CHAPTER ONE

INTRODUCTION

CHAPTER ONE: INTRODUCTION

1.1.Background

A global reality that the world is facing at the moment is the deterioration in environmental conditions. It is mostly due to continuous and uncontrolled emissions of hazardous and polluting elements to the atmosphere from various segments of human activities. Burning of fossil fuels in transportation sectors is widely acknowledged as the major contributing factor. Fossil fuels account for 85% of the world's primary energy. The production and consumption rates of petroleum increase year by year due to the much lower cost of petroleum. According to www.epa.gov 39.2% of total emission in 2007 is raised from transportation. Faced with environmental issues caused by burning of fossil fuel, innovations towards cleaner solutions to replace the ever diminishing fossil fuels have been the focus of not only researchers but governments all around the world.

In the beginning, the most sought after and immediate solutions spearheading the effort to achieve emission-free vehicles are EVs and fuel cell vehicles (FCVs). Although both solutions are theoretically sustainable and emission free, they bear a number of issues which hinder their immediate mass production and wider public acceptance. FCVs are currently still in the early stages of its development cycle and the technology is yet to reach a mature state as researchers and manufacturers are still working out on cost reduction and performance optimization. EVs use rechargeable battery packs (commonly, Lithium-ion batteries) as its source of energy to power one or more electric motors for propulsion. These batteries are quite bulky, heavy and more expensive. The present battery technology enables only a relatively short mileage per full charge, which is unsuitable for long distance trips due to unavailability of nation-wide recharge stands. Currently, EVs are only suitable for urban driving because most countries still do not have proper charging stations broadly available.

In recent years, hybrid electric vehicles (HEVs) have thrived as a lucrative solution to the aforementioned problems with its intermediate approach to achieve superior mileage and low tailpipe emission compared to conventional ICE vehicles. HEV is a term used to describe vehicles that use ICEs in combination with one or more electric motors connected to a battery pack as a secondary energy storage system providing propulsion to the wheels either together or separately. It is a culmination of mechanical, electrical, electronic and power engineering technologies embracing the best of both conventional ICE vehicles and electric vehicles (EVs). The most notable advantages that an HEV possesses over a pure EV are superior mileage and flexibility in the sizing of the components. HEVs are regarded as a step in the right direction towards cleaner and greener vehicles.

In developing countries like Nepal, many problems like shortage of fuel, electricity and other energy resources do occur. To overcome the problems aroused by the shortage of these energy resources, it is highly beneficial to use the available resources together to get a better outcome.

Hybrid vehicles are a promising answer to this need. Also, the use of hybrid vehicles helps to reduce harmful tailpipe emissions and cut our dependence on foreign oil. In Nepal, it is very beneficial if we are able to use two or more energies together to empower a vehicle so that the vehicle doesn't solely depend on a single energy source. Hence, we came across with the idea of "Hybrid Electric Vehicle" with a view to enhance fuel economy and minimizing tailpipe emissions.

1.2. Rationale

A lot of traffic jams happen daily in most of the city areas. So, a large amount of fuel is wasted when vehicles are stuck in such jams. Also, major components of IC engine gets damaged when the vehicle has to run in every conditions. Hybrid Electric Vehicles (HEVs) can be the promising solution for these types of problems.

Hazardous exhaust emissions from conventional ICE vehicles can be minimized by the use of such HEVs.

Though Nepal has large potential of producing hydro-power electricity, most of the regions of Nepal are suffering from load-shedding. This may cause some problem for recharging the batteries for electric vehicles. Also the Nepalese are comparatively poorer, so it is quite difficult to afford expensive EVs.

Considering all these problems, HEV seems to be the best solution at the present scenario in Nepal.

In this project we designed, fabricated and analyzed a hybrid electric vehicle that is both environmentally friendly and efficient in terms of fuel economy. We assembled the engine of a motorbike and electric motor and made a transmission in such a way that it can work in hybrid mode by simple mechanism. With this simple mechanism of transmission, we can make hybrid vehicles from many IC vehicles that are abandoned in our country.

Also, this vehicle has a unique design (Slingshot model) which looks quite extraordinary. People can find it different from other vehicles and like it. The riding experience can be new and exciting for them.

1.3. Objectives

1.3.1. Main Objective

The main objective of our project is to design the chassis of a three-wheeler parallel type hybrid electric vehicle and fabricate the vehicle and test and compare the performances.

1.3.2. Specific Objectives

- To design effective and economical model for hybrid setup
- To select the suitable material that sustain the structure which is also cost effective
- To design and fabricate a transmission system in a simple way that would make use of battery driven motor at low speed and IC engine at high speed
- To increase the fuel economy of the vehicle by using both battery and IC engine at their maximum efficiency state
- To test the performances of HEV
- To develop innovative ideas and inspiration for the future improvement and enhancement of the vehicle

1.4. Scope

The designing and fabrication of the three-wheeler hybrid electric vehicle is a challenging job. This project can create a platform for the students to show their skills and talents if implemented properly. Above all, it can provide a learning platform for the students. They can be familiar with various problems that come across in the real manufacturing processes and implement their theory based knowledge in a practical way. They can come out with their own ideas and use their knowledge in solving various problems. Apart from that, they can also use general tools and even complicated one during the fabrication of the vehicle by themselves. Another benefit for the students might be to learn how to work in a team in a most effective manner and bring out the best outcome. A brief scope of the project is as listed out below;

- The three-wheeler HEV is both environmentally friendly (comparatively low tail pipe emissions) and efficient in terms of fuel economy.
- The two mode of power source aids the driver to drive in either mode as wished.
- It can be a useful mode of transportation in our country.
- For developing countries like Nepal, hybrid technology can be installed in conventional vehicles by simple mechanism and at low cost.
- The unique and stylish vehicle gives exciting experience to the rider.

- It creates an encouraging platform for the development of innovative ideas and inspiration for further improvement of the vehicle.

1.5. Methodology

The methodology applied for the project is given below in a chronological order.

a) *Literature review*
This type of project has never been done in Nepal, so we mostly did the study on internet than other sources. We browsed different websites that could give us information related with the hybrid technology. We studied different books, research articles and references related to HEVs. We consulted many books to acquire different information about material selection, components design as well as project management strategies.

b) *Selection of concepts*
We discussed our project with our supervisor, teachers and seniors associated with similar fields and found out appropriate solution for different problems. The selection of the ideas and methods was based on different parameters such as simple mechanism, easy to use, low in cost, easy to fabricate, compactness in size, charging method, stability, lower maintenance, easy driving, low vehicle weight etc.

c) *Preliminary design*
Our preliminary design included various alternative designs and sketches for each component system i.e. steering system, frame and structure, etc. The designs were prepared on the basis of literature review.

d) *Final design and analysis*
Most of our designing involved reviewing the past designs. Thus, our final designs were based on some factors like cost, material availability, ease of fabrication, functionality, etc.
All the designs were prepared by using software like SOLIDWORKS.

e) *Site selection*
For the fabrication and inventory storage purpose we selected automobile lab of Pulchowk Campus. For the complicated operation that required special attention and technical supervision, we decided to consult Robotics Club.

f) *Determination of necessary materials, tools, equipment and processes*

After the finalization of the designs, we determined the required materials, tools, equipment and processes. The materials and processes were mainly selected on the basis of the availability and ease of the fabrication. Some of the components were used directly while some needed modification.

g) *Collection of materials and fabrication of the vehicle*
Due to limited budget and unavailability of some materials, the collection of materials and fabrication was done side by side. The fabrication was started from the chassis and all the other components were mounted on a chronological order. The assembly of the components (both IC engine and electric) were done at last.

h) *Test ride and test result study*
After the completion of fabrication part, initial test ride was conducted both in IC engine mode and electric mode to verify the working condition of the vehicle. Minor adjustments and modifications were done after the test ride. Performance tests and analysis were also done.

i) *Report preparation and final presentation*

j) *Project submission*

1.6. Limitations

- The platform on which the fabrication was done was not accurate according to the design so there was some deviation in the final look of the vehicle.
- Our design was based on the ideal working conditions (like perfect weld, rigid body, perfect dimension of pipe etc.) but the real working process has deviated the expected result.
- We used locally and cheaply available parts which have affected the expected efficiency.
- Due to lack of advanced machinery, the machined parts wasn’t of required accuracy.
- Since we used an engine of a motorbike, reverse driving is only possible in electric mode by engaging the engine in neutral.
- There is no protection of both passengers and body of the vehicle against rain, sun, etc. (safety consideration)

CHAPTER TWO
LITERATURE REVIEW

CHAPTER TWO: LITERATURE REVIEW

2.1. About HEV

HEVs come in many variations that are diverse in their configurations and sizing but their objectives remain the same- to achieve the best fuel economy and lowest possible tail pipe emission. However, HEVs are generally grouped into three big categories based on their configurations, namely series, parallel and power-split series-parallel. The dissimilarity that separates HEV into these categories lies in the design of the power flow from the sources of energy, i.e. the fuel and energy storage system (ESS) to the transmission.

2.2. Types of hybrid.

2.2.1. Series hybrid

In the series hybrid, the vehicle is driven by one or more electric motors supplied either from the battery, or from the IC engine driven generator unit or both. However, in either case, the driving force comes entirely from the electric motor or motors. The IC engines in a series hybrid are not coupled to the wheels and do not directly power the car.

A controller in the transmission determines how much power is needed to propel the vehicle and whether to pull it from the battery or the generator. Series hybrids feature a separate generator which is connected to the engine.

The series hybrid tends to be used only on special applications. For example, the diesel-powered railway engine is nearly always a series hybrid, as are some ships. The main disadvantage of the series hybrid is that all the electrical energy must pass through both the generator and the motors. This adds considerably to the cost of such systems.

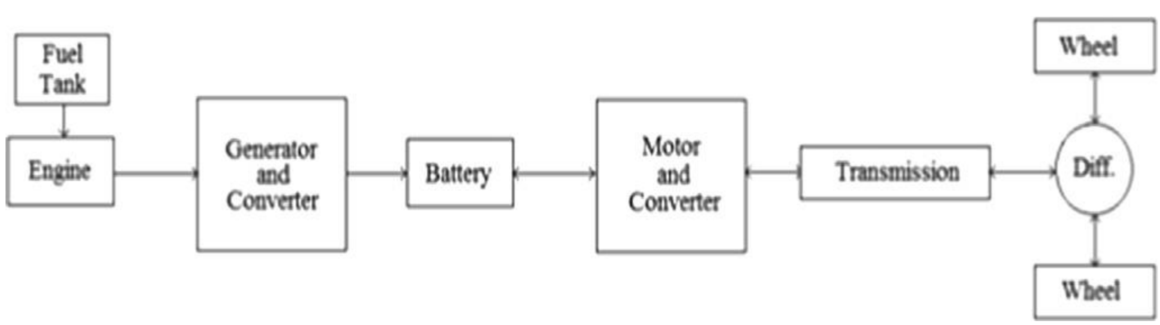


Fig.1: Series HEV configuration

2.2.2. Parallel hybrid

In the parallel hybrid, the vehicle can either be driven by the IC engine working directly through a transmission system to the wheels, or by one or more electric motors, or by both the electric motor and the IC engine at once. The gasoline engine and the electric motor are both connected to the transmission. When the fuel travels to the engine or when the electric motor is turned on, the power that is generated propels the car. A controller in the transmission determines when to operate the electric motor and when to switch to the gasoline engine.

The parallel hybrid has a scope for wide application. The electric motor can be much smaller and cheaper, as they do not have to convert all the energy. There are various ways in which a parallel hybrid vehicle can be used. In the simplest, it can run on electricity from the batteries, for example, in a city where exhaust emission are undesirable, or it can be powered solely by the IC engine, for instance, while travelling outside the city. Alternatively, and more usefully, a parallel hybrid vehicle can use the IC engine and batteries in combination, continually optimizing the efficiency of the IC engine.

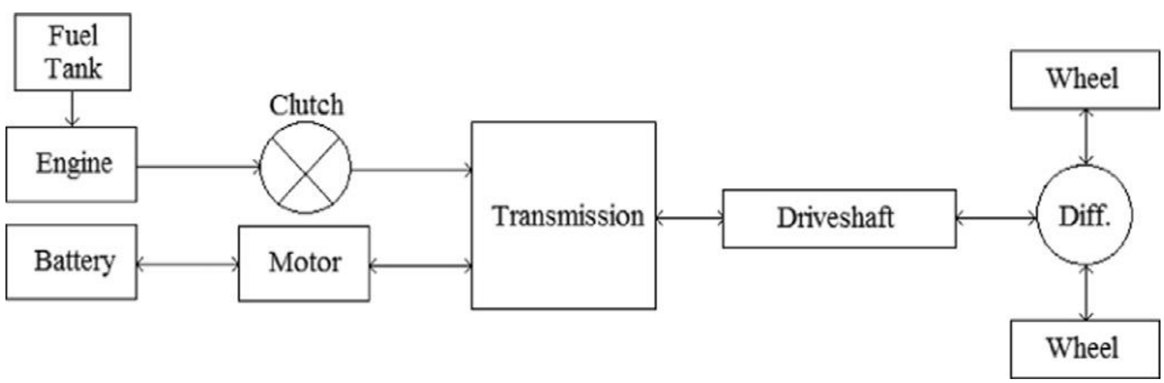


Fig. 2: Parallel HEV configuration

2.2.3. Series-parallel hybrid

In a power-split hybrid, there are two motors; an electric motor and an internal combustion engine. The power from these two motors can be shared to drive the wheels via a power splitter, which is a simple planetary gear set. The combustion engine can act as a generator charging the batteries.

On the open road, the primary power source is the internal combustion engine. When maximum power is required, for example to overtake, the electric motor is used to assist.

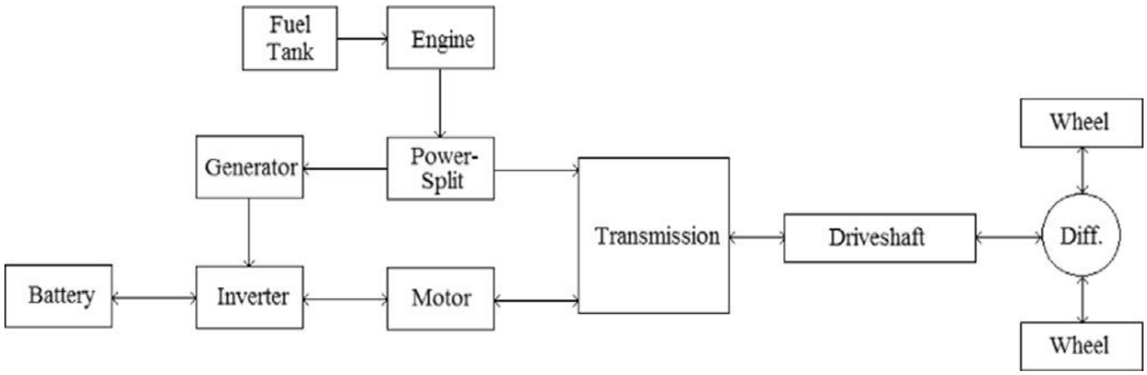


Fig. 3: Power-split series-parallel HEV configuration

Among the above described varieties, we were interested in a parallel type HEV configuration. Our project mainly focused on design, fabrication and testing of three-wheeler hybrid electric vehicle. This vehicle is powered by a gasoline engine and an electric motor driven by a no. of batteries.

2.3. History of HEV

Table 1: Evolution of Hybrid Vehicle

Year	Events
1665-1825	Flemish Jesuit priest and astronomer Ferdinand Verbiest created plans for miniature four-wheeled unmanned steam ‘car’. In 1769, Frenchman Nicholas Cugnot built a steam-powered motor carriage capable of six miles per hour. In 1825, British inventor Goldsworthy Gurney built a steam car that successfully completed 85 miles in 10 hour.
1839	Robert Anderson of Aberdeen, Scotland built the first electric vehicle.
1870	Sir David Salomon developed a car with a light electric motor and very heavy storage batteries. Driving speed and range were poor.
1888	Immisch& Company built a four-passenger carriage, powered by a one-horsepower motor and 24-cell battery. In the same year, Magnus Volk in Brighton, England made a three-wheeled electric car.
1890-1910	Period of significant improvements in battery technology, specifically with development of the modern lead-acid battery by H. Tudor and nickel-iron battery by Edison and Junger.

1898	The Austrian Dr. Ferdinand Porsche, at age 23, built his first car, the Lohner Electric Chaise. It was the world's first front-wheel-drive. Porsche's second car was a hybrid, using an internal combustion engine to spin a generator that provided power to electric motors located in the wheel hubs. On battery alone, the car could travel nearly 40 miles.
1900	American car companies made 1,681 steam, 1,575 electric and 936 gasoline cars. In a poll conducted at the first National Automobile Show in New York City, patrons favored electric as their first choice, followed closely by steam.
1902	A series-hybrid runabout competed against steam and gas-powered cars in a New York to Boston reliability test.
1904	The Electric Vehicle Company built 2000 taxicabs, trucks, and buses, and set up subsidiary cab and car rental companies from New York to Chicago. Smaller companies, representing approximately 57 auto plants, turned out about 4000 cars. Henry Ford overcame the challenges posed by gasoline-powered cars-noise, vibration, and odor and began assembly-line production of low-priced, lightweight, gas-powered vehicles. Within a few years, the Electric Vehicle Company failed.
1905	An American engineer named H. Piper filed a patent for a petrol-electric hybrid vehicle. His idea was to use an electric motor to assist an internal-combustion engine, enabling it to achieve 25 mph.
1910	Commercial built a hybrid truck which used a four-cylinder gas engine to power a generator, eliminating the need for both transmission and battery pack. This hybrid was built in Philadelphia until 1918.
1913	With the advent of the self-starter, steamers and electrics were almost completely wiped out. In this year, sales of electric cars dropped to 6,000 vehicles, while the Ford Model T sold 182,809 gasoline cars.
1916	Two prominent electric-vehicle makers-Baker of Cleveland and Woods of Chicago, offered hybrid cars. Woods claimed that their hybrid reached a top speed of 35 mph and achieved fuel efficiency of 48 mpg. The Woods Dual Power was more expensive and less powerful than its gasoline competition, and therefore sold poorly.
1920-1965	Dormant period for mass-produced electric and hybrid cars. So-called alternative cars became the province of backyard tinkerers and small-time entrepreneurs.
1968-1971	Three scientists working at TRW, a major auto supplier, created a practical hybrid powertrain. Dr. Baruch Berman, Dr. George H. Gelb and Dr. Neal A. Richardson developed, demonstrated and patented the system-designated as an electromechanical transmission (EMT) providing brisk vehicle performance with an engine smaller than required by a conventional internal combustion engine drive. Many of the engineering concepts incorporated in that system are used in today's hybrids.

1969	The GM 512, a very lightweight experimental hybrid car, ran entirely on electric power up to 10 miles per hour. From 10 to 13 miles per hour, it ran on a combination of batteries and its two-cylinder gas engine. Above thirteen miles per hour, the GM 512 ran on gasoline. It could only reach 40 miles per hour.
1970s	With the Arab oil embargo of 1973, the price of gasoline soared, creating new interest in electric vehicles. The U.S. Department of Energy ran tests on many electric and hybrid vehicles produced by various manufacturers, including a hybrid known as the “VW Taxi” produced by Volkswagen in Wolfsburg, West Germany. The Taxi, which used a parallel hybrid configuration allowing flexible switching between the gasoline engine and electric motor, logged over 8,000 miles on the road, and was shown at auto shows throughout Europe and the United States.
1975	AM General, a division of American Motors, began delivery of 352 electric vans to the U.S. Postal Service for testing. The U.S. Energy Research and Development Administration began a government program to advance electric and hybrid technology.
1976	U.S. Congress enacted Public Law 94-413, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. Among the law’s objectives were to work with industry to improve batteries, motors, controllers, and other hybrid-electric components. General Electric was chosen to construct a parallel-hybrid sedan, and Toyota built its first hybrid-a small sports car with a gas-turbine generator supplying current to an electric motor.
1977-1979	General Motors spent over $20 million in electric car development and research, reporting that electric vehicles could be in production by the mid-1980s.
1980	Briggs and Stratton, the company known for manufacturing lawn mower engines, developed a hybrid car powered by a twin cylinder four-stroke 16hp gasoline engine and an electric motor-for total of 26 horsepower. The hybrid drivetrain provided power for a custom-designed two-door vehicle with six wheels-two in front and four in the back.
1989	Audi unveiled the first generation of the Audi Duo experimental vehicle, based on the Audi 100 Avant Quattro. The car had a 12.6 horsepower electric engine, which drove the rear wheels instead of a propeller shaft. A nickel-cadmium battery supplied the energy. The front-wheel drive was powered by a 2.3-litre five-cylinder engine with an output of 136 horsepower. Two years later, Audi unveiled the second generation Duo, also based on the Audi 100 Avant Quattro.
1991	The United States Advanced Battery Consortium (USABC), a Department of Energy program, launched a major program to produce a “super” battery to get viable electric vehicles on the road as soon as possible. The USABC would go on to invest more than $90 million in the nickel hydride (NiMH) battery. The NiMH battery can accept three times as many charge cycles as lead-acid, and can work better in cold weather.

1992	Toyota Motor Corporation announced the "Earth Charter," a document outlining goals to develop and market vehicles with the lowest emissions possible.
1993	The Clinton Administration announced a government initiative called the Partnership for a New Generation of Vehicles (PNGV). In the program, the government worked with the American auto industry to develop a clean car that could operate at up to 80 miles per gallon. Several years and a billion dollars later, the PNGV emerged with three prototypes for their 80 mpg car. Every prototype was a hybrid.
1997	The Toyota Prius was introduced to the Japanese market, two years before its original launch date, and prior to the Kyoto global warming conference held in December. First-year sales were nearly 18,000.
1997	Audi became the first manufacturer in Europe to take a hybrid vehicle into volume production: the Audi duo based on the A4 Avant. The vehicle was powered by a 90 horsepower 1.9-litre TDI in conjunction with a 29 horsepower electric motor. Both power sources drove the front wheels. A lead-gel battery at the rear stored the electrical energy. The Duo was not a commercial success and therefore discontinued, prompting European carmakers to focus their R&D investment on diesels.
1997-1999	A small selection of all-electric cars from the big automakers including Honda’s EV Plus, GM’s EV1 and S-10 electric pickup, a Ford Ranger pickup, and Toyota’s RAV4 EV, were introduced in California. Despite the enthusiasm of early adopters, the electrics failed to reach beyond a few hundred drivers for each model. Within a few years, the all-electric programs were dropped.
1999	A small selection of all-electric cars from the big automakers-including Honda’s EV Plus, GM’s EV1 and S-10 electric pickup, a Ford Ranger pickup, and Toyota’s RAV4 EV-were introduced in California. Despite the enthusiasm of early adopters, the electrics failed to reach beyond a few hundred drivers for each model. Within a few years, the all-electric programs were dropped.
2000	Toyota released the Toyota Prius, the first hybrid four-door sedan available in the United States.
2002	Honda introduced the Honda Civic Hybrid, its second commercially available hybrid gasoline-electric car. The appearance and drivability of the Civic Hybrid was (and still is) identical to the conventional Civic.
2004	The Toyota Prius II won 2004 Car of the Year Awards from Motor Trend Magazine and the North American Auto Show. Toyota was surprised by the demand and pumped up its production from 36,000 to 47,000 for the U.S. market. Interested buyers waited up to six months to purchase the 2004 Prius. Toyota Motor Sales U.S.A. President Jim Press called it "the hottest car we’ve ever had." In September, Ford released the Escape Hybrid, the first American hybrid and the first Sport Utility Vehicle (SUV) hybrid.

2006	General Motors Saturn Division began to market a mild parallel hybrid.
2009	The Hyundai Elantra LPI Hybrid was unveiled at the 2009 Seoul Motor Show, and sales began in the South Korean domestic market. The Elantra LPI (Liquefied Petroleum Injected) is the world's first hybrid vehicle to be powered by an internal combustion engine built to run on liquefied petroleum gas (LPG) as a fuel.
2009	The Mercedes-Benz S400 Blue Hybrid was unveiled. BMW began sales of its full hybrid BMW Active Hybrid X6.
2010	The 2011 Lincoln MKZ Hybrid was unveiled at the 2010 New York International Auto Show and sales began in the U.S. in September 2010. The MKZ Hybrid is the first hybrid version ever to have the same price as the gasoline-engine version of the same car. The Porsche Cayenne Hybrid was launched in the U.S in late 2010.
2011	Volkswagen announced the launch of the 2012 Touareg Hybrid, which went on sale on the U.S. in 2011. VW also announced plans to introduce diesel-electric hybrid versions of its most popular models- Jetta, Golf Hybridand Passat. Other gasoline-electric hybrids released in the U.S. in 2011 were the Lexus CT 200h, the Infiniti M35 Hybrid, the Hyundai Sonata Hybrid and its sibling the Kia Optima Hybrid.
2012-2013	The Audi Q5 Hybrid, BMW 5 Series Active Hybrid, BMW 3 series Hybrid, Ford C-Max Hybrid, Acura ILX Hybrid, Toyota Avalon Hybrid, Volkswagen Jetta Hybrid, Corolla Axio, Range Rover Hybrid were released in U.S.
2014	Ford Motor Company, the world’s second largest manufacturer of hybrids after Toyota Motor Corporation, reached the milestone of 400,000 hybrid vehicles. After 18 years since the introduction of hybrid cars, Japan became the first country to reach sales of over 1 million hybrid cars in single year.

2.4. Current Hybrid Vehicle Design

A hybrid vehicle uses some combination of electric and combustion power to create an ultra-high efficient source of propulsion. Depending on the auto maker, this combination between the power sources will vary. These combinations range from “mild” to “full”. The most modest setup is the belt-driven starter-alternator. GM will offer on its Chevrolet Equinox and Malibu in 2006 and 2007. Instead of having a traditional starter and alternator, GM has replaced the typical setup worth an electrical control system which switches from being a generator to a motor, as needed. Electrical energy is stored in a battery and can be accessed for acceleration or starting the vehicle. A more complex hybrid design instead replaces the traditional engine flywheel with a slim, large-diameter starter-generator. This design is currently offered in the Honda Insight and Civic. Later this year it will be available from GM in the Chevrolet Silverado and GMC Sierra pickups, while next year it will be offered in the Dodge Ram. The Dodge and GM systems will provide household type outlets for power tools, camping gear, or other electrical appliances. "Full" or parallel hybrid designs are the most complex. These systems allow a vehicle to be powered solely by electric power when the additional power of a combustion engine is not needed. They are the most expensive to manufacture, but have the greatest full efficiency. A parallel design is currently offered in the Toyota Prius, next year's Ford Escape, and 2005's Saturn VUE. Perhaps the most complex hybrid design available today is Toyota's newly released Estima in Japan. The Estima is a unique four wheeled drive hybrid minivan. Not only does it have four wheel independent drives, but it also has four-wheel independent regenerative braking. The Estima's insulated body and humidity control system allow the vehicle to conserve even more fuel. It boasts a 44.6 mpg fuel economy.

While hybrid vehicles are becoming increasingly popular amongst consumers, they still have a long way to go. In 2002, hybrids accounted for just 0.2% of the U.S automobile sales market. The 36,000 hybrids purchased by Americans are expected to rise to over 58,000 this year. With the large number of hybrids t market in the coming years, the sales are expected to increase. Even the U.S. army is considering lowering its fuel costs by jumping to the fuel cell technology. They may purchase 30,000 hybrids by the decade's end. The luxury car market will begin its move to hybrid design, as Toyota's Lexus will release a new RX330 in 2005. Toyota believes that hybrid vehicles are a stepping-stone to the elimination of the combustion engine. In the future the gasoline engines in today's hybrids will be replaced by hydrogen cells to create zero emission vehicles (Hiserote& Pickard, 2004).

Fig. 4: Toyota Prius

2.5. Slingshot Model Vehicle

Fig. 5: A Polaris Slingshot Model

The Polaris Slingshot is a three-wheeled motor vehicle manufactured by Polaris Industries. It has a tilt-adjustable steering wheel, side-by-side bucket seats and does not lean. It has no roof, doors or side windows. The steering wheel, gear stick and brake, clutch and throttle pedals have a conventional automobile layout. The Slingshot weighs 1,743 pounds (791 kg) and is powered by a 2.2 liter inline four engine derived from the GM Ecotec. The 2015 Polaris Slingshot has a 2384 cc displacement, with a five-speed manual transmission. The standard Slingshot has two 17" front wheels and a singular 18" wheel in the rear of the vehicle, while the Slingshot SL and SL LE Edition have two 18" forged aluminum front wheels with a 20" rear wheel. All models have a double-wishbone front suspension with a sway bar to control the front end.

2.6. History of HEV in Nepal

Electric Vehicles were introduced in Kathmandu in 1975 when the Chinese Government set up the trolley bus system along the 13-km route between Tripureswor and Surya-Binayak. After that, the EV movement took off in 1989, when a fuel crisis resulting from the India imposed trade embargo prompted a group of engineers to find an alternative arrangement for transportation. The group called the Electric Vehicle Development

Group converted an old car into an EV in 1992.In 1993, the Global Resources Institute, with assistance from USAID, began a program to develop EVs as a profitable industry. The project converted 7 polluting diesel operated three-wheelers into EVs (Safa Tempos), and successfully operated them as public vehicles for six months. At the end of the pilot project in early 1996, a group of Nepali professionals and entrepreneurs bought the 7 EVs and started the first EV Company, Nepal Electrical Vehicle Industry (NEVI), in Kathmandu. Currently, over 600 Safa Tempos are plying on the streets of the valley and there are five EV manufacturers.

Following rapid growth in the late 1990s, the EV industry has been unable to grow further in the last few years mainly because of conflicting government policies and high operation costs.

Recently, Hulas Company has introduced a new full electric vehicle named ‘Da-Vinci car’ or ‘Biddhut car’ in 2016.The retrofitting of an ICE equipped motorbike into hybrid electric bike was done by a group of students from Pulchowk Campus as their final year project in 2015. A solar hybrid car was made by a group of students from Western Regional Campus in 2016.

Currently, there are two hybrid cars namely, Toyota Prius and Honda Insight, used in Nepal since 2013. Both cars offer comfortable ride like any normal car with added fuel bonus. The two maybe hybrids with motor-assisted charging, but are vastly different in sizes, fuel efficiency, controls and of course price. Both the cars offer an alluring mileage of over 20 km/l for an engine capacity of 1.6l. If tax rates are reduced the hybrid cars can be a viable car due to its amazing mileage and will pay for itself.

2.7. Overall system

Our study on the tri-wheel vehicle design and fabrication is based on internet study and books related to automobile components and working. The tri-wheel design of the vehicle was inspired from the Polaris slingshot model. On the course of our study we fragmented the overall system in the following parts:

i. Wheels and Tires
ii. Steering system
iii. Frame/body/chassis
iv. Transmission/drive system
v. Clutch system
vi. Suspension system
vii. Braking system

2.7.1. Wheels and tires

The automotive chassis includes a brake system, steering system and suspension system. The chassis components that drive the vehicle and support its weight are wheels and tires. Tires are the only part of the vehicle that comes in contact with the road surface. Basically all the tires are built to perform the following two functions:

- Tires are filled cushions that absorb most of the shocks caused by road irregularities. This reduces the effect of road shocks on vehicle, passenger and hence serve as a part of suspension system.
- The tires grip the road to provide good traction. This enables the vehicle to accelerate, brake and make turns without skidding.

2.7.2. Steering system

The steering system allows the driver to control the direction of the vehicle movement. This is made possible by linkage that connects the steering wheel to the steerable wheels and tires. The basic function of the steering system is to allow flexible movement of steerable wheels (front wheels) around the knuckle joint and about the steering axis, so that the driver could direct the movement of the vehicle in a desirable path with ease and comfort.

There are many types of steering system available in the local market. The most commonly used was found to be rack and pinion type. Out of various such types we narrowed our choices to the following types that could be used in the tri-wheel hybrid vehicle fabrication:

1. Worm and wheel steering gear
2. Worm and roller steering gear
3. Worm and sector steering gear
4. Can and lever steering gear
5. Rack and pinion steering gear
6. Re circulating ball steering gear

1. Worm and wheel steering gear

In this type of steering gear box there is worm at the bottom end of steering inner column. This worm meshes with a wheel in steering gear box housing. When steering wheel turned, the steering column revolves and the wheel is rotated along with it. This causes the drop arm to move and thereby move drag link and other steering linkages like Tie-rod, king pin etc.

2. Worm and Roller

In this steering gear, there is a worm at the bottom end of inner column and a roller is there in the steering gear box. When the worm rotates, the roller which is attached to it also rotates causing the Roller to rotate and there by moving drop arm.

3. Worm and Sector Steering Gear

In this type of steering gear, there is a worm at the bottom end of steering inner column and a part of sector shape is there in the steering gear housing. The worm meshes with sector and it moves by the rotation of worm and there by moving drop arm which is attached to it.

4. Cam and Lever steering gear

In this type of steering gear, a special worm called cam is located at the end of inner column which it attached to column in the steering gear. When the worm is rotated, the lever is also moved in the groove provided in the worm. This causes the lever to swing through an arc.

5. Recirculating Ball Steering Gear

In this steering gear there will be some steel balls in the grooves of steering inner column which move along with the steering worm. This enables to control the friction among them and thereby reducing noise. It increases the mechanical advantage of the operator for easy and smooth operation of steering.

6. Rack and pinion Steering gear

In this steering gear, a pinion is mounted at the end of the steering inner column. It engages the rack which has ball joints at each end to allow the rise and fall of the wheels, the rods are connected with ball joints to the sub axles. The rotary movement of steering wheel turns the pinion which moves the rack sideways parallel to tie rod.

2.7.3. Body/Frame/Chassis

Chassis frame is the basic frame work of the automobile. It supports all the parts of the automobile attached to it. It is made of drop forged steel. All the parts related to automobiles are attached to it only. All the systems related to automobile like power plant, transmission, steering, suspension, braking system etc. are attached to and supported by it only.

- Layout of Chassis and its main components

"Chassis" a French term which means the complete automobiles without body and it includes all the systems like power plant, transmission, steering, suspension, wheels tires, auto electric system etc. without body. If body is also attached to it them it is known as the particular vehicle as per the shape and design of the body.

Fig. 6: Simple frame structure

- The Functions of the Chassis frame

1. To carryall the stationary loads attached to it and loads of passenger and cargo carried in it.

2. To withstand torsional vibration caused by the movement of the vehicle.

3. To withstand the centrifugal force caused by cornering of the vehicle.

4. To control the vibration caused by the running of the vehicle.

5. To withstand bending stresses due to rise and fall of the front and rear axles.

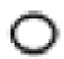
- Types of Chassis frame

There are different types of chassis frame sections as;

1. Channel section

2. Box section

3. Tubular section



The conventional frame is also known as non-load carrying frame. In this types of frame, the loads on the vehicle are transferred to the suspension by the frame which is the main skeleton of the vehicle.

The channel section is used in long members and box section in short members. Tubular section is used now-a-days is three wheelers, scooters, matadors and pickup vans.

The frames should be strong enough to bear load while sudden brakes and accidents.

- Various loads acting on the chassis frame

The loads acting on the chassis frame are as follow

1. Stationary loads namely the loads of permanent attachment like all the parts of the chassis, body etc.

2. Short duration loads while turning, braking etc.

3. Momentary loads while quick acceleration, sudden braking etc.

4. Loads applied while crossing roads of irregular and uneven surfaces

5. Loads caused by sudden accidents, head on collusions etc.

6. Loads caused by irregular and overloading of vehicle.

2.7.4. Transmission/drive system

The most powerful engine in the world is of little use unless the power from the engine can be safely and effectively transmitted to the ground. This, then, is the primary function of the transmission and driveline. In addition to being able to transmit the torque and power from the engine, the transmission and driveline also must allow the vehicle to operate over a wide range of speeds-from a standstill to the maximum speed of the vehicle. This implies that the system must inherently have some method of disconnecting the engine from the remainder of the driveline to allow the vehicle to remain stationary. Furthermore, the transmission also must be designed to satisfy the conflicting requirements of quick acceleration, high speed, and adequate fuel economy. Thus a transmission consists of following components:

- Clutch
- Gearbox
- Propeller/drive shaft
- Universal joints
- Differential gear set
- Axles
- wheels

The drive system of the motorbike is basically the same, the only difference being its use of chain and sprockets instead of propeller shaft, universal joints and differential gear set. The use of one rear wheel in a tri-wheeler vehicle eliminates the use of differential gear set on the final drive. This reduces the weight, simplifies the chassis design and reduces the manufacturing cost but comes with a price i.e. propensity to overturn.

- Requirements of Transmission System
  1. To provide means of connection and disconnection of engine with rest of power train without shock.
  2. To provide a varied leverage between the engine and the drive wheels.
  3. To enable power transmission at varied angles and varied lengths.
  4. To enable speed reduction between engine and the drive wheels.
  5. To bear the effect of torque reaction, driving thrust and braking effort effectively.

2.7.5. Clutch system

As we know the hybrid system uses two independent sources of power generation viz. ICE and electric motor. The selection between the two sources of power to drive, in parallel hybrid configuration, is done automatically in most of the latest model. But due to its complexity and limitations of required material, we used a simple clutch for this operation. Considering all the required operation, we decided the best choice would be to use the clutch of tractor. The clutch is a multi-plate clutch with pulley grooves on its outer circumference and holes for shaft in the center. When the clutch engages the shaft and the body of the clutch rotates in same speed and when it disengages, the shaft and the body of the clutch can rotate independently. One of the two sources can be connected to the shaft and other source can be connected to the body of the clutch through belt drive. This way we can choose between either source by simply pulling a lever to engage or disengage the clutch.

Fig. 7: A Clutch used in Tractor

2.7.6. Suspension system

The suspension system is located between the wheel axles and the vehicle body or frame. The basic function of a suspension system is to:

1. Support the weight of the vehicle.
2. Cushion bumps and holes in the road.
3. Maintain traction between the tires and the road.
4. Hold the wheels in alignment
5. Act as a link between vehicle frame and tire.

The suspension system allows the vehicle to travel over rough surfaces with a minimum of ups-and-downs body movement. It's also allows the vehicle to corner with minimum roll or tendency to lose traction between the tires and the road surface, this provides a cushioning action so road shocks have a minimum effects on the occupants and the load in the vehicle. Road shocks are the actions resulting from the tires moving up and down as they meet bumps or holes in the road.

- Requirement of automobiles suspension system

The automobile suspension system is having the following requirement:

1. To have minimum deflection to the vehicles with required stability
2. To have minimum wheel hop.
3. To safe guard the occupants and cargo against road shocks
4. To minimize the effects of stresses due to road shocks on the mechanism of the vehicle.
5. To keep the body perfect in level while travelling over rough an uneven roads.
6. To keep the body of the vehicle safe from road shocks.

- Types of suspension system

There are different types of suspension system provided in different vehicles. Those are

1. Conventional suspension system
2. Independent suspension system

1. Conventional suspension system

In this suspension system the wheels are fitted on beam type which is attached to the chassis frame through road springs. In this type of suspension the effect on one wheel is directly transmitted to the other side wheel through the axle.

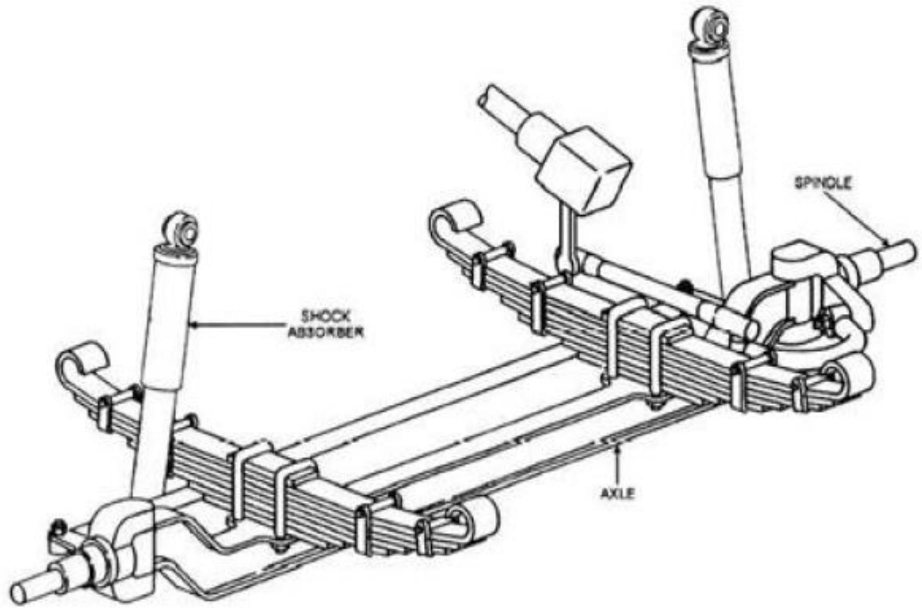


Fig.8: Conventional Suspension System

2. Independent suspension system

In this system the suspension for each wheel in an independent unit and in free from the effect of one another. There will be no effect of road shocks on the vehicle directly.

- Types of independent suspension system
    a. Wishbone arm system
    b. Trailing link system
    c. Sliding pillar system

a. Wishbone arm system

Wishbone arm type independent suspension system is most popular type of all independent suspension system. In this system transverse springs along with coil, springs are mostly used. In European cars, torsion bars instead of coil springs are used. In this system there are two suspension or control arms are used in each side of the vehicle. There arm are like two legs of chicken wishbone or better 'V', these wishbone arms are connected with chassis frame on the open end. The closed end spread out of the chassis frame. One arm is below whereas the other is above the frame. The closed ends of both upper and lower suspension arms are connected with steering knuckle support to which the steering knuckle is attached by means of kingpin. A coil spring is placed between the frame and the lower wishbone arm. Mostly, the open end of upper control arm is connected with the shock absorber shaft which is fitted at the frame when there is a bump, the wheel tends to go up and the control since the shock absorber is fitted with the upper control arm to damps the vibrations setup in the coil spring due to road irregularities.

b. Trailing link system

The trailing link independent suspension use parallelogram linkages lying beside the frame side members usually a horizontal coil springs is used in this type of suspension system. During compression and rebound, the spring winds and unwinds. In some vehicles, the torsion bar may also be fitted instead of horizontal coil spring.

c. Sliding pillar system

In this system the pillar or elongated king pin is attached to the wheel and slides up and down in the axle type beam a fixed rigidly to the vehicle frame.

2.7.7. Braking system

In Automobiles, brakes play important role in slowing down and stopping of the vehicle as and when required by the driver. Fundamentally, the brakes are of two types:

a. Internal expanding
b. External contracting type.

Different types of brakes are used in different vehicles as per the requirement. According to application, the brakes are of different types- mechanical, hydraulic air, vacuum, Air assisted Hydraulic.

- Functions of Brakes
  1. To slow down or to stop the vehicle as and when required.
  2. To control the vehicle when the vehicle is rolling down on a slope road down ward.
  3. To travel smoothly and safely even in heavy.

- Requirement of Automobile Brakes

  1. The brakes must stop the vehicle within shortest possible distance.
  2. These must be released suddenly after releasing them.

3. Total control of the vehicle should be there.

- Stopping time and Stopping Distance

The stopping time and stopping distance shows the efficiency of brakes. The maximum retarding force applied by the brake at the wheels, F, depends upon the coefficient of friction between the road and tire surface,μ, and the component of the weight of the vehicle on the wheel, w,

$$F = \mu.$$

In actual practice 100% of brakes efficiency is not used. The stopping time and distance depend upon

1. Vehicle speed
2. Condition of road surface
3. Condition of tire treads.
4. Coefficient of friction between the tire tread and road surface.
5. Coefficient of friction between brake drum and brake lining (in case of drum brake)
6. Coefficient of friction between the disc and the friction pad (in case of Disc brakes).
7. Brake force applied by the driver.

However, during emergency braking, the reaction of the driver and response time of the brakes also play an important role. The total stopping distance in case of emergency braking may be divided into three parts:

1. Distance travelled during the reaction time of the driver.
2. Distance travelled between the times elapsed between driver pressing the brake pedal and actual application of brakes at wheels.
3. Net stopping distance, depending upon the deceleration.

Keeping all the factors in view, the assumed brake efficiencies for some of the vehicle may be like the valves given in the table approximately.

- Types of Braking system- Disc and Drum Braking system

1. Disc Brakes
   The disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of vehicle, like axle casing or the stab axle and is cast in two parts, each part containing a piston. In between each piston and the disc, there is a friction pad held in position by

retaining pins, spring plates etc.

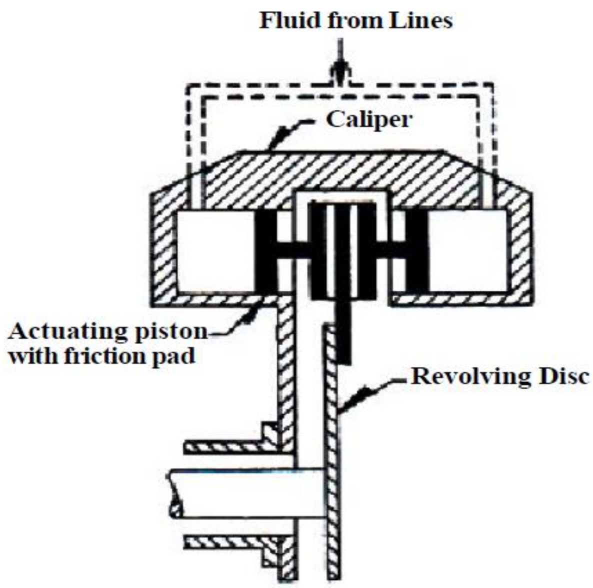


Fig. 9: Disc Brake

When the brakes are applied, hydraulically actuated piston move the friction pads into contact with the disc, applying equal and opposite forces on the later. On releasing brakes, the rubber sealing rings act as return springs and retract the pistons and the friction pads away from the disc.

2. Drum Brakes
   In this type of brakes, a brake drum is attached concentric to the axle hub whereas on the axle casing is mounted a back plate. In case of front axle, the brake plates are bolted to the steering knuckle. The back plate is made of pressed steel and is ribbed to increase rigidity and to provide support for the expanding brake shoes. These brakes are also known as internal expanding brake.

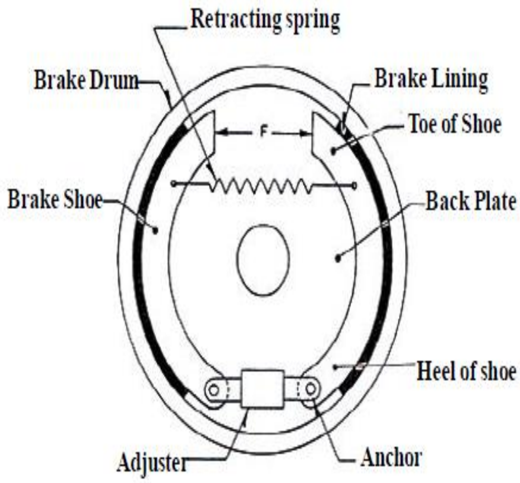


Fig. 10: Drum Brake

2.8. Joints

2.8.1. Welded joints

The strongest and the most common of the permanently joining steel components together is by welding. Of the many welding techniques available, arc welding is the most important since it is adaptable to various manufacturing environments and is relatively cheap.

In arc welding, an electric arc at the extremity of a travelling consumable electrode maintains a pool of molten metal in which the components and electrode material coalesce, forming a homogenous hole (ideally) when the pool later re-solidifies. But no joint can be perfect, and it is the designer's job to allow for practicalities and to ensure that the joint is adequate and economical. The materials of the components and the electrode must be compatible from the point of view of strength, ductility and metallurgy.

Welds can be geometrically prepared in many different ways. The five basic types of weld joints are the butt joint, corner joints, edge joints, lap joints and tee joints.

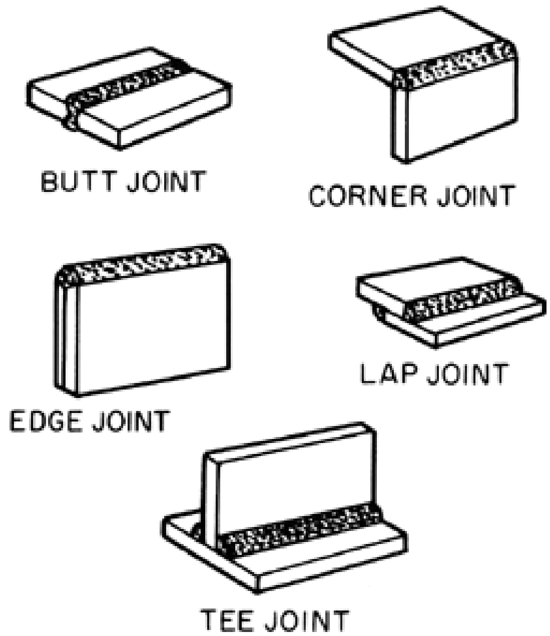


Fig 11: common welded joint types

The most common form is the butt and the fillet joints. A butt weld aims usually for full penetration with no voids in the complete joint, so edge preparation – to allow electrode insertion is required for all but the thinnest wieldable components. In consistencies may be minimized by double welding (i.e. welding from both sides as sketched). In non-critical applications, correctly fashioned butt joints carried out by competent welders are taken to be just as strong as the joined components- that is. Provided the electrode is correctly chosen and the welding technique is satisfactory then joint safety does not have to be separately addressed.

i. **Bolted joints**

Bolted joints are one of the most common elements in the construction and machine design. They consist of cap screws or studs that capture and join other parts, and are secured with the mating of screw threads.

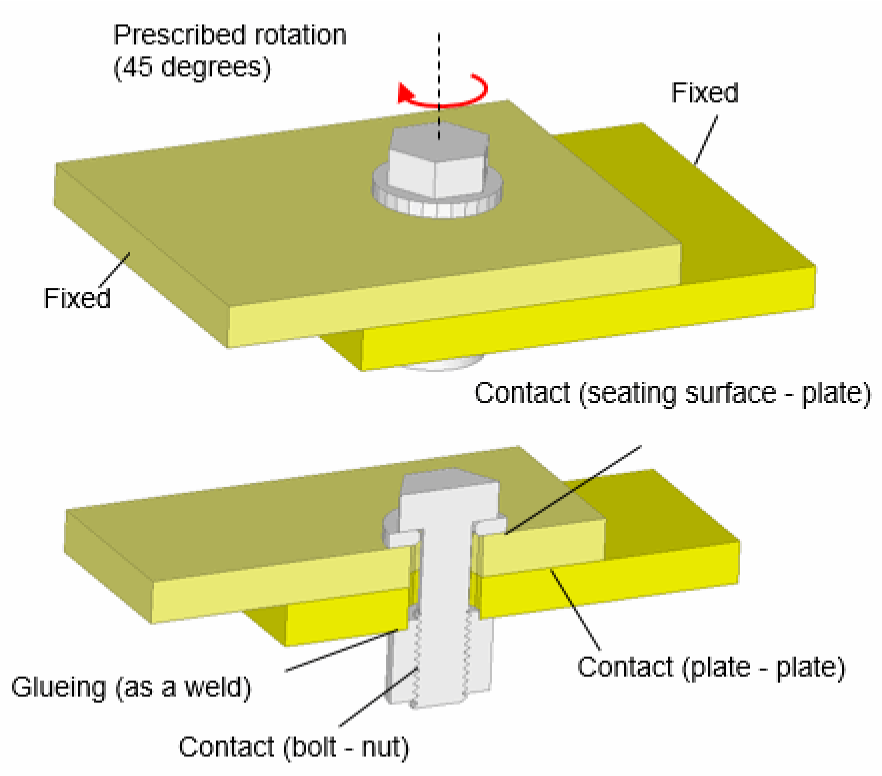


Fig 12: bolted joint

There are two main types of bolted joint designs. In a method the bolt is tightened to a calculated clamp load, usually by applying a measured torque load. The joint will be designed such that the clamp is never overcome by the forces acting in the joints (and therefore the jointed parts see no relative motion).

The other type of bolted joint does not have a designed clamp load but relies on the shear strength if the bolt shaft. This may include clevis linkages, joints that can move, and joints that rely on locking mechanism (like lock washers, thread adhesive, and lock nuts).

Failure modes of bolted joints

- The most common mode of failure is overloading. Operation forces of the application produce loads that exceeds the clamp load and the joints works itself loose, or fail catastrophically.
- Over torqueing will cause failure by damping the threads and deforming the hardware. The failure might not occur until ling afterwards. Under torqueing can cause failures by allowing a joint to come loose. It may also allow the joints to flex and thus fail under fatigue.

- Brinelling may occur with poor quality washers, leading to a loss of clamp load and failure of the joints.
- Corrosion, embedment and exceeding the shear limit are other modes of failure.

Locking mechanism

Locking mechanisms keep bolted joints from coming loose. They are required when vibration or joint movement will cause looseness of the clamp load and joint failure, and in equipment where the security of bolted joints is essential.

- Two nuts, tightened on each other
- Locknut (prevailing torque nuts)
  - Polymer insert nut
  - Oval lock nut
- Lock washer
- Thread washer
- Lock wire. Castellated nuts/cap screws (common in the aircraft industry)

Fig.13: bolted joints in an automobile wheel

In the above figure the outer four fasteners are studs with nuts that secure the wheel. The central nut (with locking cover and cotter pin) secures the wheel bearing to the spindle.

2.9. Tolerance and fits

The term tolerance refers to the permissible deviation of a dimension form the specific basic size. The proper performance of a machine can depend in the tolerances specified for its parts, particularly those that must fit together for the location are for suitable relative motion.

The term fit usually refers to the clearances that are permissible between mating parts in a mechanical device that must assemble easily and that must often move relative to each other during normal operation of the device. Such fits are usually called running or sliding fits. Fit can also refer to the amount of interference that exists when the inside part should be larger than the outside part. Interference fits are used to ensure that mating parts do not move relative to each other.

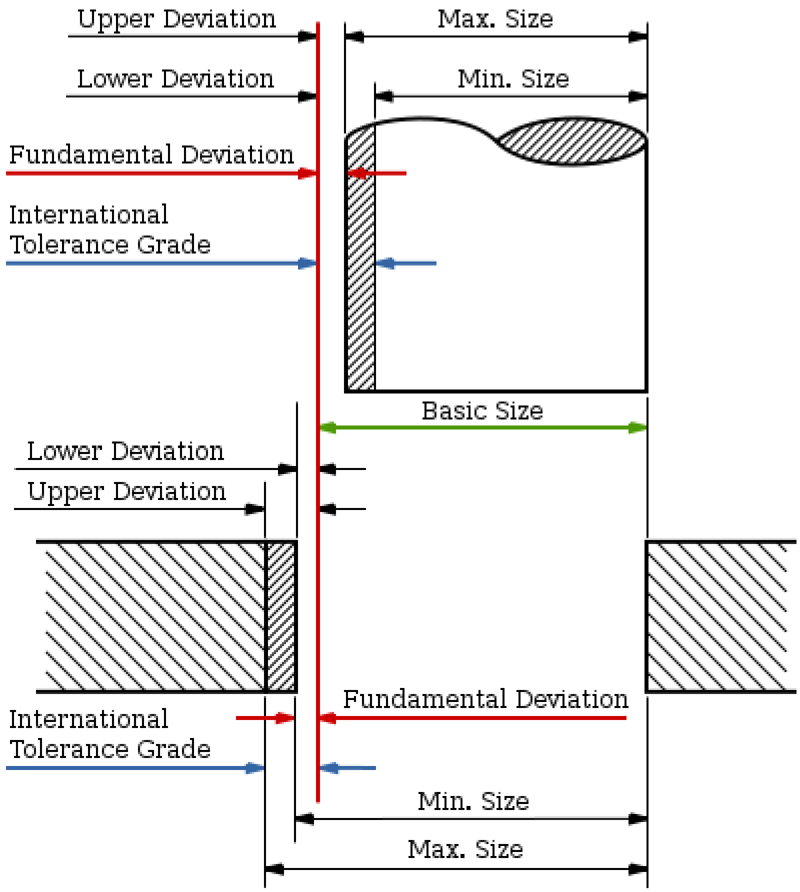


Fig 14: Tolerance and fit

2.9.1. Types of fits

Depending on the mutual position of tolerance zones of the coupled parts, 3 types of fit can be distinguished:

a) Clearance fit
b) Transition fit
c) Interference fit

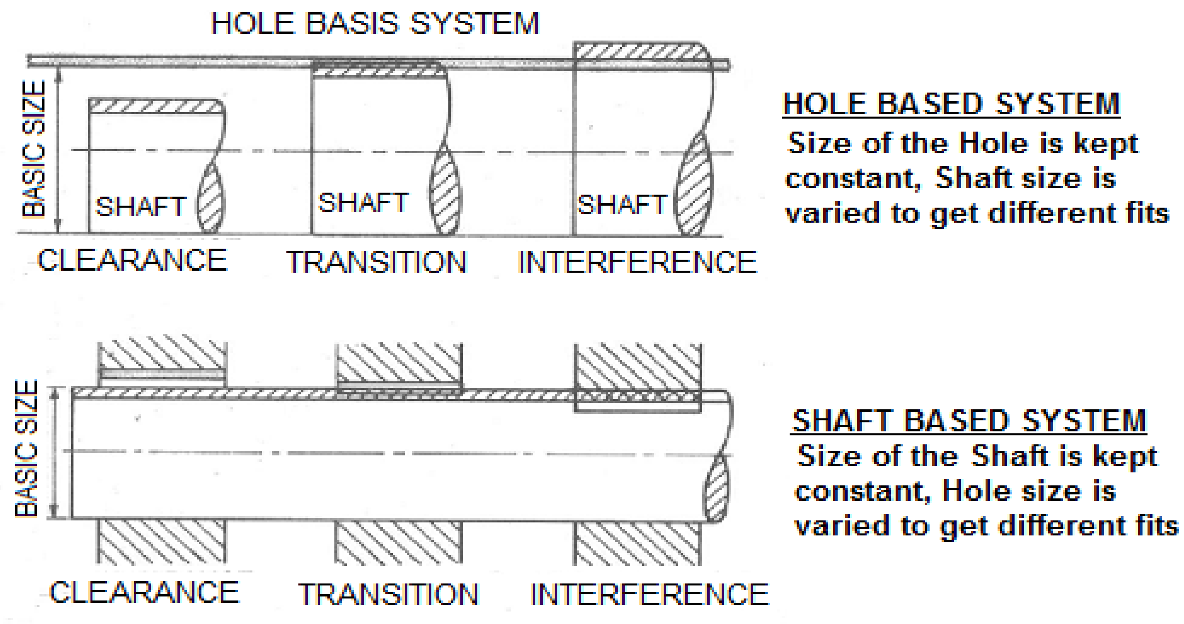


Fig. 15: Types of fits

a) Clearance fit

It is a type of that always enables a clearance between the hole and the shaft in the coupling. The lower limit size of the hole is greater or at least equal to the upper limit size of the shaft.

b) Transition fit

It is a fit where (depending on the actual size of the hole and the shaft) both clearance and the interference may occur in the coupling. Tolerance zones of the hole and the shaft partly or completely interfere.

c) Interference fit

It is a fit always ensuring some interference between the hole and the shaft in the coupling. The upper limit size of the hole is smaller or at least equal to the lower limit.

2.10. Bearings

A bearing is a device to allow constrained relative motion between two parts, typically rotation or linear movement. Bearings may be classified broadly according to the motions they allow and according to their principle of operation as well as by the directions of the applied loads they can handle.

Table 2: Types of Bearings

Types	Description	Speed	Life	Notes
Plain bearing	Rubbing surfaces, usually with lubricant	low to very high	Moderate (depends on lubrication)	The simplest type of bearing, widely used, relatively high friction. Some bearings use pumped lubrication and behave similar to fluid bearings. At high speeds life can be very short.
Rolling element bearing	Ball or rollers are used to prevent or minimize rubbing	Moderate to high (often requires cooling)	Moderate to high (depends on lubrication, often requires maintenance)	Used for higher loads than plain bearing with lower friction.
Jewel bearing	Off-centered bearing rolls in seating	Low	Adequate (requires maintenance)	Mainly used in low-load, high precision work such as clocks. Jewel bearings may be very small.
Fluid Bearing	Fluid is forced between two faces and held in by edge seal.	very high (speed usually limited by seals)	Virtually infinite in some applications, may wear at startup/shutdown in some cases	Can fail quickly due to girt or dust or other contaminants. Maintenance free in continuous use.
Magnetic bearing	Faces of bearing are kept separate by magnets	No Practical limit	Indefinite	Often needs considerable power.Maintenance free
Flexure Bearing	Material flexes to give and constrain movement	very high	Very high or low depending on materials and strains in application	Limited range of movement, no backlash, extremely smooth motion

2.11. Chain drive

In its simple form, a chain drive consists of an endless chain running over two sprockets-driver and driven. A sprocket is a wheel with teeth of special profile. A chain drive operates without slipping like a gear drive and thus provides a positive drive, but precision timing is required these cannot be used. The alignment of the shafts must be more accurate than belt drives.

Principle advantages of chain drive

- It can be employed both for relatively long or short distances. The center may be as large as 8 meters.
- A small and compact size as compared to belt drives.
- It can have efficiency as high as 98 to 99 percent when operating under ideal conditions.
- It is possible to transmit power or motion to several shafts with the help of one chain only.

At the same time, a chain drive has got the following disadvantages

- Due to wear of chain joints, the chain gets stretched that increases the chin pitch resulting in velocity fluctuations and necessitating the use of take u drives.
- Relatively high production cost.
- Noisy operation.
- A chain drive requires more amount of servicing, maintenance and repairs compared to belt drives.
- More complicated design than that for a belt drive.

Chain drives can either be open or closed like a gear drive. Modern chain drives are used for velocity ratios of less than 8 with chain velocities up to 2 m/s and power rating up to 110kW or even more.

2.12. Main components of electric drive train of the vehicle

2.12.1. Batteries

A battery is a device for storing chemical energy and converting that chemical energy into electricity. A battery is made up of one or more electrochemical cells, each of which consists of two half-celled or electrodes. One half-cell, called the negative electrode, has an overabundance of the tiny, negatively charged subatomic particles called electrons. The other, called the positive electrodes, has a deficit of electrons. When the two halves are connected by a wire or an electrical wire, electron will flow from the negative electrodes to the positive due to the chemical reaction of these electrodes with electrolyte generating DC electricity. The energy of these moving electrons can be harnessed to do work, for example, running an electric motor. As electrons pass to the positive side, the flow gradually slows down and the voltage of the electricity produced by the battery drops. Eventually, when there are as may electrons on the positive side as on the negative side, the battery is considered ‘dead’ and is no longer capable of producing an electric flow.

Automobile batteries need to be rechargeable, so they don’t require constant replacement. In a rechargeable battery, electrical energy is used to reverse the negative and positive halves of the electrochemical cells, restarting the electron flow.

Lead acid battery

Lead acid battery was invented in 1859 and is the oldest form of rechargeable battery still use. The main reasons for this are that the main constituents (lead sulfuric acid, a plastic container) are not expensive, that it performs reliable reliably, and that it has a gases while being used leading to loss of electrolyte if the battery is overcharged an also there is a risk of explosion. In order to avoid this problem, VRLA has been introduced where a valve releases gas at certain pressure. In addition to this, the electrolyte is a gel rather than liquid. So, the maintenance of the electrolyte is no longer needed.

In the lead acid cells, the negative plates have a spongy lead as their active material, whilst the positive plates have an active material of lead dioxide. The plates are immersed in an electrolyte of dilute sulfuric acid. The sulfuric acid combines with the lead and the lead oxide to produce lead sulfate and water, electrical energy being released during the process. The overall reaction is:

$Pb + PbO_2 \leftrightarrow 2PbSO_4 + 2H_2O$

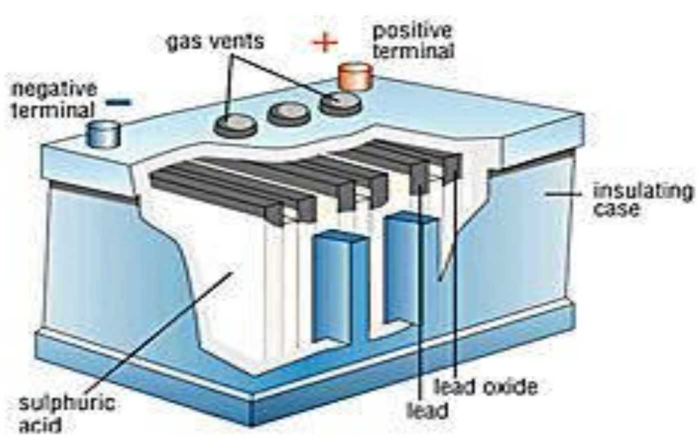


Fig. 16: lead acid battery (www.gravitatechnomech.com)

2.12.2. Electric motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. It is one of the key components of electric drive train of hybrid vehicle. The various types of electric motors that may be used in the HEVs are as follows:

a) The "brushed" DC motor

In a typical electric motor, there are permanent magnets on the outside and a spinning armature on the inside. The permanent magnets are stationary, so they are called the stators. The armature rotates, so it is called the rotor.

The armature contains an electromagnet. When you run electricity into this electromagnet, it creates a magnetic field in the armature that attracts and repels the magnets in the stator. So the armature spins through 180°. To keep it spinning, you have to change the poles of the electromagnet. The brushes handle this change in polarity. They make contact with two spinning electrodes attached to the armature and flip the magnetic polarity of the electromagnet as it spins.

b) The "brushless" DC motor (BLDC)

With the advent of cheap computers and power transistors, it became possible to "turn the motor inside out" and eliminate the brushes. In BLDC, you put the permanent magnets on the rotor and you move the electromagnets to the stator. Then you use a computer (connected to high-power transistors) to charge up the electromagnets as the shaft turns. Because a computer controls the motor instead of the mechanical brushes, it's more precise. The computer can factor the speed of the motor into equation. This makes brushless motor more efficient. These BLDC motors need a strong permanent magnet for the rotor. The advantage of this is that currents do not need to be induced in the rotor making them somewhat more efficient and giving a slightly greater specific power.

c) The induction motor

The induction motor is very widely used in industrial machines of all types. Its technology is very mature. Induction motors require an AC supply, which might make them seem unsuitable for DC source such as batteries or fuel cells. However, as we have seen, AC an easily be generated using an inverter, and in fact the inverter needed to produce the AC for an induction is no more complicated or expensive than the circuit needed to drive the brushless DC or switched reluctant motors. So, these widely available and very reliable motors are well suited to use in hybrid electric vehicles.

2.12.3. Motor controller

The design of any electric vehicle requires the use of a motor controller. A motor controller is the device that controls the speed of the motor. It supplies the motor with voltage form the battery packs. The amount of voltage that is sent to the motor is generally controlled be the throttle connection which is basically a simple potentiometer that relates a displacement to resistance. The motor controller then correlates this resistance to voltage and supplies the corresponding voltage from the battery pack to the motor. This voltage is then used by the motor to produce mechanical energy as a means to drive the vehicle. There is a wide range of various motor controllers currently being produced however they all tend to be very similar. Generally the only real difference amongst them is their current and voltage operating ranges. One distinct aspect found in some motor controller that distinguishes them from the rest is the ability to not only dictate the voltage supplied to the motor but also to control the current. The speed or rotation of a motor is directly linked to the voltage supplied to motor. A greater voltage corresponds to a greater speed. However, accelerating at low speeds and voltages requires a large amount of current to provide the power needed to increase the motor speed. At really low speeds this current draw can be very large and potentially damaging to the motor. Certain motor controller possess the ability to limit the current sent to the motor which in turn will protect the motor from these damaging currents. In addition to limiting the current some controller possess an inductive throttle control which will slowly increase the current to the motor when a throttle is quickly changed rather than rapidly providing a big increase in current supplied to the motor. These particular aspects in motor controllers provide great advantages in hybrid electric technology (Hiserote& Pickard, 2004)

2.12.4. Throttle

A throttle is the mechanism by which fluid flow is managed by constriction or obstruction. An engine's power can be increased or decreased by the restriction of inlet gases (i.e. by the use of a throttle), but usually decreased.

Similarly in an electric throttle system, the throttle consists of magnet and sensors which alter current accordingly to the twist given to the throttle hence accelerating and decelerating.

2.13. BLDC Motor-Torque and Efficiency relation

For the study of electric motors, torque is a very important term. By definition, torque is the tendency of force to rotate an object about an axis.

Torque (Nm) = Force (N) × Distance (m)

Thus, to increase the torque, either force has to be increased- which requires stronger magnets or more current or distance must be increased for which bigger magnets will be required.

Efficiency is critical for motor design because it determines the amount of power consumed. A higher efficiency motor will also require less material to generate the required torque.

Efficiency = output power/input power

Where,

Output power = Torque ×angular velocity

Input power= voltage × current

Having understood the above provided equations, it becomes important to understand the speed vs. torque curve.

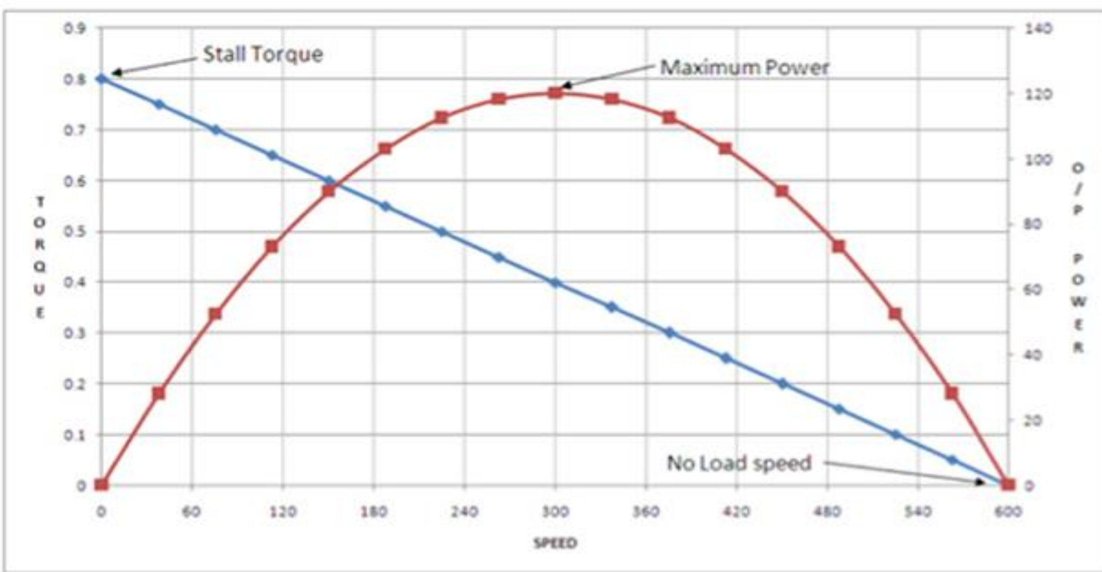


Fig 17: Speed-torque-Power graph (www.edn.com)

Following are the takeaways drawn from the graph shown in figure…

- With an increase in speed, the torque reduces(considering the input power is constant)

- Maximum power can be delivered when the speed is half of the “no load” speed and torque is half of the stall torque (Madaan, 2013).

CHAPTER THREE

SYSTEM DESIGN

CHAPTER THREE: SYSTEM DESIGN

3.1. General Overview

3.1.1. Overall Vehicle

The foremost job for us to do was to develop a concept for the overall appearance of the vehicle. This depended on various factors like the number of wheels, number of seats, chassis design, transmission system, ease of fabrication, etc.

Considering all these factors, we outlined our designs as;

- A three-wheeler vehicle
- A four wheeler vehicle

The four-wheeler vehicle needed a differential at rear axle for the transmission of power to the wheels. This could make the designing and fabrication process a little bit complex. After some literature reviews, we came to learn about a new Slingshot model vehicle and were impressed and inspired by its design. So, we decided to design a chain driven three-wheeler vehicle so that following advantages could be drawn;

- ➢ Reduce in vehicle weight,
- ➢ Easy to fabricate and assemble,
- ➢ New look of the vehicle, etc.

3.1.2. Chassis

Different chassis have their own advantages and disadvantages. The chassis was chosen on the basis of major influencing factors like availability, simplicity, vehicle weight, strength and ease of fabrication.

Our chosen chassis had to support total vehicle weight along with two passenger, two pair of batteries, engine load, electric motor and controller weight.

We designed the chassis in SOLIDWORKS initially considering all the loads and impacts and analyzed the stress and torsion results. After getting satisfactory results, we step our foot into fabrication process.

Our proposed design and final real chassis after fabrication is shown below;

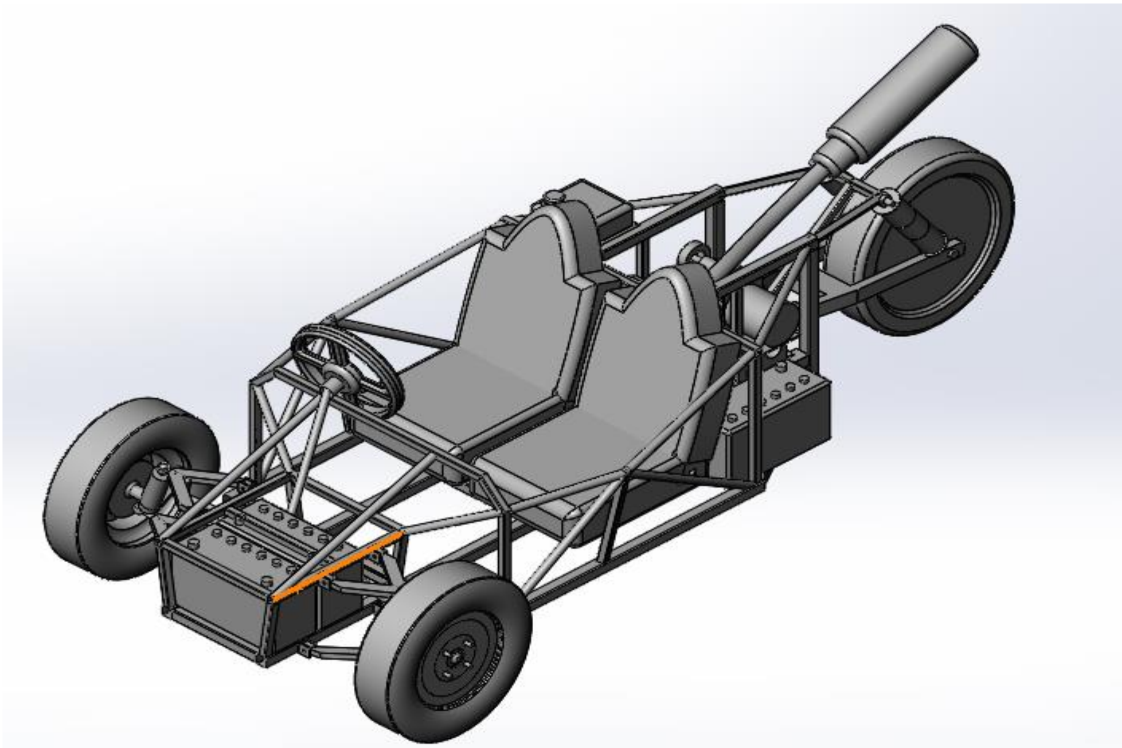


Fig.18: Vehicle design in SOLIDWORKS

Fig. 19: Actual chassis after fabrication

3.1.3. Suspension System

The suspension systems that could be installed in the vehicle were as follows:

- Leaf spring suspension
- Coil spring
- Torsion bar

The leaf spring would require larger space and linkages and also the vehicle weight would rise. Design of the chassis wasn't suitable for torsion bar and would be less effective if installed. So, we used two pair of motorbike coil spring (of Karizma 225 cc) in our vehicle.

The rate of the springs used in motorbike is almost constant through their operating range or deflection. This is stated by Hook's law i.e. as applied to coil springs: The spring will compress in direct proportion to the weight/load applied.

- <u>Spring arrangement:</u>

Springs are used in various ways to achieve satisfactory ride quality and control. We installed two coil springs in front and two in rear side of the vehicle with some inclination as shown in figure below;

Fig. 20: Front coil spring

Fig. 21: Rear coil spring

- <u>Control Arms for front wheels:</u>

We needed to install two control arms- lower and upper for stability, steering control, suspension in each front wheels. For that, we first prepared dies of some dimensions taken from the design and with its help, control arms were fabricated. The design required a ball joint. Then, each arms were fitted on the wheel and main frame with the help of the joint and fasteners.

Fig. 22: Lower A-arm

Fig. 23: Upper A-arm

3.1.4. Steering System

A number of steering systems were studied and analyzed. Finally, we selected a rack-and-pinion type steering system for the vehicle. The selection was based according to the analysis of availability, ease of fabrication, assembly of components and convenience of use.

We simply dismantled the steering system from an unused Toyota Corolla car and after some modification and arrangements, we installed the steering system in our vehicle. It is mechanically operated.

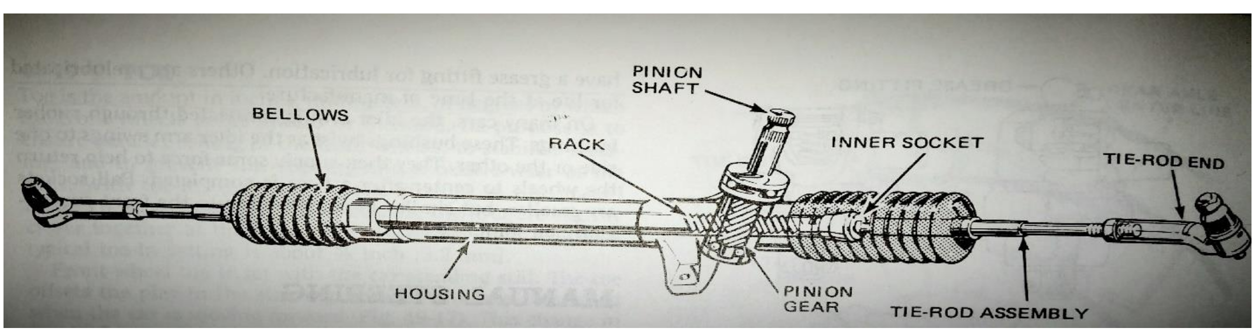


Fig. 24: Manual rack-and-pinion steering system

- <u>Steering wheel:</u>

The steering wheel is taken from the same car- Toyota Corolla. It is assembled in the vehicle after some modifications.

Fig. 25: Steering wheel

3.1.5. Power transmission:

In our vehicle, the power coming through the engine or from the motor is passed to the rear wheel through chain drive. Since our vehicle is a parallel type hybrid electric vehicle, the two power sources should be exploited according to the different operating conditions of the vehicle.

- <u>Operating mode and control system</u>

When the vehicle has to travel short distance (like while parking), the use of electric power source is best. Similarly, in traffic jam or when the vehicle has to travel at low speed, the EV mode of the vehicle is suitable as the fuel consumption rate as well as pollutants emission is decreased substantially. However, the EV mode is not quite suitable for every operating conditions due to its low battery power and charging problem. When the vehicle has to travel long range or at high speed, switching the vehicle into ICE mode is advantageous. The switching of vehicle from ICE mode to EV mode and vice-versa is simple and done manually. Due to lack of budget and time for the project and as well as lack of our technical knowledge, we selected the simplest way.

The control system of the vehicle mainly consists of a clutch as shown in figure below which helps to switch the power modes of the vehicle.

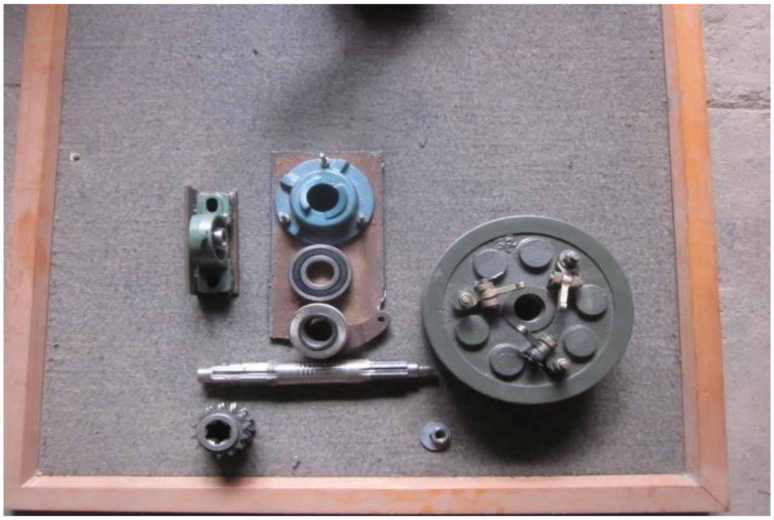


Fig. 26: A clutch system

Our vehicle transmission system consists of both electric motor drive and the drive from the IC engine. The two system is linked together by a clutch. For the clutch, we used a belt driven type clutch used in the tractors. The clutch assembly consists of a shaft that contains sprocket that drives the chain from the engine and belt is fitted on groove on outer surface of the clutch that drives belt from the motor. The drive to the wheel is given by a second sprocket fitted in the same shaft. The choice of the drive between motor and the engine will be controlled by engaging or disengaging the clutch.

3.1.6. Electric system:

For electric drive mode, we installed and connected four batteries, a motor, a speed controller and a throttle. All these components is being used in E-rickshaw that has been running on plain roads of Terai region of Nepal.

Fig. 27: Exide batteries

Fig. 28: BLDC electric motor

Fig. 29: Speed controller

Fig. 30: Throttle

3.1.7. Specification of main components of the vehicle:

1. **IC engine**

Type	Air cooled, 4-Stroke Single Cylinder
Displacement	223 cc
Max. power	19.47 Ps at 7500 rpm
Max. torque	19.35 Nm at 6000 rpm
Max. speed	126 km/h
Fuel	Petrol

2. **Electric Motor**

Type	Brushless, DC, gear
Nominal Power	1000 W
Nominal Voltage	48 V
Continuous Current	25 A
Rated Speed	3300 rpm
Torque	20-45 Nm

3. Speed Controller

Type	Brushless, DC
Nominal Power	1000
Voltage	48 V
Continuous Current	50 A

4. Battery

Type	Lead-acid, automotive
Voltage	12 V
Weight	28.1 kg
Capacity	100 Ah

3.1.7. Other components:

(1) Seat

We designed our vehicle chassis that could accommodate two person (driver and a passenger) so we brought two seats. These seats were of a Maruti Suzuki taxi.

Fig. 31: Seats

(2) Fuel tank

We used fuel tank that is used in a generator.

Fig. 32: Fuel tank

3.2. Components and Standardization

Making or buying of various components used in the project is one of the most important decisions for making the project economic and cost effective. The various factors that govern this decision making can be summarized as followings;

Table 3: Factors governing make or buy decision

Make	Buy
Standard product	Specific design consideration
Economical	Unavailability of product
Precise	Use of available resources
Easy availability	Low cost of product
Aesthetic	Compatibility of different components

The following tables show various components and remarks regarding the decision.

Table 4: Components which were made

S.N.	Description	Remarks
1.	Chassis	Design need and utilization of available resources
2.	Upper and lower control arms	Suspension and steering
3.	Gear shifter	Ease of driver
4.	ABC pedal and linkages	Ease of driver
5.	Shifter for clutch	Parking brake
6.	Housing and support of main components	Design
7.	Bearing Housing	

Table 5: Components which were bought

S.N.	Description	Remarks
1.	Coil Spring suspension	Readily available of standard
2.	Bearings	Availability
3.	Wheels	Availability
4.	Sprocket and chain	Availability
5.	Seats	Availability
6.	Clutch lever (parking brake)	Availability
7.	Engine	Availability
8.	Electric motor	Availability
9.	Motor controller	Availability
10.	Batteries	Availability
11.	Throttle	Availability
12.	Fasteners	Availability

3.3. Material Selection

For the various components and systems of ‘Three-wheeler Hybrid electric Vehicle’, a number of materials were essential with varying mechanical properties. Some needed to be hard while the other needed to be tough according to functional requirement but the basic criteria was that all materials needed to be light weight with required strength. Most of the materials used were metals but a few non-metallic materials were also used. Non-metallic materials were of advantages when the requirements like corrosion resistance, light weight, etc. were to be fulfilled. Material selection was done by mainly considering functionality, workability, availability and economy.

Almost all the materials used to make frame are mild steel. Some high carbon steel fasteners were also used.

Aluminum pipe was used for exhaust pipe.

The non-metallic materials used were:

i. Leather seats
ii. Plastic boxes

- Mild Steel

Mild steel is one of the alloys of iron and carbon which contains about 0.1% to 0.25% carbon. The advantage with mild steel was that it was easily wieldable and provided reasonable strength. The mild steel pipes and rods were easily cut and drilled.
The various forms of mild steel used were as follows;

➢ Mild steel square pipes (27 mm and 40 mm) and circular pipes:
These pipes were used to make frame structure and control arms.

➢ Mild steel fasteners:
The nuts and bolts were used for joining various major and minor components.

➢ Mild steel rods:
These were used to make shafts and supports.

Besides these, some rivet joints were also used.

3.4. The fabrication process

The vehicle was made by combining a large number of components. Many of the components were bought from the market and a number of components were fabricated. A no. of components bought were also modified as per the requirement. For the fabrication process, basically following machines and machining process were used;

Machines used

- Drilling machine
- Hand grinder
- Bending machine

- Electric arc welding
- Lathe machine
- Air compressor

Machining processes

- Drilling
- Grinding
- Cutting
- Bending
- Welding
- Turning
- Boring

3.5. Product assembly

1) Chassis assembly
   After complete weld joining of chassis materials, all the components were fitted on the frame by making some arrangements. Engine, motor, controller and batteries were fitted on the frame. Similarly, steering system, seats, fuel tank, bearings, ABC pedals, wirings and linkages were fitted or held together to the frame. This was done either by welding, fasteners or just by clamping.

2) Control arms and wheels
   The control arms were bolted on the frame. The other end was joined to the wheel hub with the help of ball joints. The front tires were fitted on the hub respectively. The rear wheel was also fitted to the frame.

3) Suspension
   Two coil spring were fitted on front just between the frame and the wheel hub in some inclination to the ground. Similarly, two springs were fitted on rear wheel and the frame.

4) Steering system
   The rack-and-pinion steering system was fitted on the frame. The two ends of the rack were joined to the wheel hubs by ball joint. The steering wheel was fitted on the rack with the help of universal joint and bearing.

5) Transmission system
   The tractor clutch has shaft which is modified to have two sprockets. One sprocket has chain connecting to the engine while other sprocket connects to the rear wheel. So, if clutch is disengaged the engine rotates the sprocket and the one at rear wheel, thus engine drive takes place. If the clutch is engaged, then the motor drives a pulley which is connected to the clutch pulley with belts, thus electric drive takes place.

3.6. Cost estimation

Table 6: Cost estimation of materials

S.N.	Item	Qty.	Rate	Amount (in 000)
1.	Engine	1		60
2.	Wheels (Front)	2	30	60
3.	Wheel (Rear)	1		20
4.	Chassis materials			15
5.	Steering system	1		30
6.	Suspension	4	6	24
7.	Brakes	3		40
8.	Battery	4	20	80
9.	Electric motor	1		7
10.	Speed controller	1		8
11.	Throttle	1		1
12.	Miscellaneous			80
	Total			Rs. 4,25,000

CHAPTER FOUR
RESULTS

CHAPTER FOUR: RESULTS

4.1. Design and stress analysis

We wanted our vehicle to be functional, safe and manufacturable. So, creating an accurate design of the vehicle was most important. Design is a preliminary and highly iterative process. It is also a decision-making process.

We mainly focused on the design and analysis of chassis as it is the foundation of a vehicle. All the components are mounted on the chassis of the vehicle and it also determines the strength, load capacity, steering and suspension service. So chassis design was the foremost and most important job for us. The simulation of the design was even critical.

We created the fundamental design of the chassis in Solidworks software. After completion of the chassis design, different analysis were done on the basis of various design considerations. The geometry and dimensions of the design were selected by considering many design factors. So that, the vehicle, which will be fabricated, could meet the desired objectives like safe to drive, cheap, easy to manufacture and moreover functional in reality.

The basic design considerations that were studied in the simulation of the design are;

a) Weight
b) Volume
c) Strength/stress
d) Distortion/deflection/stiffness
e) Manufacturability

In Solidworks, we chose square pipe of the material of Steel AISI 1020 for the chassis frame design. After the weldment of the pipes in Solidworks, we obtained various information about the chassis.

The material as well as mass properties of the chassis as given by the Solidworks are shown below;

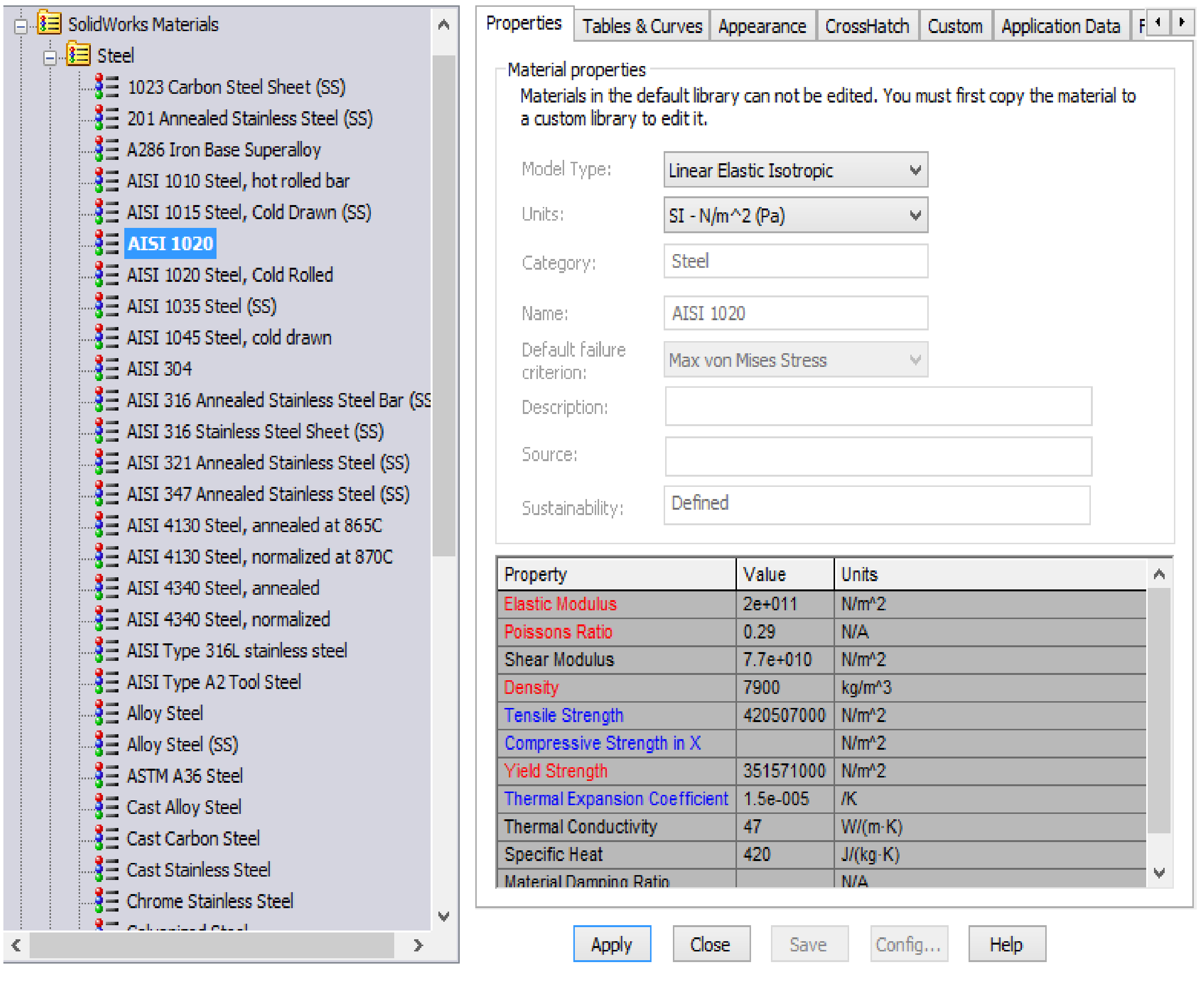


Fig 33: properties of the material used

The pipes used for the design of the chassis frame are square type of two different sizes but same thickness. The thickness of the pipes is 1.8 mm. The larger one with dimension 40×40 is used for the base portions only so that the load capacity as well as strength is maintained. And the smaller one with dimension 27×27 is used for rest of the portions where there is less probability of distortions and stress. The use of the small pipes also lessens the chassis weight.

We also performed stress analysis of the chassis frame in Solidworks. The analysis was done after applying weld in frame parts. Following results were obtained;

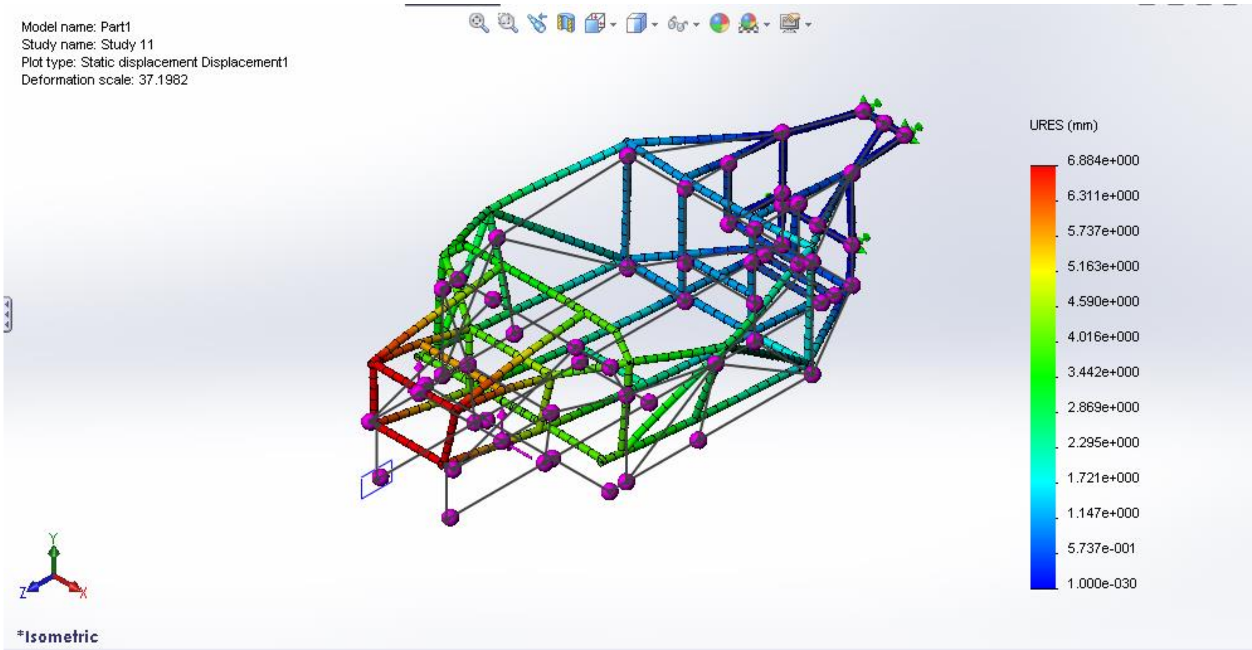


Fig: static displacement

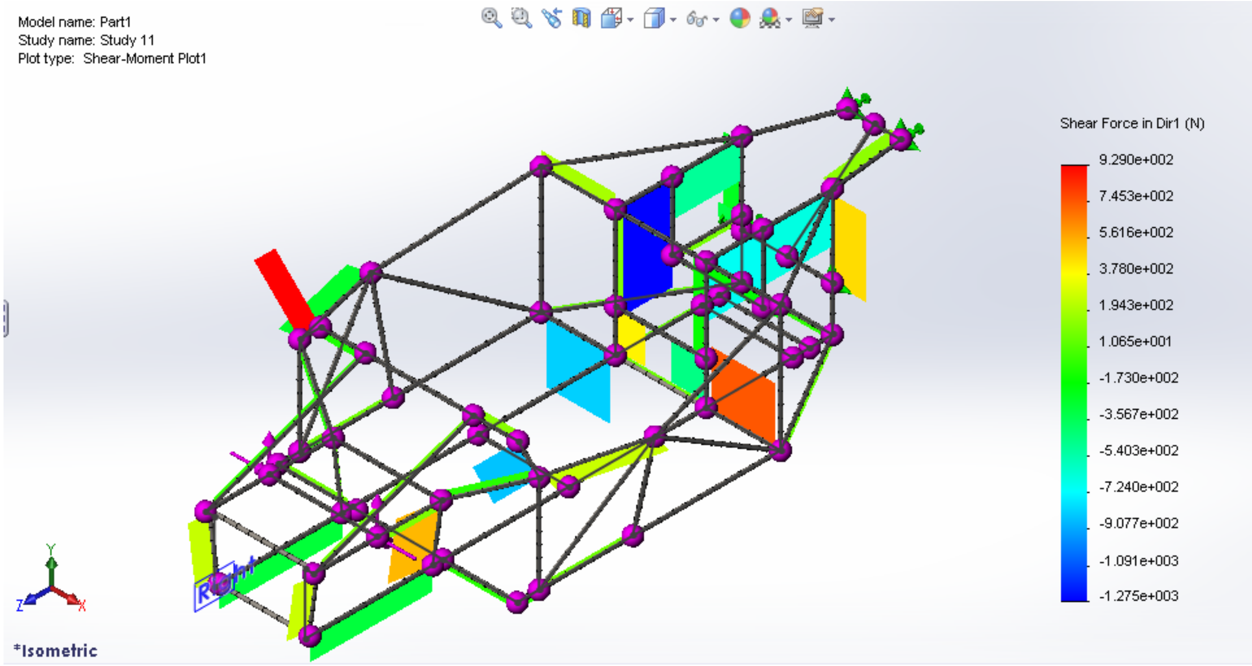


Fig: shear force

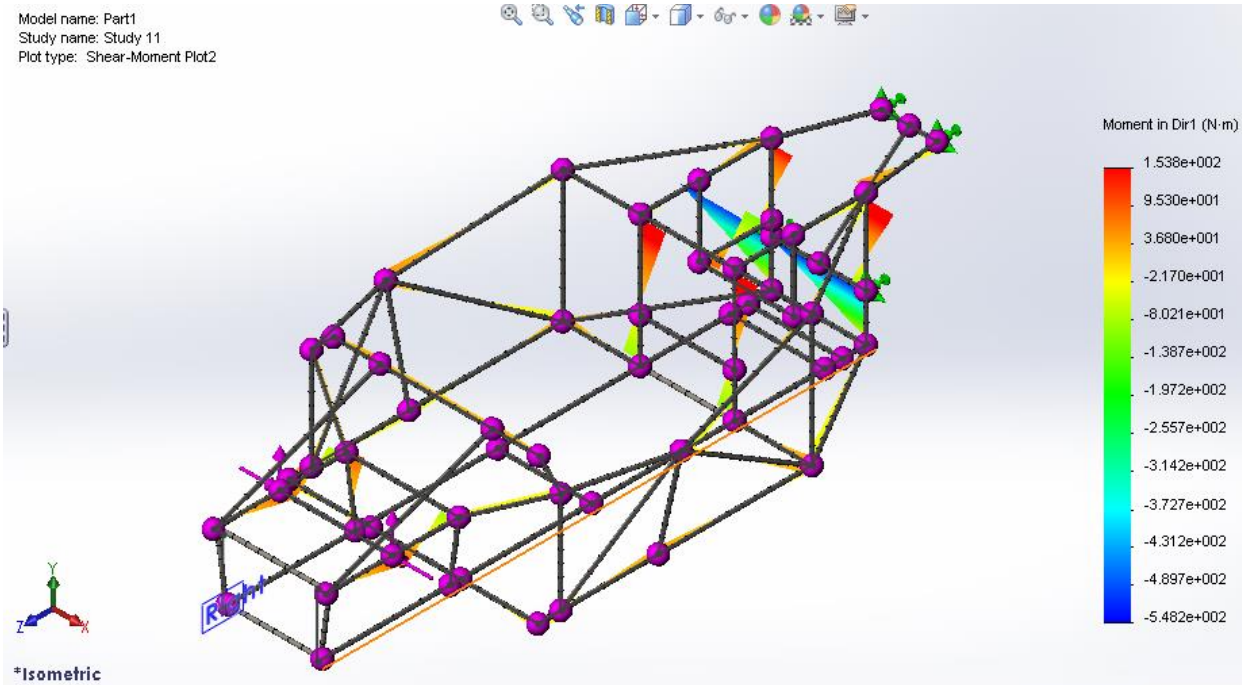


Fig: Moment in each member

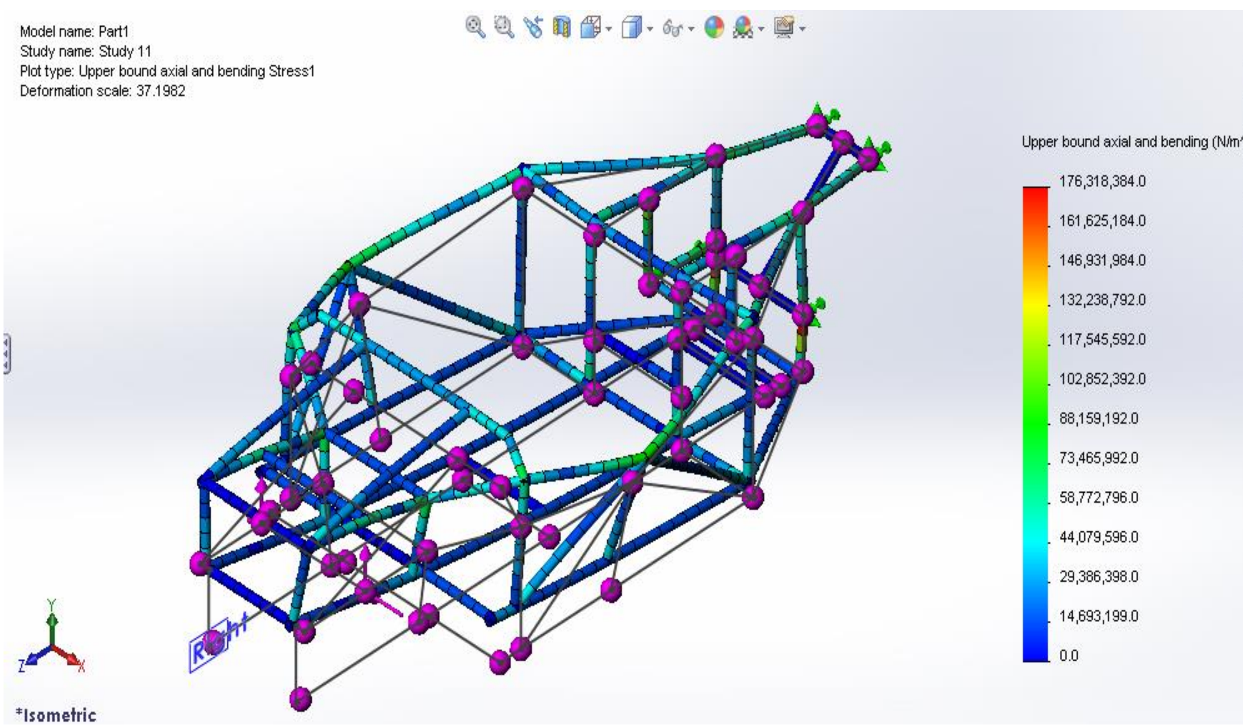


Fig 34: stress analysis of the frame

We assumed that the total weight of the vehicle including two passengers and all the components would not exceed 450 kg. Now, assuming that the C.G stays at the center of the frame and the weight is uniformly distributed among three wheels which is 150 kg each. The main deformations that act on the vehicle frame are:

- Longitudinal torsion

  Torsion loads result from applied loads acting on one or two oppositely opposed corners of the car. The frame can be thought of as a torsion spring connecting the two ends where the suspension loads act. Torsional loading and the accompanying deformation of the frame and suspension parts can affect the handling and performance of the car.

- Vertical bending
  The weight of the driver and components mounted to the frame, such as the engine and other parts, are carried in bending through the car frame. The reactions are taken up at the axles. Vertical accelerations can raise or lower the magnitude of these forces.

- Lateral bending
  Lateral bending loads are induced in the frame for various reasons, such as road camber, side wind loads and centrifugal forces caused by cornering. The sideways forces will act along the length of the car and will be resisted at the tires. This causes a lateral load and resultant bending.

- Horizontal lozenging
  Forward and backward forces applied at opposite wheels cause this deformation. These forces may be caused by vertical variations in the pavement or the reaction from the road driving the car forward. These forces tend to distort the frame into a parallelogram shape.

It is generally thought that if torsional and vertical bending stiffness are satisfactory then the structure will generally be satisfactory. Torsional stiffness is generally the most important as the total cornering traction is a function of lateral weight transfer.

Considering only the vertical bending stress, the above figure shows that the maximum stress occurring in the frame is about 1.76×10^8 N/m^2 which is quite less than the yield strength of the material used for the frame design i.e. 3.51×10^8 N/m^2. Thus, the result signifies that there is less chances of deflection of frame parts due to load impact. It means the designed chassis is safe and suitable to fabricate.

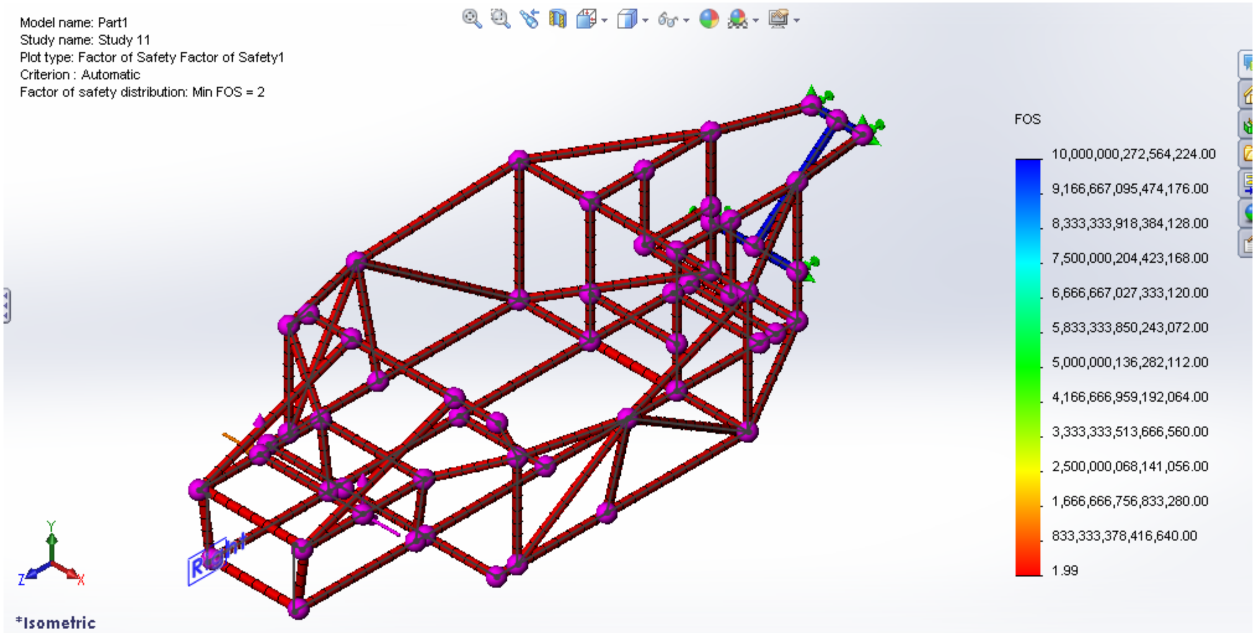


Fig 35: stress analysis of the frame

The above figure shows that the factor of safety for the designed frame is 1.99 which means the chassis can withstand the load or stress 1.99 times than intended. This also proves that the design of the chassis frame is safe and appropriate to fabricate.

4.2 Steering radius calculation

A normal car, for instance Toyota corolla, has got a turning radius of about 5.4 meter and that of the new tri wheel model Polaris's "slingshot" is about 3.2 meters. It shows that tri wheel vehicle has less turning radius than 4 wheel vehicles. For our hybrid tri-wheel vehicle we had to design a steering system which would allow the easy handling and steering of the vehicle for turning. Deciding a value for turning radius is quite critical as high value as well very low value of turning radius may result in the inefficiency of the entire steering mechanism.

For the tri wheeler hybrid vehicle, we calculated the turning radius depending on the turning degree of the front wheel with the relative forward direction. Too much of the turning radius could result in the contact of the front wheel with the chassis as higher value of turning radius requires greater angular deflection of the front wheels with relative forward direction.

A simple calculation done for evaluating the turning radius is as explained below.

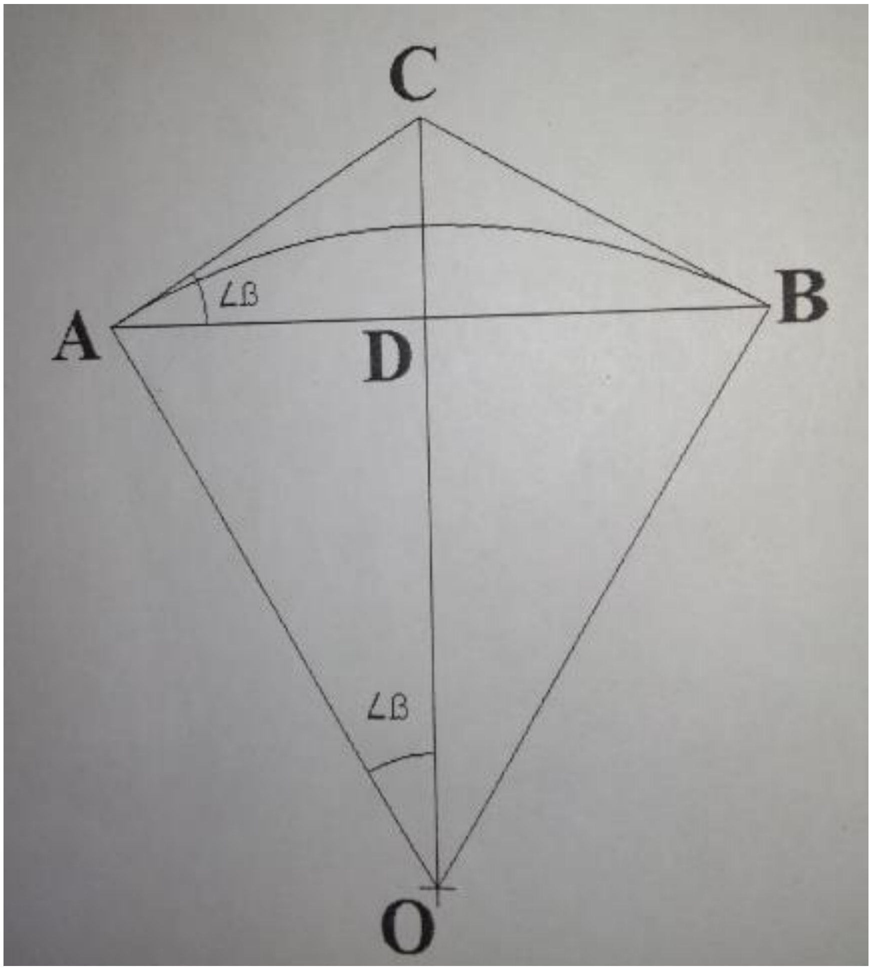


Fig 36: turning radius geometry

In the figure,

AO=Turning Radius = R (say)

AB= Length of the vehicle (distance between the tire centers) =243cm

0= Center of the turning curvature

AC= Tangent denoting the initial forward direction of the vehicle

CB= Tangent denoting the final forward direction of the vehicle after steering

<u>Calculation of Angle "β"</u>

Sin β = (AD/DC)

Or, Sin β = (AB/2AQ)

Or, Sin β = (243/2R)

Therefore,

$\beta = \sin^{-1}$ (121.5/R)…………………………………………………….(i)

Then,

2β = 2sin-1 (121.5/R)……………………………………………….(ii)

Relation (ii) gives the actual angular deviation of the front tire with respect to the forward direction of the vehicle i.e. angle 2β represents the angular displacement of the front two tires.

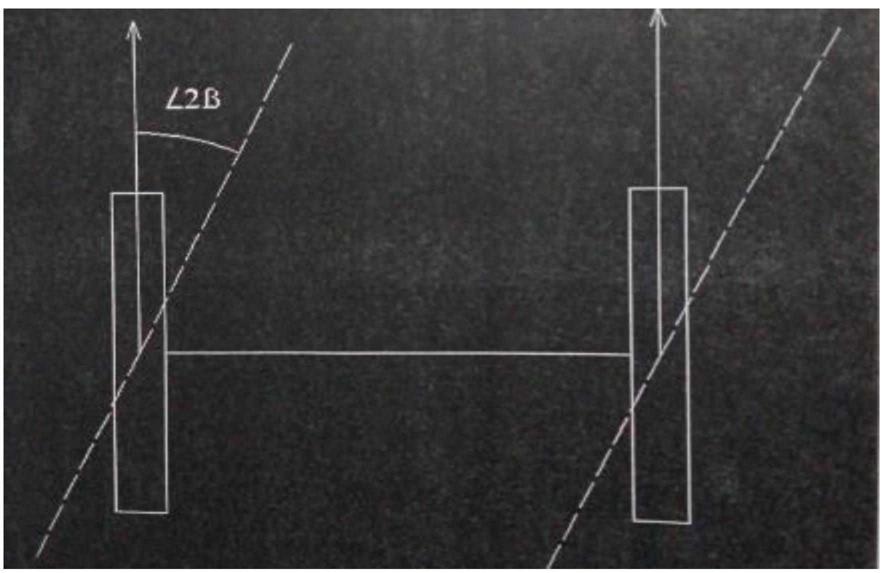


Fig 37: angular displacement of the front two tires

For our system, we calculated the angular displacement of the tire using simple geometry, which was found to be 31.5°. Now putting this value in equation (ii) we can calculate the turning radius of the tri wheel hybrid vehicle.

For $\beta = 31.5^\circ$, from relation (ii)

$31.5^\circ = 2\sin^{-1}$ (121.5/R)

Or, R=121.5/sin (31.5/2)

Or, R = 447.61cm

4.3 Evaluation and speed ratio calculations of transmission

As the hybrid tri wheeler uses two sources of power viz. motor and ICE. The power from the ICE is driven to the wheel by chain between two sprockets.

Fig: transmission (chain drive)

The transmission ratio is calculated as follows:

No of teeth in driver sprocket= 14 (A)

No. of teeth in intermediate sprocket = 14 (B)

No of teeth in driven sprocket= 44 (C)

Now,

The speed ratio from the driver sprocket to driven sprocket= driven/driven

$$= (C/B) \times (B/A)$$

$$= 3.143$$

The drive from the electric motor consists of both pulley and sprockets. The motor drives the helical gear which in turns rotates the bigger helical gear connected to the pulley. The pulley is connected to the clutch through belt drive. The clutch is connected to one end of the shaft and to the other end of the shaft, another sprocket is connected which at last drives the sprocket of the wheel through chain drive. The electric drive system of the tri wheeler hybrid vehicle is shown in the fig below:

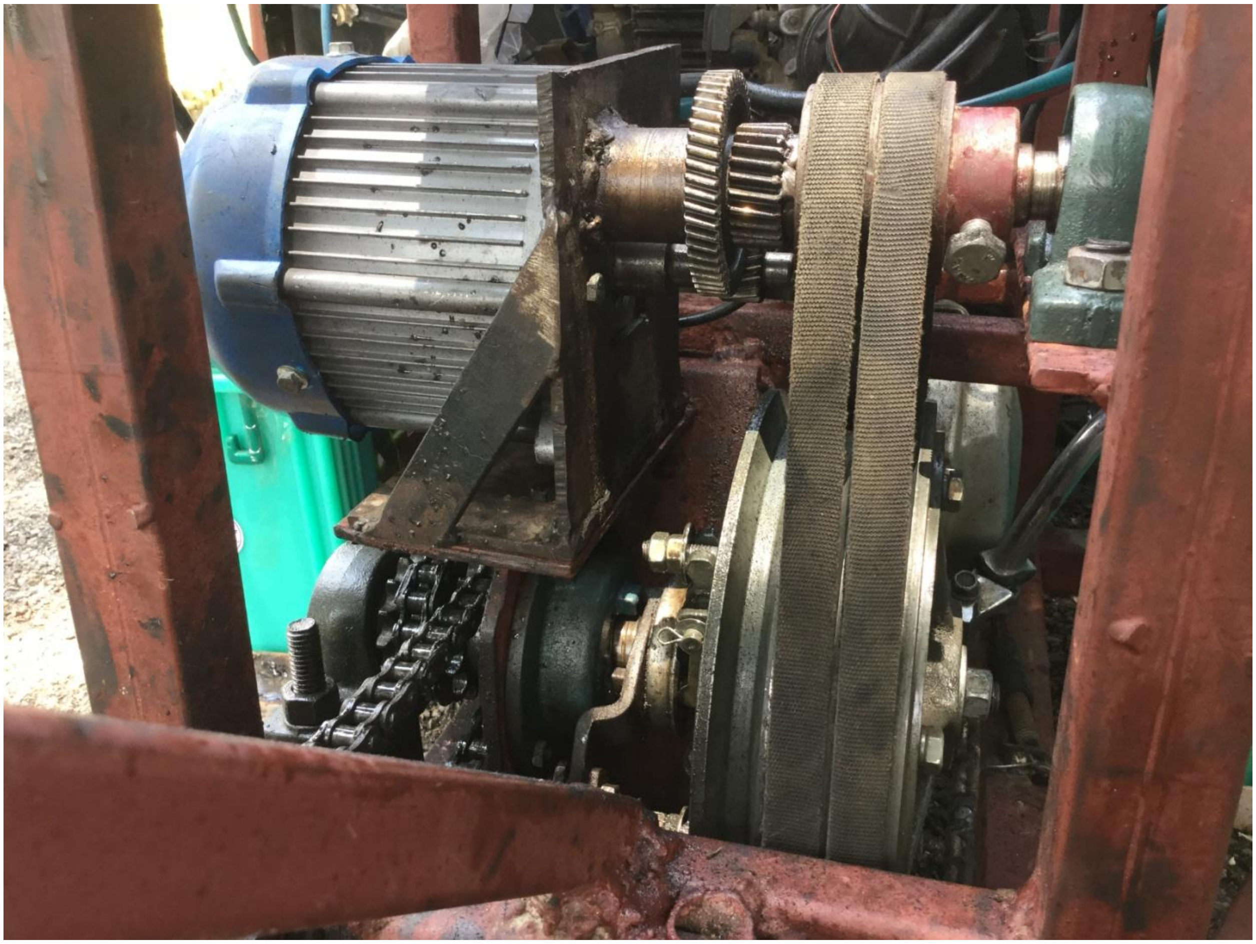


Fig 38: electric drive system of the tri wheeler hybrid vehicle

<u>Calculation of the transmission ratio of the electric drive</u>

No of teeth of the smaller helical gear (N1) = 16

No of teeth of the bigger helical gear (N2) = 52

Diameter of the smaller pulley (D1) = 21 cm

Diameter of the clutch (D2) = 5 cm

No of teeth in the driver sprocket (N3) = 14

No of teeth in the driven sprocket (N4) = 44

No. of the final transmission ratio is calculated as

(N2/N1)*(D1/D2)*(N4/N3)

= 42.9

4.4 Front Suspension Angle Calculation

According to the analysis of the suspension used in other double A-arm suspension system, the inclination is found to be kept between 45° to 70° for the optimum performance. Thus to maintain the angle of the suspension within the specified region the suspension was inclined at 50°.

Fig 39: Control arms with shock absorber

Shock absorber inclination with horizontal plane at rear wheel is maintained the same as that in front.

4.5 Results after test ride

After the completion of fabrication process some tests were performed. Most of the tests were done in Pulchowk Campus vicinity and some were done outside the campus. Following tests were performed.

1. Turning radius
2. Mileage
3. Maximum speed
4. Maximum acceleration

Turning radius test

As per Indian Standards 12222, the turning circle is measured by drawing a circle as shown in Fig. 13 on which the outer most wheel moves when the steering wheel is turned to the maximum lock and the vehicle moving at a speed below 5km/h. This measurement is done on both the sides of the steering wheel lock and the average of these two circles diameter is represented as the turning circle diameter and half of this value is termed as the turning radius of the circle. Following data was taken during the test. Average diameter was taken during the test.

Experiment number	Data 1(cm)	Data 2(cm)	Data 3(cm)	Average (cm)	Total average(cm)
1	814	798	794	802	792.5
2	799	790	788	792	
3	784	788	780	784	
4	790	788	798	792	

Hence the average turning radius was found to be (7.925/2)=3.96 m. Theoretical value was found to be 4.476 m. Difference between these two results was 0.516m.

Mileage test

Mileage test was done in road of Pulchowk Campus. First of all ¼ liter was filled in empty fuel tank. Distance was measured for each round. Then the number of turns was measured. In this way mileage was measured.

Numbers of turns (n) = 16.5

Length of each round (l) = 400m

Distance travelled in ¼ liter= 16.5*400=6600m

Total distance that will be travelled in 1 liter = (6600*4)/1000=26.4 km

Mileage =26.4 km/l

Maximum speed

No speedometer was fitted to the fabricated hybrid car. So speed was measure using android application. Its tolerance was found to be ±5 km/hr. Its maximum speed was noted to be 46.3±5 km/hr. Steering system seems to be more stable below this speed.

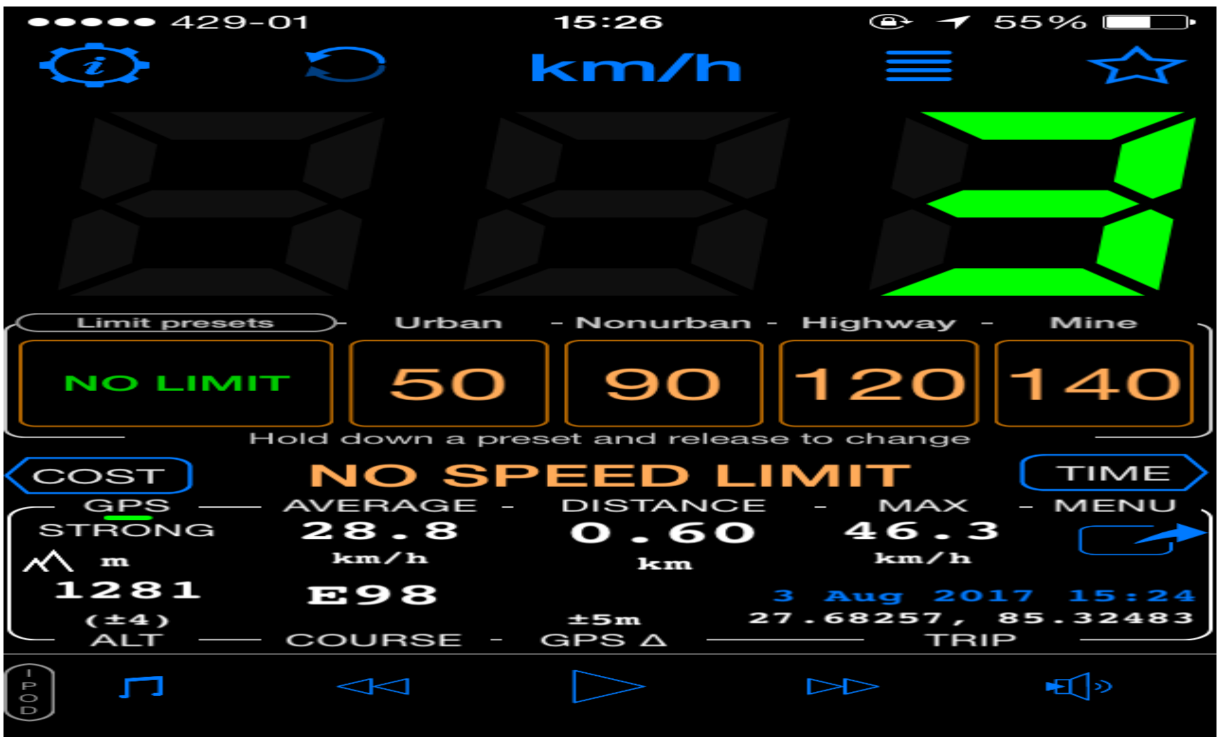


Fig 40: screenshot of the speed of the vehicle in ICE mode calculated by the app.

Maximum acceleration

For its acceleration testing the vehicle was accelerated for a fixed length i.e. 60 m. Time and speed were noted at the end of the line. Two acceleration values were calculated using two parameters time and distance relationships.

u= initial speed=0 m/s

v=final speed

t=time

s=distance

a= acceleration

$a1=v^2/(2\times s)$

$a2=v/t$

Experimei	Time(s)	Initial speed(m/s)	Final speed(m/s)	distance travelled(m)	Accleration(a1) (m/s^2)	Accleration(a2)(m/s^2)
1	9	0	10.27	60	0.878940833	1.141111111
2	9.8	0	10	60	0.833333333	1.020408163
3	9.2	0	10.27	60	0.878940833	1.116304348

Here, acceleration using velocity parameter i.e. a1 was found less than acceleration using time parameter i.e. a2. This was because of error during measurement of speed of vehicle using android application.

4.6. Financial Analysis

The economic feasibility of the hybrid electric vehicle can be studied by comparing it with the running cost of gasoline engine and running cost of electric drive separately.

a) Financial analysis of gasoline engine only:

- Mileage of Karizma 225 cc engine (after installation on the HEV) = 27 km/L
- Price of fuel = Rs. 98
- Travelling distance per day on average = 20 km
- Number of running days in a month = 30
- Amount of fuel consumed per month = (20×30)/27 = 23 liters
- Total distance travelled per year = 7,200 km
- Cost of a tire = Rs. 8,000 (front) & Rs. 3,500 (rear)
- Front tire changing time = 70,000/7,200 = 9 years (Tire change every 70,000 km)

- Rear tire changing time = 15,000/7,200 = 2 years (Tire change every 15,000 km)
- Tire changing cost per year = (8,000/9) + (3,500/2) = Rs. 2,640
- Price of Air filter = Rs. 600
- Fuel Cost = 23×12×98 = Rs. 27,050

Table: Expenses due to gasoline engine only

S.N.	Running Cost	Price per year
1.	Fuel	Rs. 27,050
2.	Tires change	Rs. 2,640
3.	Lubricating oil	Rs. 500
4.	Servicing Cost (3 times)	Rs. 1500
5.	Repair and maintenance • Air filter change (3 times) • Engine • Replacement of spare parts • Wiring repairs and brakes • Miscellaneous	 Rs. 1800 Rs. 1000 Rs. 500 Rs. 500 Rs. 200
6.	Total	Rs. 35,690

b) <u>Financial analysis of electric drive only:</u>

Motor specification = 1000 W

Let, the average velocity of the vehicle operation be 12 km/h. Then, the energy (E) consumed by the motor in 1 km is given as;

E = Power (W) × Time (hr)
= 1000 × (distance (km)/ velocity (km/h))
= 1000 × (1/12) Wh
= 1000 × 1/(12 × 1000) KWh
= 0.08333 KWh

Distance travelled in a year = 7,200 km
So, E (for 1 year) = 0.08333 × 7,200
= 600 KWh

Tariff rate per unit electricity = Rs.13

So, the expense on electricity per year = 13 × 600
= Rs. 7,800

Table: Expenses due to electric drive only

S.N.	Running cost	Price per year
1.	Electricity Cost	Rs.7,800
2.	Tires change	Rs.2,640
3.	Servicing cost	Rs.1500
4.	Repair and Maintenance • Electric drive • Replacement of spare parts • Wiring repairs and brakes • Miscellaneous	 Rs. 500 Rs. 500 Rs.500 Rs.200
5.	Cost For electric drive Life • Battery (4) 5 • Controller 5 • Motor 10 • Throttle 3	 Rs.16,000 Rs.1400 Rs.800 Rs.330
6.	Total	Rs.32,170

c) Financial analysis of hybrid mode:

We analyzed the usage of dual power in simple way and concluded that it constitutes- 60% electric and 40% fuel.
So,

Distance travelled by fuel per year = 0.4 × 7200 = 2880 km
Distance travelled by electric per year = 0.6 × 7200 = 4320 km
Then, fuel cost = (2880/27) × 98 = Rs. 10,450
Electricity cost = 4320 × 0.0833 × 10 = Rs. 3600

So, total power cost = 10,450 + 3600= Rs. 14,050

Table: Expenses due to hybrid drive

S.N.	Running cost	Price per year
1.	(electricity +fuel) cost	Rs. 14,050
2.	Lubricating oil	Rs. 500
3.	Tires change	Rs. 2640
4.	Servicing cost	Rs. 1500
5.	Repair and maintenance • Electric drive • Replacement of spare parts • Wiring repairs and brakes • Miscellaneous	 Rs.500 Rs. 500 Rs.500 Rs.200
6.	Cost for electric drive — Life • Battery (4) — 5 • Controller — 5 • Motor — 10 • Throttle — 3	 Rs. 9,600 Rs.1400 Rs.960 Rs. 330
7.	Total	Rs. 32,680

When we compare the annual economic expenses on the vehicle running on gasoline and electricity respectively, we found that electric drive is economical. But in electric drive, the speed range is quite low (max. 12 km/h). We may need to drive in high speed than 12 km/h in some conditions. So, driving the vehicle in hybrid mode may be the solution i.e. for low speed and short distance drive choosing electric mode and for high speed and long distance drive choosing IC engine mode. Thus, it is verified that the hybrid mode is economical than sole IC engine mode for the vehicle.

CHAPTER FIVE

RECOMMENDATION, DISCUSSION AND CONCLUSION

5.1. Recommendation

The vehicle developed in this project fulfills all the basic requirements as per the objectives listed. But it still leaves ample space for further development and enhancements. Some feasible steps that can be implemented are as follows:

a) Further work and study under the topic "Hybrid Electric Vehicle" can be done.
b) Weight and cost effective materials can be chosen.
c) Further study and modification can be done in the clutch system used in power transmission.
d) Disc brake mechanism can be installed in the frontal wheel for better braking and handling maneuvers.
e) A high cc engine can be used for generation of more power to the drive.
f) A body cover can be set up after the thorough study of aerodynamics of the vehicle.
g) Li-ion or Li-polymer batteries can be used instead of Lead-acid batteries as these batteries have very high energy density and high life cycles which not only occupy lesser space but also reduce the overall weight of the bike. Consequently, the efficiency of the vehicle increases.
h) Regenerative braking system can be introduced into the hybrid vehicle so that the vehicle's kinetic energy can be converted into electricity for recharging the batteries.
i) Due to inaccessibility of testing ramp and time restrictions, test results obtained for various performance parameters were not satisfactory. For better analysis of fuel economy, torque ratings, energy consumption, emission measurement and other performance parameters, we recommend to test the vehicle on special test ramp.
j) Provision of manufacturing instructor along with design instructor is recommended.

5.2. Discussion and Conclusion

The project "Design of Chassis, Fabrication and Testing of a Three-Wheeler Hybrid Electric Vehicle" was successful to obtain the expected outcomes and to fulfill the desired objectives. This project required continuous dedication and patience and was a great challenge for all the people involved in the project. A large number of mechanisms were involved as the components of the whole system. All these different mechanisms required detail evaluation before and after the fabrication and testing process. Lack of sufficient skills for use of the various machine tools made the fabrication process a little bit complicated. We also realized that when designing is done without considering the materials available in the market then the fabrication process becomes extremely complex. Thus, before designing, the market availability of the materials should be checked.

With several ups and downs along with failures and successes, the project was completed meeting almost all the basic requirements of the system planned. The project was basically about team work and co-ordination between the members of the team. Further development and enhancement in the system can be achieved with considerable efforts and analysis. Throughout the project, we were able to gain some skill and knowledge of the tools and processes used in the workshop and also acquainted ourselves with the various systems used in automobile. Also, we became familiar with the current hardware market status.

Thus, this project can be an inspiration for mechanical students to initiate these types of projects in Nepal which can improve technical skills and group co-ordination.

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APPENDIX A

DESIGN AND SIMULATION

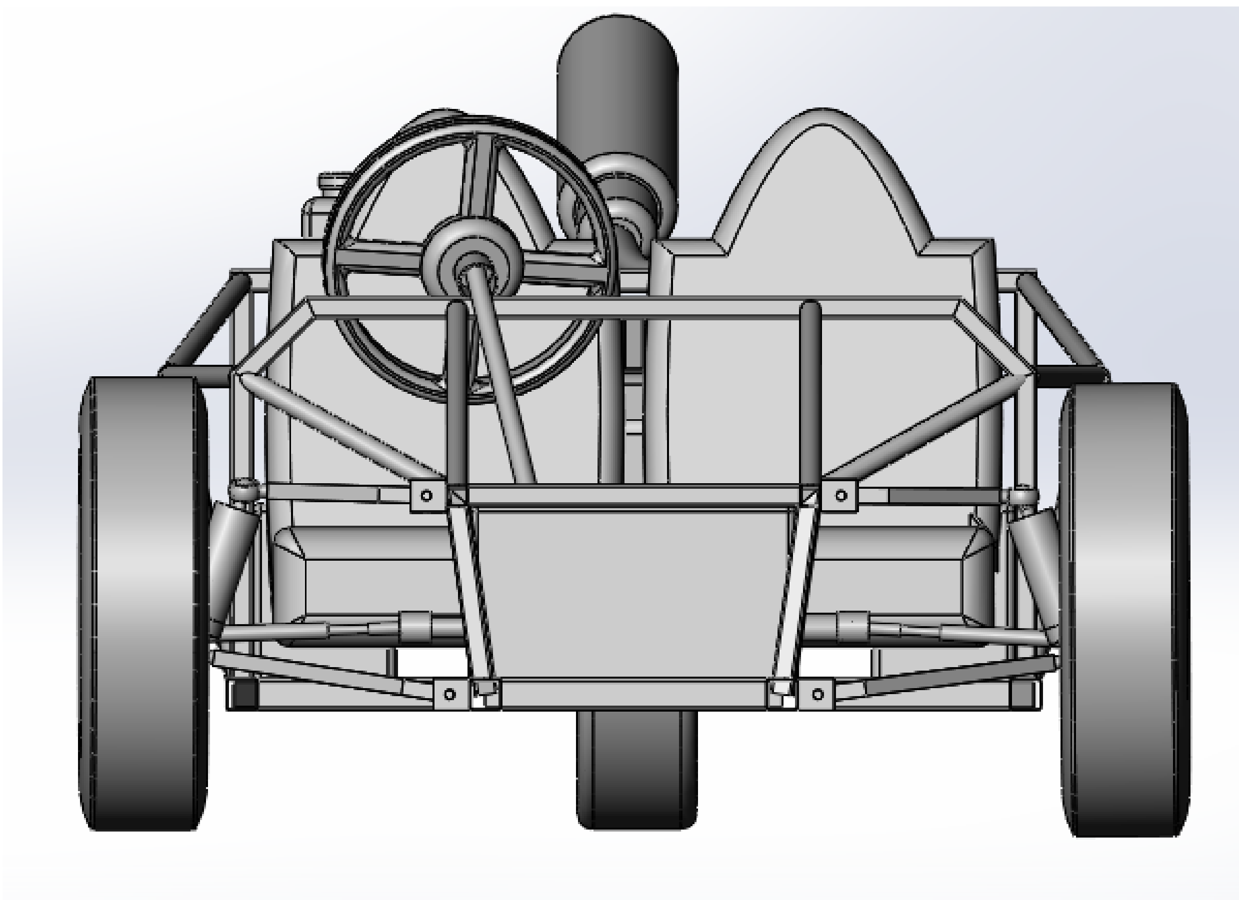


Fig: front view

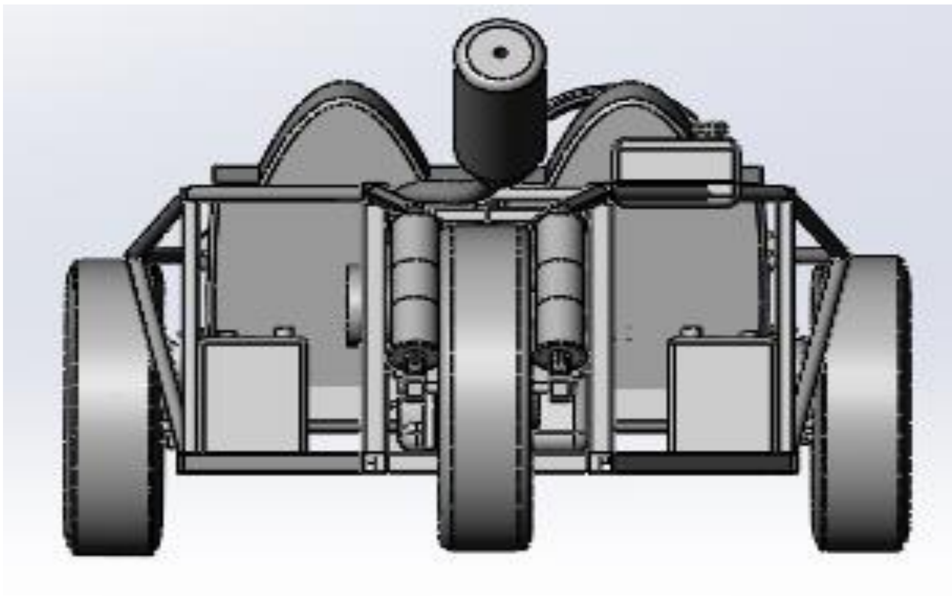


Fig: Rear view

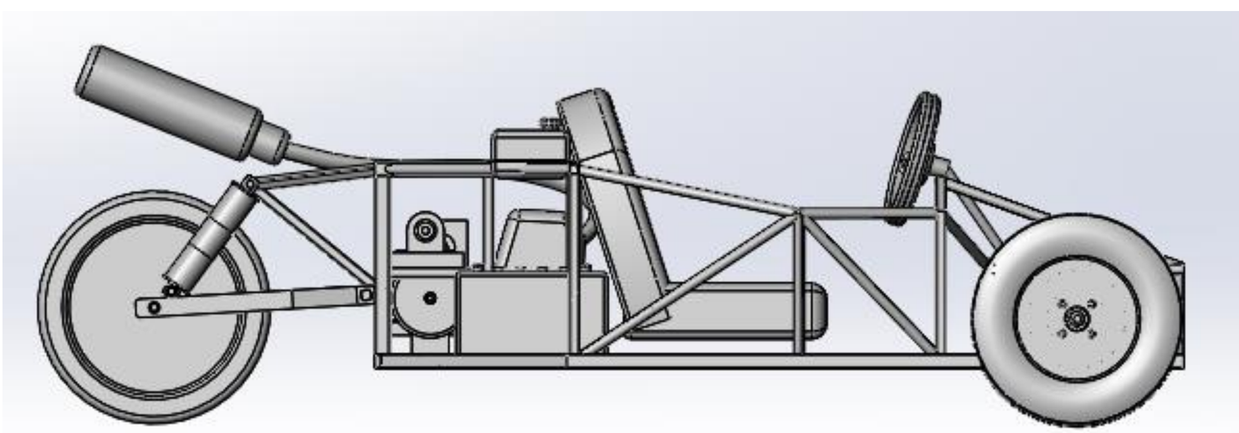


Fig : Side view

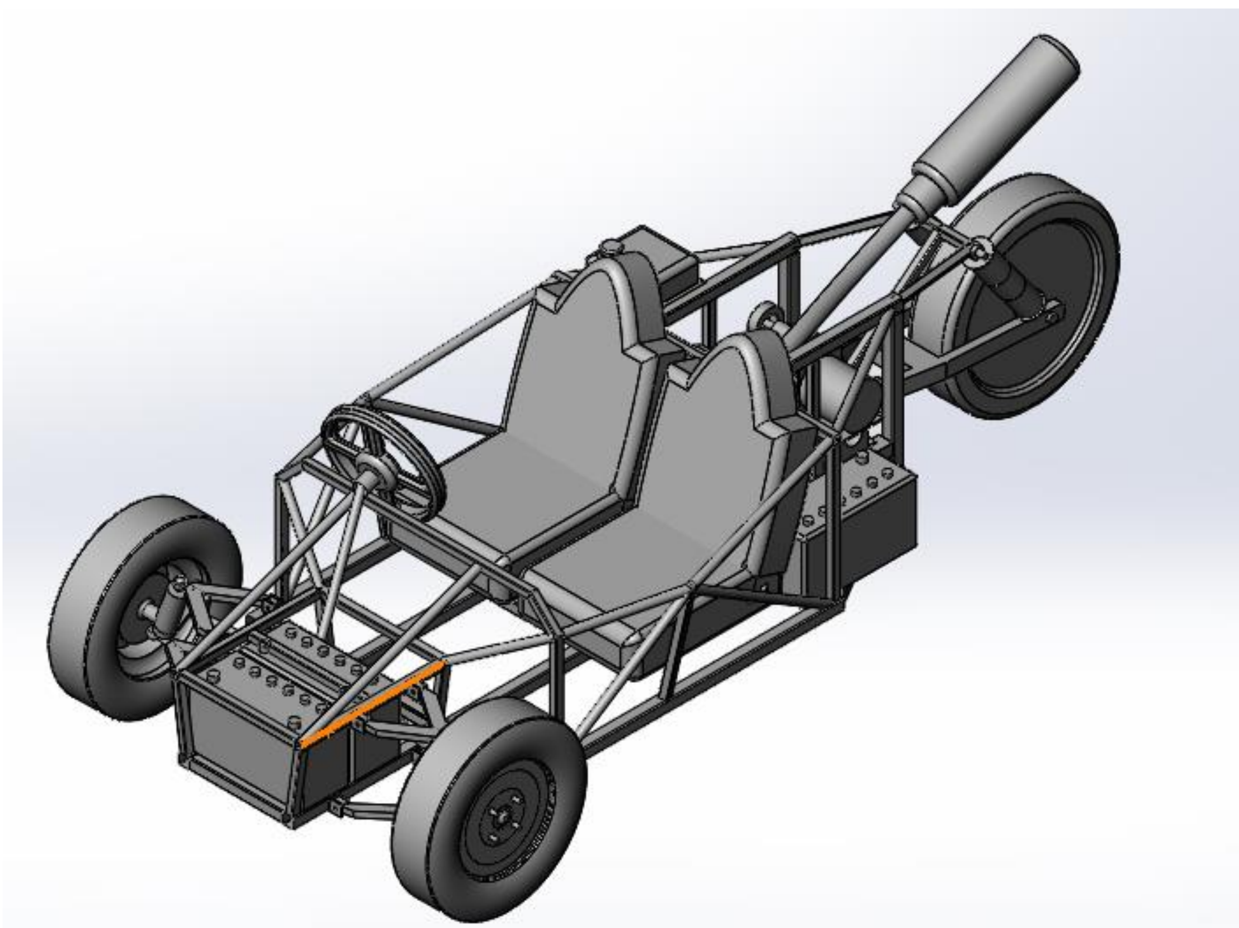
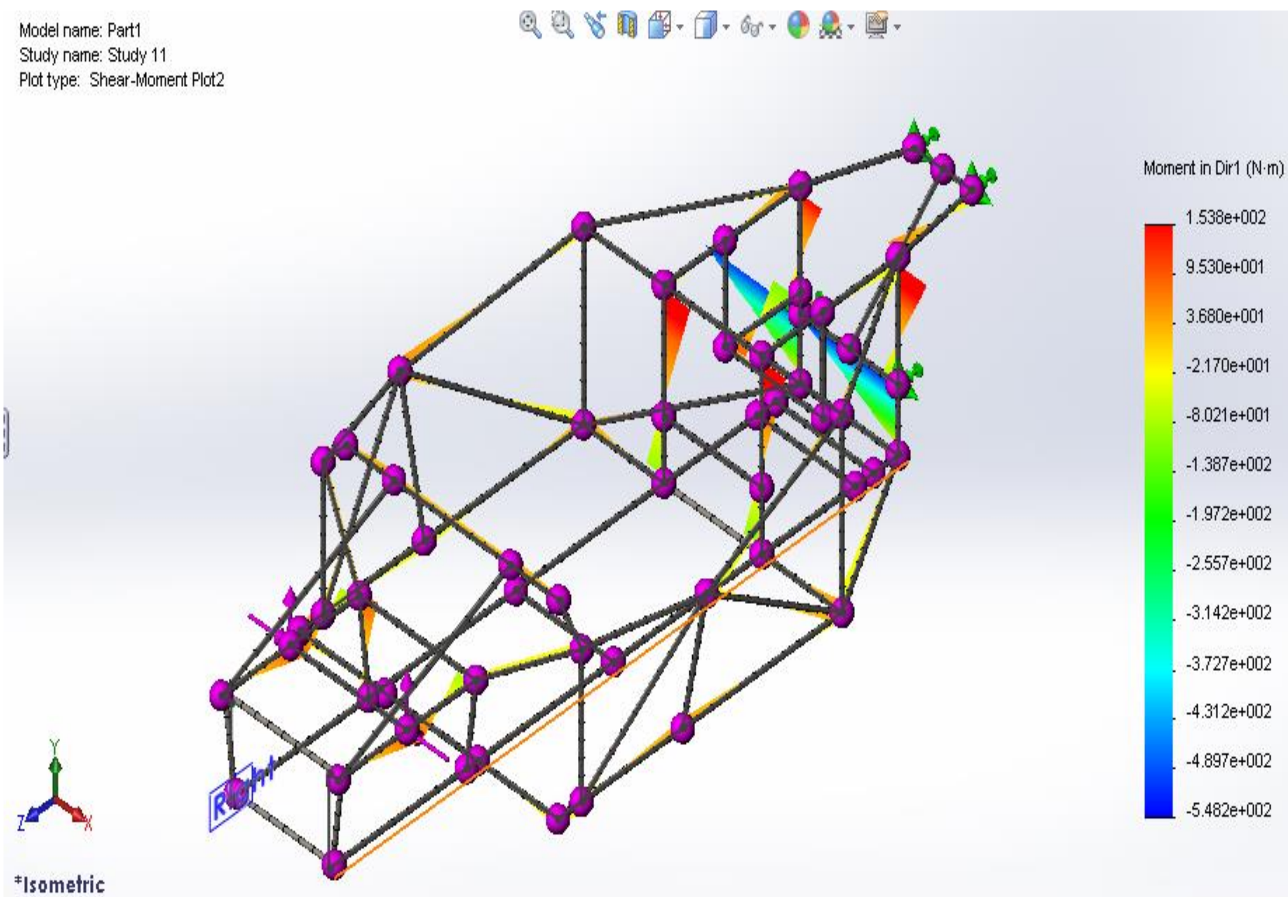


Fig. Isometric view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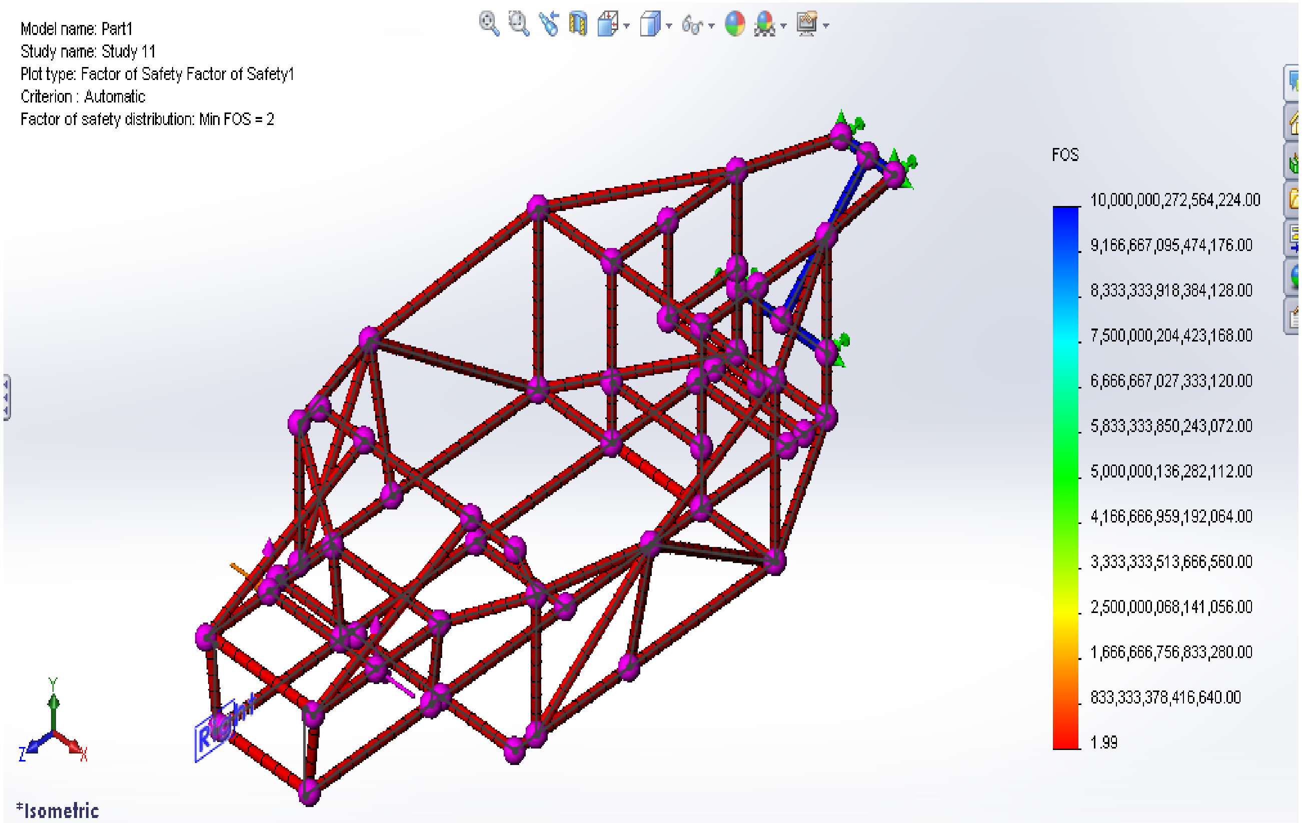
Study name: Study 11
Plot type: Shear-Moment Plot2
Moment in Dir1 (N·m)
1.538e+002
9.530e+001
3.680e+001
-2.170e+001
-8.021e+001
-1.387e+002
-1.972e+002
-2.557e+002
-3.142e+002
-3.727e+002
-4.312e+002
-4.897e+002
-5.482e+002
*Isometric



Model name: Part1
Study name: Study 11
Plot type: Factor of Safety Factor of Safety1
Criterion : Automatic
Factor of safety distribution: Min FOS = 2
FOS
10,000,000,272,564,224.00
9,166,667,095,474,176.00
8,333,333,918,384,128.00
7,500,000,204,423,168.00
6,666,667,027,333,120.00
5,833,333,850,243,072.00
5,000,000,136,282,112.00
4,166,666,959,192,064.00
3,333,333,513,666,560.00
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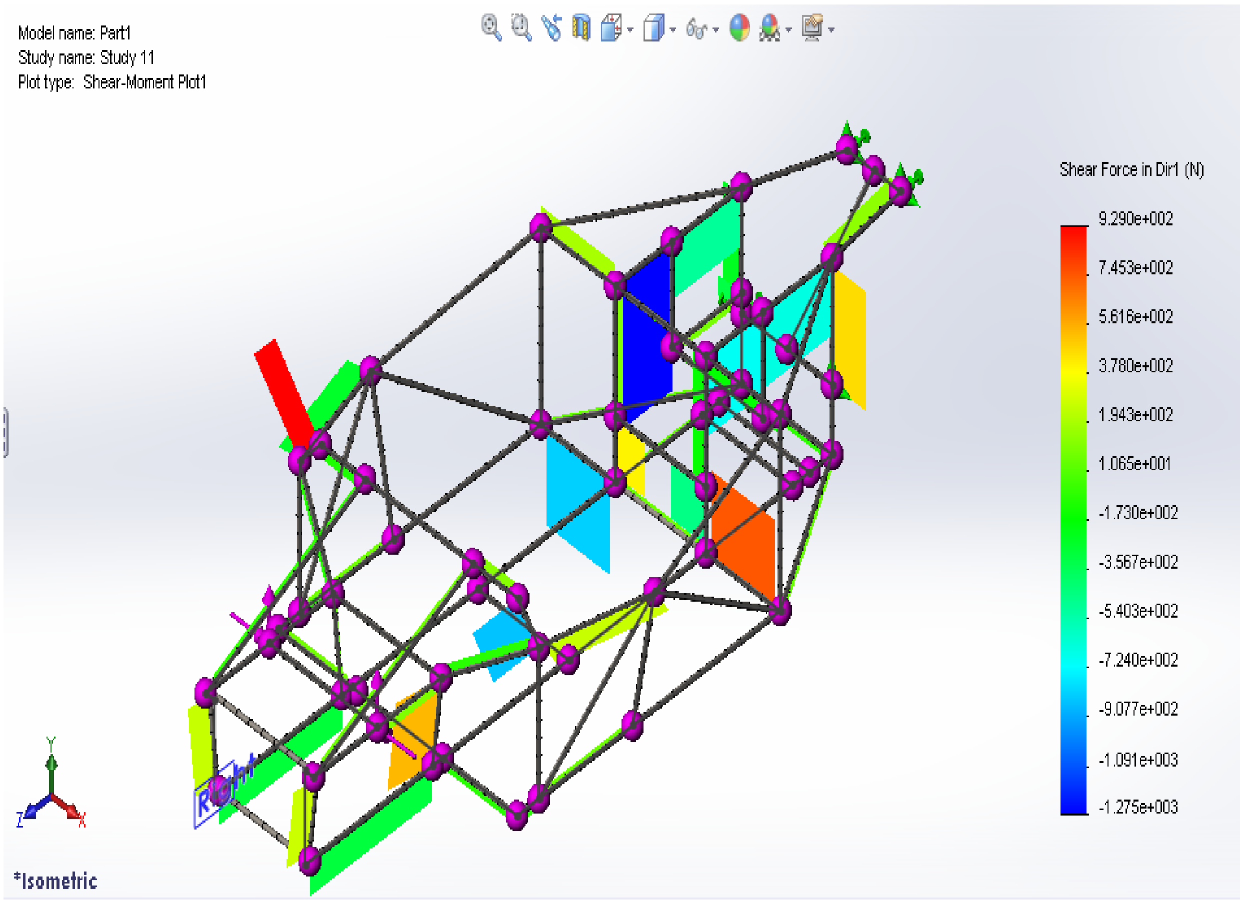
1.99
*Isometric



Model name: Part1
Study name: Study 11
Plot type: Shear-Moment Plot1
Shear Force in Dir1 (N)
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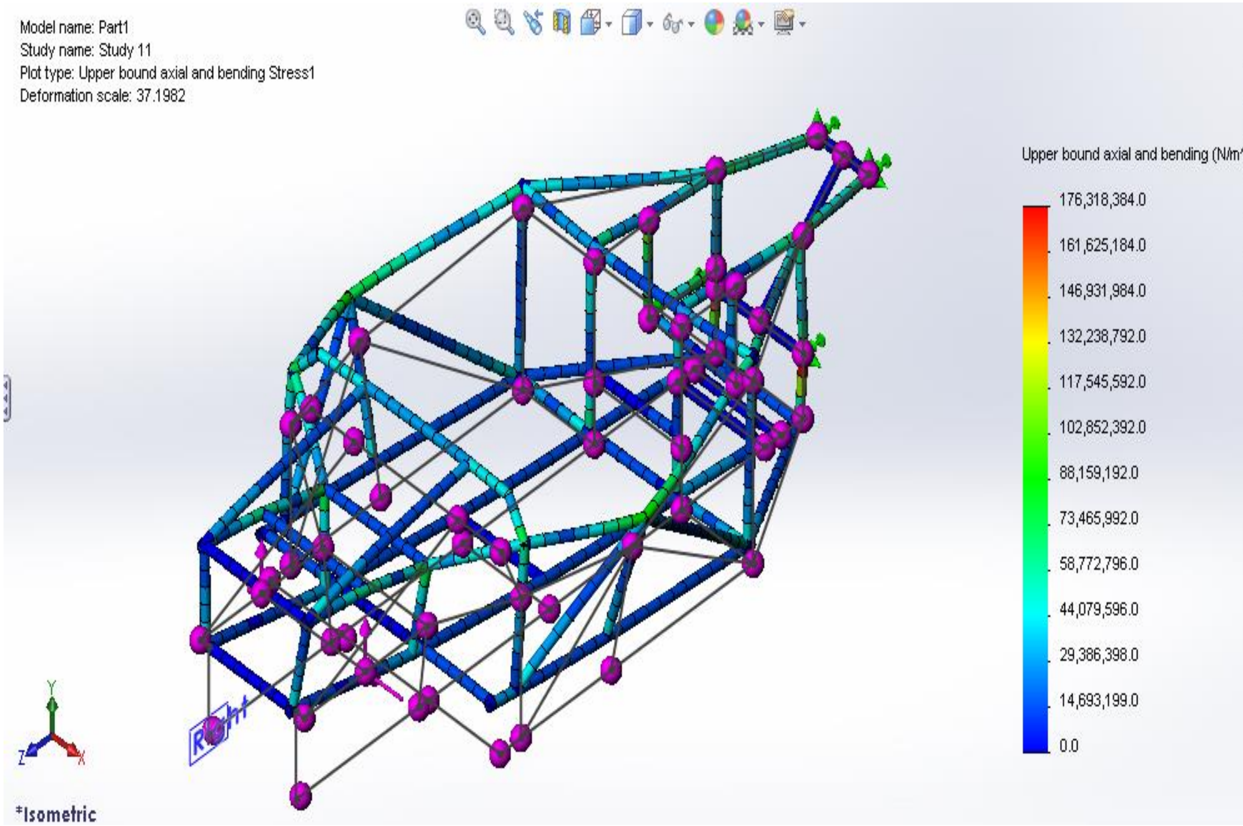
7.453e+002
5.616e+002
3.780e+002
1.943e+002
1.065e+001
-1.730e+002
-3.567e+002
-5.403e+002
-7.240e+002
-9.077e+002
-1.091e+003
-1.275e+003
*Isometric


Model name: Part1
Study name: Study 11
Plot type: Upper bound axial and bending Stress1
Deformation scale: 37.1982
Upper bound axial and bending (N/m^
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161,625,184.0
146,931,984.0
132,238,792.0
117,545,592.0
102,852,392.0
88,159,192.0
73,465,992.0
58,772,796.0
44,079,596.0
29,386,398.0
14,693,199.0
0.0
*Isometric

APPENDIX B

Photo Gallery

Fig: Base of Chassis on a Plain Wooden Surface

Fig: Dies of Lower and Upper A-arms

Fig: Upper and lower A-arms assembled along with Steering System and Suspension

Fig: Complete Frame Structure of the Vehicle

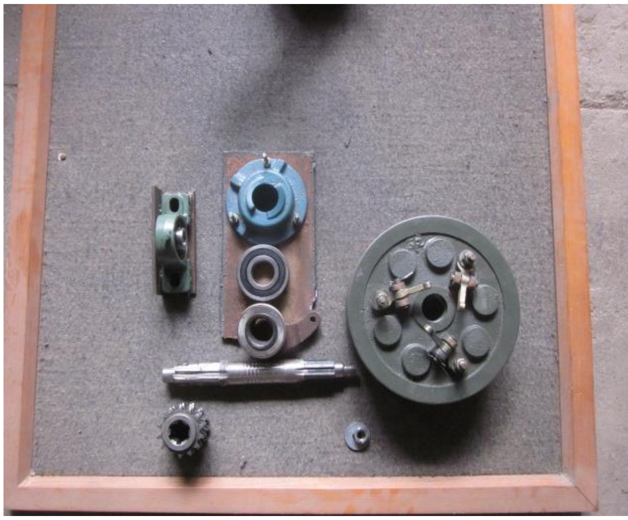

Fig: Parts of the Clutch Fig: Motor and Meshing Gear

Fig: 225 cc engine of Karizma bike Fig: Rear wheel

Fig: Project Members painting the Vehicle's Frame

Fig: Project Members dismantling the Motorbike

Fig. : batteries provided by Sipradi Trading Pvt. Ltd.

Fig. : Final look of our vehicle