environment. What is more, the workbenches (as CATIAs modules are called) provide a seamless and consistent user interface across multiple disciplines.

## 3.3 CATIA for Mechanical Engineering

CATIA 3D modelling tools provide mechanical engineers with valuable insights into key factors of quality and performance early in the product development phase. Digital prototyping, combined with digital analysis and simulation, allows product development teams to virtually create and analyze a mechanical product in its operating environment. CATIA’s mechanical design products allow the user to create parts in a highly productive and intuitive environment, to enrich existing mechanical part design with wireframe and basic surface features. CATIA also provides advanced drafting capabilities through the associative drawing generation from 3D part and assembly designs. Mechanical Design products can address 2D design and drawing production requirements with a stand-alone state-of-the-art 2D tool Interactive Drafting.

**Key Benefits**

3.3.1 Create any type of 3D part, from rough 3D sketches to fully detailed industrial assemblies.

3.3.2 Unbreakable relational design - a new way to manage links between objects and related behaviors in configured assemblies.

3.3.3 Enables a smooth evolution from 2D- to 3D-based design methodologies.

3.3.4 Productive and consistent drawing update removes the need for additional user operations.

3.3.5 Process oriented tools capture the manufacturing process intent in the early stages of design.

3.3.6 A wide range of applications for tooling design, for generic tooling in addition to mold and die.

3.3.7 Advanced technologies for mechanical surfacing, based on a powerful specification driven modeling approach.

## 3.4 CATIA for Design / Styling

From product to transportation industries, the style & design of the product plays a major role in its success on the market. Develop shape & material creativity, reach a high level of surface sophistication & quality, and get the right decision tools with physical & virtual prototypes. These are the key elements of CATIA Design/Styling to boost design innovation. From 3D sketching, subdivision surface, Class-A modeling to 3D printing, reverse engineering, visualization and experience, CATIA Design/Styling provides all the solutions for design creativity, surface excellence and product experience.

**Key Benefits**

3.4.1 **Industrial Design**: whether starting 3D ideation from scratch or from 2D sketches, industrial designers can manipulate shapes with unrivaled freedom and take advantage of a true creativity accelerator to explore more ideas in the early conceptual phase.

3.4.2 **Advanced Surface Modeling**: fully addresses the Automotive Class-A shape design process with a solution for surface refinement that integrates industry-leading Icem surfacing technologies. Delivers a powerful and intuitive suite of tools for modeling, analyzing and visualizing aesthetic and ergonomic shapes for the highest Class-A surface quality.

3.4.3 Since **it is feature rich** – regardless of the discipline you would like to work on – training on how to use CATIA is very important to derive maximum benefits from the software.

## 3.5 Various Modules

3.5.1 CATIA offers many workbenches that can be loosely termed as modules. A few of the important workbenches and their brief functionality description is given below:

3.5.1.1 **Part Design**: The most essential workbench needed for solid modelling. This CATIA module makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to iterative detailed design.

3.5.1.2 **Generative Shape Design**: allows you to quickly model both simple and complex shapes using wireframe and surface features. It provides a large set of tools for creating and editing shape designs. Though not essential, knowledge of Part Design will be very handy in better utilization of this module.

3.5.1.3 **Assembly:** The basics of product structure, constraints, and moving assemblies and parts can be learned quickly. This is the workbench that allows connecting all the parts to form a machine or a component.

3.5.1.4 **Kinematic Simulation**: Kinematics involves an assembly of parts that are connected together by a series of joints, referred to as a mechanism. These joints define how an assembly can perform motion. It addresses the design review environment of digital mock-ups. This workbench shows how a machine will move in the real world. These are only four of the many workbenches that CATIA offers. A few of the other modules include Machining, Equipment & System, Infrastructure and Ergonomics Design & Analysis.

# CHAPTER 4

# SIMULATION

Analysis of the deep drawing operation is done in ANSYS.

## 4.1 ANSYS.

4.1.1 ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

4.1.2 In general, a finite element solution may be broken into the following three stages.

4.1.3 This is a general guideline that can be used for setting up any finite element analysis.

4.1.3.1 **Pre-processing: defining the problem;** the major steps in pre-processing are given below:

- Define keypoints/lines/areas/volumes
- Define element type and material/geometric properties
- Mesh lines/areas/volumes as required
- The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axi-symmetric, 3D).

4.1.3.2 **Solution:** assigning loads, constraints and solving; here we specify the loads (point or pressure), constraints (translational and rotational) and finally solve the resulting set of equations.

4.1.3.3 **Postprocessing:** further processing and viewing of the results; in this stage one may wish to see:

- Lists of nodal displacements
- Element forces and moments
- Deflection plots
- Stress contour diagrams

4.1.4 ANSYS uses certain inputs and evaluates the product behavior to the physics that you are testing it in. It is a general purpose software used to simulate the interactions between various physics like dynamics, statics, fluids, electromagnetic, thermal, and vibrations. ANSYS typically creates the user an opportunity to create a virtual environment to simulate the tests or working conditions of the products before manufacturing the prototypes. This would certainly reduce the cost of producing prototypes and mainly the time. In this competitive world the accuracy and time are the most deciding factors for the company or the organization to sustain. ANSYS helps in increasing the accuracy and decreasing the time of outcome of the final product.

## 4.2 Advantages

4.2.1 ANSYS can import all kinds of CAD geometries (3D and 2D) from different CAD software's and perform simulations, and also it has the capability of creating one effortlessly. ANSYS has inbuilt CAD developing software's like Design Modeler and Space Claim which makes the work flow even smoother.

4.2.2 ANSYS has the capability of performing advanced engineering simulations accurately and realistic in nature by its variety of contact algorithms, time dependent simulations and non linear material models.

4.2.3 ANSYS has the capability of integrating various physics into one platform and perform the analysis. Just like integrating a thermal analysis with structural and integrating fluid flow analysis with thermal and structural, etc.

4.2.4 ANSYS now has featured its development into a product called ANSYS AIM, which is capable of performing multi physics simulation. It is a single platform which can integrate all kinds of physics and perform simulations.

4.2.5 ANSYS has its own customization tool called ACT which uses python as a background scripting language and used in creating customized user required features in it.

4.2.6 ANSYS has the capability to optimize various features like the geometrical design, boundary conditions and analyse the behavior of the product under various criterion's.

## 4.3 Meshing

4.3.1 ANSYS provides general purpose, high-performance, automated, intelligent meshing software that produces the most appropriate mesh for accurate, efficient multiphysics solutions from easy, automatic meshing to highly crafted mesh. Smart defaults are built into the software to make meshing a painless and intuitive task, delivering the required resolution to capture solution gradients properly for dependable results.

4.3.2 ANSYS meshing solutions range from easy, automated meshing to highly crafted meshing. Methods available cover the meshing spectrum of high-order to linear elements and fast tetrahedral and polyhedral to high-quality hexahedral and mosaic.

4.3.3 ANSYS meshing capabilities help reduce the amount of time and effort spent to get to accurate results. Since meshing typically consumes a significant portion of the time it takes to get simulation results, ANSYS helps by making better and more automated meshing tools.

4.3.4 Whether performing a structural, fluid or electromagnetic simulation, ANSYS can provide us with the most appropriate mesh for accurate and efficient solutions. The below image gives us a glimpse of ANSYS meshing.

# CHAPTER 5

# METHODOLOGY

**Phase 1 Data Collection**

Data collection phase involves the collection of reference material for project concept.

**Phase 2 System Design**

The system design comprises of development of the mechanism so that the given concept can perform the desired operation.

**Phase 3 Mechanical Design**

The parts in the part list will be designed for stress and strain under the given system of forces, and appropriate dimensions will be derived.

**Phase 4 Drawing**

Production drawings of the parts are prepared using AutoCAD, with appropriate dimensional and geometric tolerances.

**Phase 5 Results**

Results derived from the study is processed and saved for the record. This can be used in future applications and improvements.

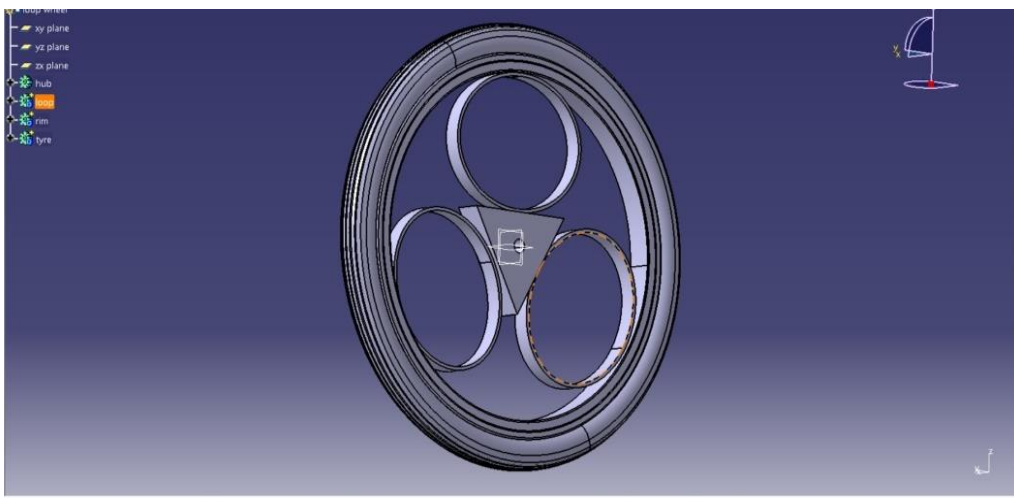


Fig 5.1 (a) Part Drawing (RAW)

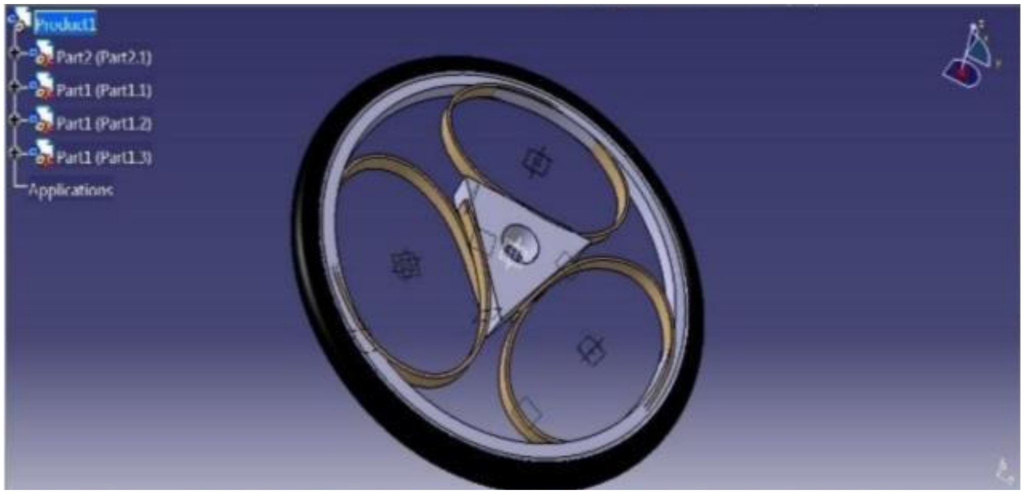


Fig 5.1 (b)  CATIA Model (Material Allotmet**)**

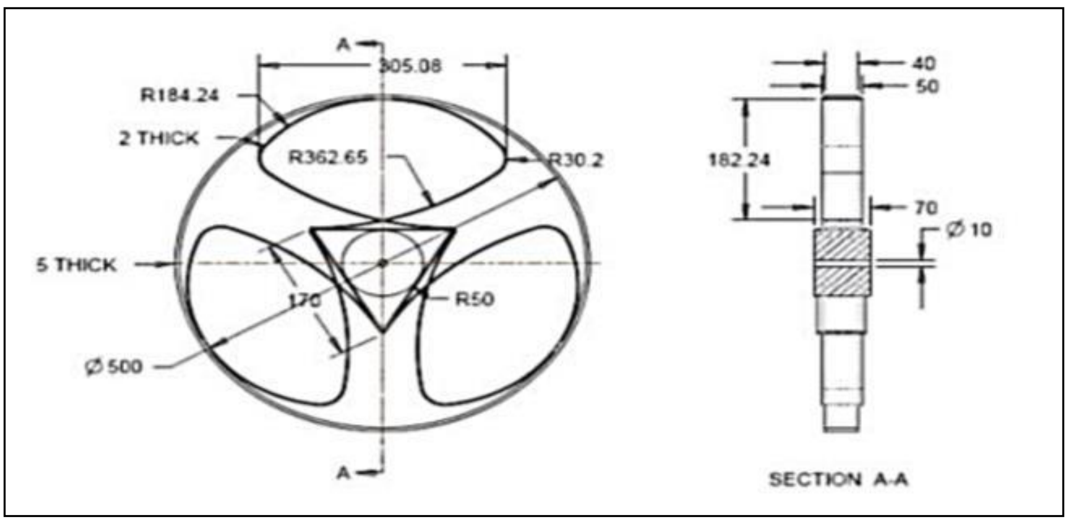


Fig 5.2 CAD Model

# CHAPTER 6

# CALCULATIONS

## 6.1 Material used: C10 material

**Material Properties**:

Tensile strength = 365N/mm2
σ max = 365/1=365 N/mm2
Given data: for 75kg weight(person and body)
F=370.22N
Major Axis of loop spring=L=300mm
Minor axis of loop spring=h=200mm
E= 210MPa
Number of spring strips, n= 1
Width of spring b = 25.4mm
Thickness of spring t = 5mm

**Calculation of Maximum Principal Stress**

$$\sigma_{max} = \frac{3FL}{2nbt^2} = \frac{3*370.22*300}{2*1*25.4*5^2} = 183.45 \text{ N/mm}^2 < 365 \text{ N/mm}^2$$

**Calculation of Maximum Deflection**

$$\Delta max = \frac{3FL^3}{8Enbt^3} = \frac{3*370.22*300^3}{8*210*1*25.4*5^3} = 3.44 \text{ mm.}$$

Above calculations were done considering half portion of spring hence total defection would be,

$$\Delta max = 3.44*2 = 6.88 \text{ mm.}$$

**Hence design is safe.**

## 6.2 **Material used**: C20 material

**Material Properties**:
Tensile strength = 560N/mm2
σ max = 560/1=560 N/mm2

Given data: for 75kg weight(person and body)
F=370.22N
Major Axis of loop spring=L=300mm
Minor axis of loop spring=h=200mm
E= 200MPa
Number of spring strips, n= 1
Width of spring b = 25.4mm
Thickness of spring t = 5mm

**Calculation of Maximum Principal Stress**

$$\sigma\ max = \frac{3FL}{2nbt^2}$$

$$= \frac{3*370.22*300}{2*1*25.4*5^2}$$

$$= 262.36\ N/mm^2 < 560\ N/mm^2$$

**Calculation of Maximum Deflection**

$$\Delta max = \frac{3FL^3}{8Enbt^3}$$

$$= \frac{3*370.22*300^3}{8*200*1*25.4*5^3}$$

$$= 5.90\ mm.$$

Above calculations were done considering half portion of spring hence total defection would be,

$$\Delta max = 5.90*2$$

$$= 11.80\ mm.$$

**Hence design is safe.**

| Material | Result |
|---|---|
| C10 | 6.82 |
| C20 | 11.8 |

Table 6.1 Calculated Deflection in both Materials

| Material | Result |
|---|---|
| C10 | 7.81 |
| C20 | 14.65 |

Table 6.2 Experimental Deflection in both Materials

# CHAPTER 7

# RESULT AND CONCLUSION

The safety of the design. Using impulse momentum principle, force was calculated when the cycle hits a rigid wall with a velocity of 30 kmph. The resultant Equivalent Stress (MPa) and Total Deformation as shown in table. The force obtained was 370.22N. i.e. 75 Kg.,

| Material | Maximum | Minimum | Average deflection |
|---|---|---|---|
| C10 | 6.82 | 0 | 3.41 |
| C20 | 12.162 | 6.635 | 9.39 |

Table 7.1: Result of Deformation and Stress developed.

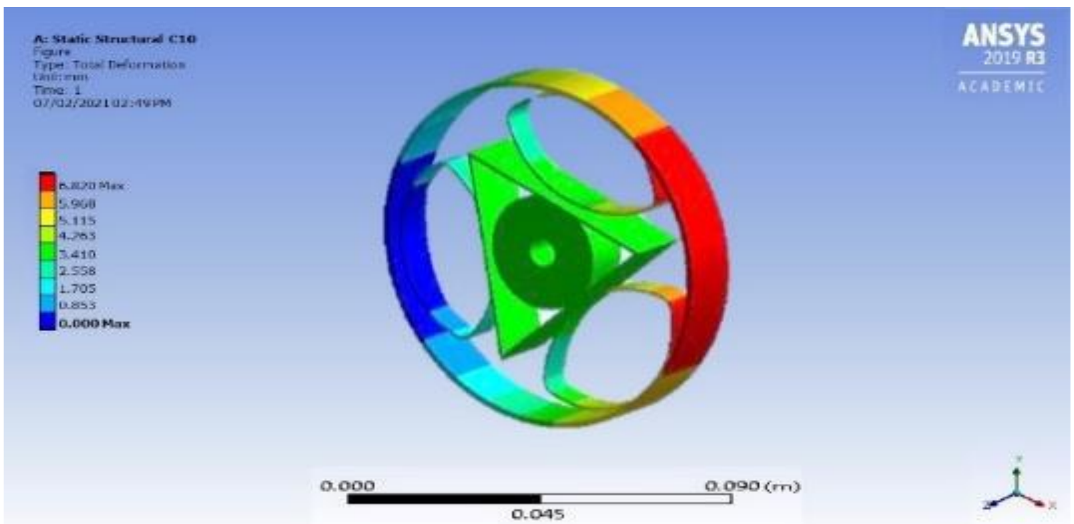


Fig 7.1 ANSYS Result of Deformation for C10 Material

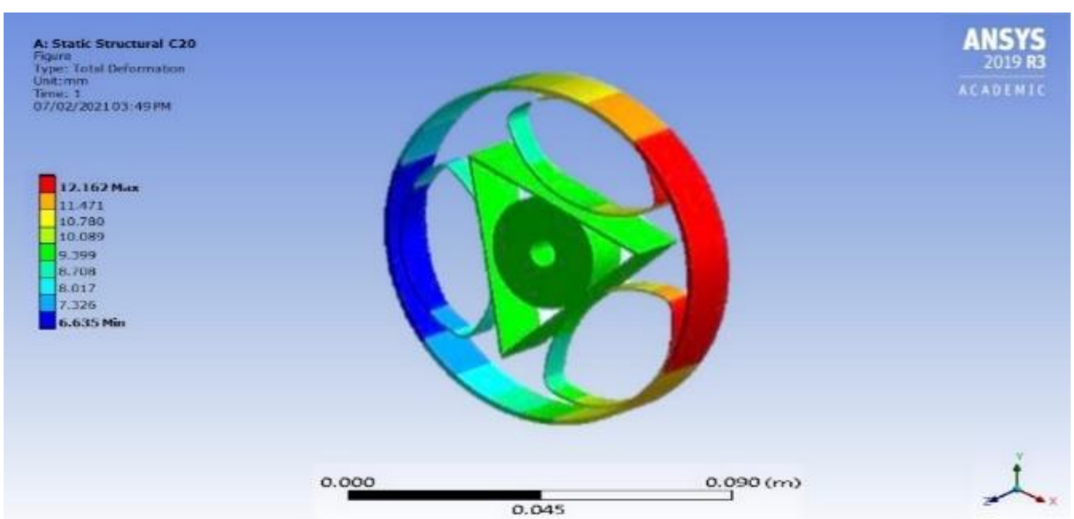


Fig 7.2 ANSYS Result of Deformation for C20 Material

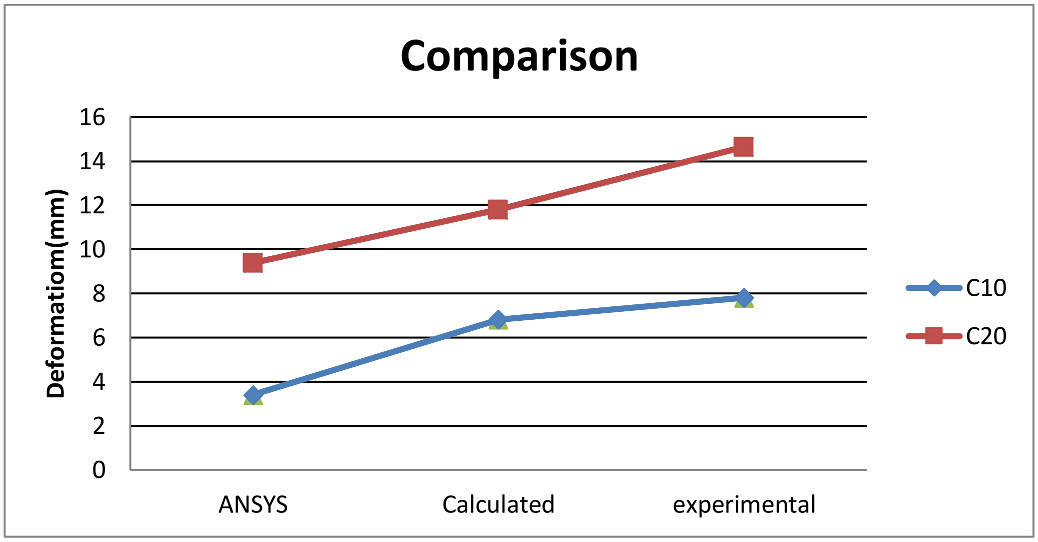

Fig 7.3 Graphical Comparison

## CONCLUSION

Smooth ride, sky-scraping shock captivation capacity is achieved by bicycle with loopwheel suspension system and avoids basics of other suspension system. Additionally this paper implies the applications like wheelchairs, mountain bikes for their scope to counter terrain and cushioning road abnormalities. Examination is done which shows that calculated and the ethics obtained by means of ANSYS 2019 R3 workbench is in accordance with other which implies that the outline is safe.

## FUTURE SCOPE

Going back to the loop wheels problem of how best to make the springs and thinking that carbon composites were going to be the answer, I took inspiration from my immediate environment. One idea that carbon composite archery bows probably went through similar kinds of stresses as the springs in wheels. So let's try out for other designs like archery bow with carbon composites, no matter it is costly than steel but it is better effective than steel because of its material properties and simple of manufacture. A spring framework between the center point and the edge of the wheel pads the rider from knocks and potholes in the street. Since the suspension framework is situated inside.

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