

Design and Analysis of a monowheel Electric bike.

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ABSTRACT:-E-bikes are electric bikes which are driven by the use of electricity as the source of fuel. E-bikes are opted for its eco-friendliness and cost-effectiveness for transportation. In the present study, optimum design for an electric bike was modeled and analyzed for stress and failure rate for commercial purpose. Frame is backbone of the bike; it supports and holds the whole load. The main objective of the paper was to design and fabricate a light weight still strong, safe, and economical than the conventional ones. This paper describes process, planning and designing of electric drive for one-wheeled bike, providing details and challenges for selection and implementation of components. The components that are proposed for electric drive are selected using the reference of models available in the market having advantage of smaller size, low maintenance and less vibrations. The present mechanism design ties up mechanical system with the electric drive and electro-control system to power onwheeled bike effectively. Closed loop control system is proposed to be designed to assist effective transmission and balancing of one-wheeled bike.

Keywords:- mono-wheel, Electric Vehicle, E-bike.

I. INTRODUCTION

A one wheel has always been curiosity to ride and engineer for human imagination. One wheel electric bike is a travel device and a “Body Mover” which creates an eco-friendly travelling vision and transportation. The rider are under complete control and can cruise from one place to another. It is capable of running at speeds of 15km per hour. It is a consistent innovation in today’s era because its establishment is a success based on its principles like eco-friendly feature and perfect design. The dynamics and rapid locomotion of a monowheel with naturally aspirated gyroscopic effect or by electronic integrated gyroscopic circuit.[i] 2020 , a year full of pollution can be free from emissions by introducing such mono-wheel electric bikes which literally have zero emissions.

Due to increasing automobile sector millions of cars and trucks are being sold which contribute to the increase of pollution and they occupy large space areas for their use, so to overcome such problems the mono-wheel has been introduced which hardly require large space. Fuel depletion problem can be a overcome by saving energy and introducing electrical bikes.[ii] However with the help of technological advancement it is now possible to design and engineer a one wheel electric bike. A mono-wheel electric bike by name itself signifies a bike with one wheel based on electrical transmission with the help of a motor unit powered by batteries or Ultra Capacitor Hybrids. Self-balancing is to be achieved with a sensor module which is a closed loop servo system which takes input of position and orientation in fraction of seconds and accordingly powers the motor with some modified voltage signals.[iii] The forward motion of the vehicle is achieved by leaning forward along with the frame which also stabilizes the frame with principles of Inertia.[iv] A gyroscopic microprocessor based motor control system has been used to regulate motor speed and torque as per the frame angle.[v] Most of the self-balancing unicycle are commercial unit in the regulation of travel with lateral stability being provided by the mono-wheel rider.[vi] Frame, being an integral part of bike, it is important for structure to be safe to withstand various collision impact forces for safety concerns. Therefore, structure simulation of frame is necessary for bike design safety and design optimisation. It is an important and crucial step as per design point of view.[vii-viii]

Design of controller and control strategies is also an important part of our modified system. The closed control loop does all the work in control algorithm.[ix] Vehicle dynamic stability and motion control using weight transfer is a function of electronic parameters which needs to be calibrated properly for riders safety as well as proper functioning of bike. The control system is responsible for stability and ride quality.[x] To extend the variety of e-bikes and improve the production, fuel cells and petrolelectric hybrids

could be introduced which are also in the verge of development and thus improving the efficiency of the electric drive system. The usage of electric bikes has turned out to be a solution for reducing pollution to a larger extent.[xi-xii]

There is plenty of work done on bicycles, several researches on impacts and effects of environmental parameters on the performance of bicycles have been done to increase the performance of the bicycles. Ebagnale et al. explains a dynamic model for performance and also environmental impacts on a bike.[xiii] Sindhwani et al. solved the problem of designing for higher Efficiency.[xiv]Azaei explains selection of the right motor for an electric vehicle.[xv] To burgeon the sale of e-bikes it needs to be enhanced in quality, the mono-wheel is designed with frame which is light in weight when compared to conventional bikes for the purpose of efficacy. Our aim was to design, Analyse one wheel electric bike a fully function able bike for the short distance transportation of single person from one destination to another without any problem. It is electrically powered and can be driven by natural movements; forward and backwards motion should be achieved by leaning forwards and backwards. Turning is achieved by the body weight and forcing the handlebar in direction of taking turn. This bike maintain its upright position when it is in idle condition and when start's it moves forward or backward. Travelling with constant speed, it uses the body balance to make small change in the heading angle. One of the goals was to design economical bike. More specifically, the project concept is stated as follows:

“There is no throttle, the bike just needs you”

Table 1.Details of components's dimensions, specifications and cost			
Components	Dimension	Specifications	Cost(INR)
Battery	Cuboid 2*4*4	2* (12V 20Ah)	2400
Motor	Cylindrical body D8”	24V 350W	4000
Controller	Cuboid 1.5*3*3	24V 350W	1500
Arduino& Gyro	Cuboid 0.5*3*1.5	MPU6050	1000

- Collecting dimensions of various components for design.
- Collecting data of COG and Inertia for calculation purpose □ Collecting data of various components to be used in project □ Collection of data for logistics.

1. Design methodology:-

In methodology portion a flowchart shows that how the design and analysis of the frame was done, according to the requirement of our need. The data collection involve of several facts such as availability, machinability, cost, reliability, feasibility and ergonomics. The key concepts of design methodology such as the total length, height and weight of the monowheel were also taken into considerations.

1. Data Collection:-

Collecting the theoretical data from the standard research papers, Actual conditions , market survey, Design models to get deep understanding about the project.



Fig-1 Methodology Procedure

II. CAD MODEL

The CAD model design is created on solidworks software. All the components are design like (wheel, Batteries, motor, motor controller, frame, handle bar) in CAD or simulating software and then assembled. After assembling all the parts we get a proper design or a rendered idea of our project.

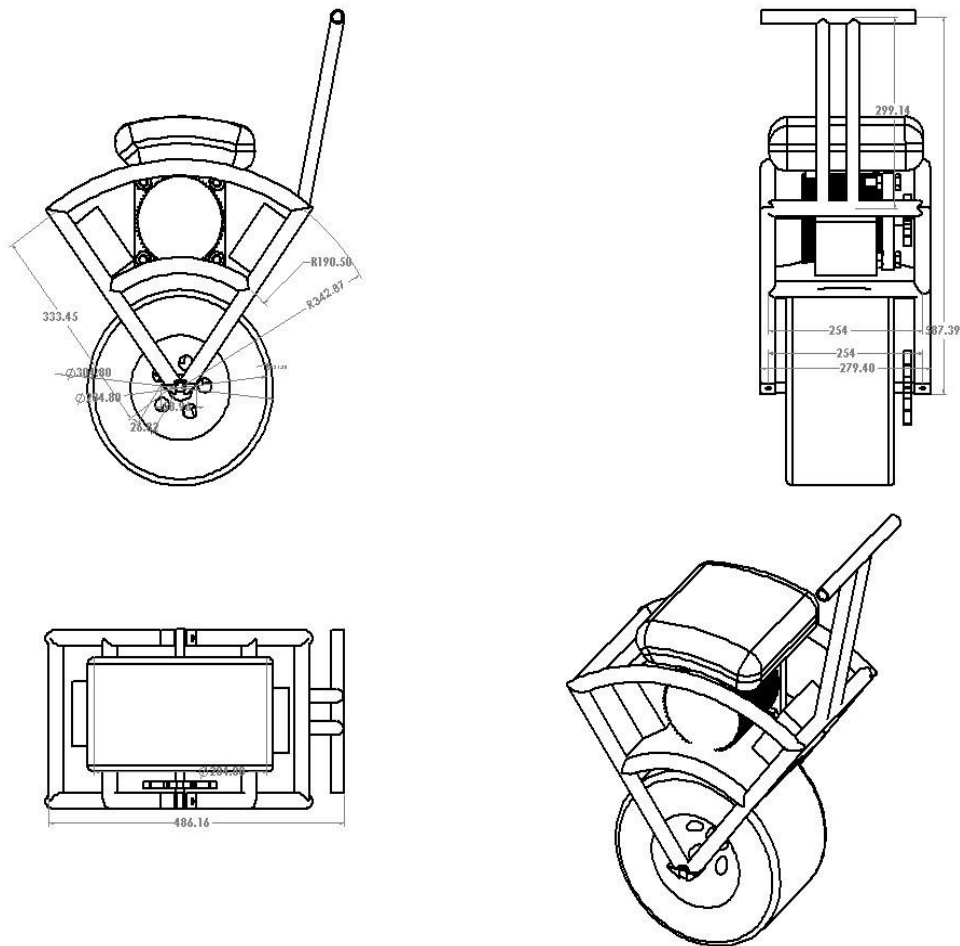


Fig-2 2D Drawing of CAD model assembly of bike



Fig-3 (a), (b) Complete Assembly of Mono-wheel bike Solidworks

III. Meshing

There are various meshing methods in ansys, that can be chosen for a suitable result for a particular

model. These meshing methods are chosen according to the complexity of our

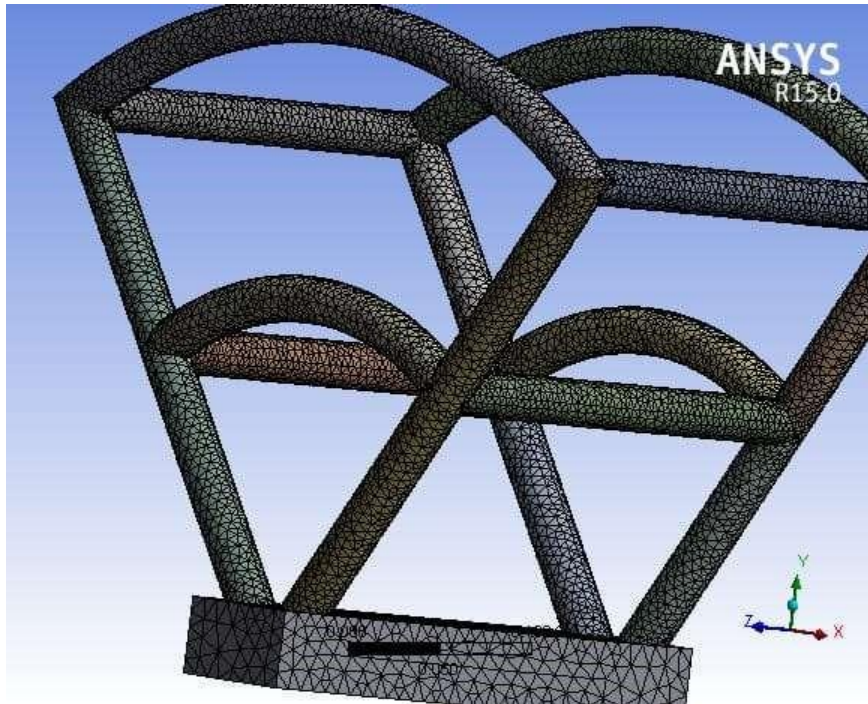


Fig-4 Meshing of Frame on Ansys Workbench 15

model. One may even chose to have multi-zonal meshing in which complex parts may have higher order meshing and simple part have lower order mesh to simplify the calculations.

In this model, tetrahedral meshing is selected since the model have simple curvature but because of sharp bents the element sizing is reduced to fine with fast transition and higher smoothing for better accuracy with the results and real world conditions.

IV. MATERIAL SELECTION

Comparing different materials for our monowheel design depending upon various facts such as weight, strength, machinability, cost,

availability, load, climatic condition, and overall outlay. Keeping the above factors into our consideration, selection of a suitable material for monowheel design which can be efficient and economical type for the frame. Steel Alloys, Aluminium and its alloys, Titanium alloy and Carbon Fiber which are much stronger and provide light weight to the monowheel were also preferred during the material selection. Comparatively, AISI 4130 Alloy Steel (1 inch diameter and 1.2 Thickness) was finally selected because of its easily availability, cost effectiveness and highly improved mechanical properties. Below are the properties of material which we selected.

Table 2.Properties of materials			
Mechanical properties	Value	Content	Percentage
Young's modulus	200GPa	Iron	97.03-98.22
Yield strength	460MPa	Chromium	0.80-1.10
Ultimate tensile strength	560MPa	Manganese	0.4-0.6
Poisson ratio	0.27 -	Carbon	0.28-0.33

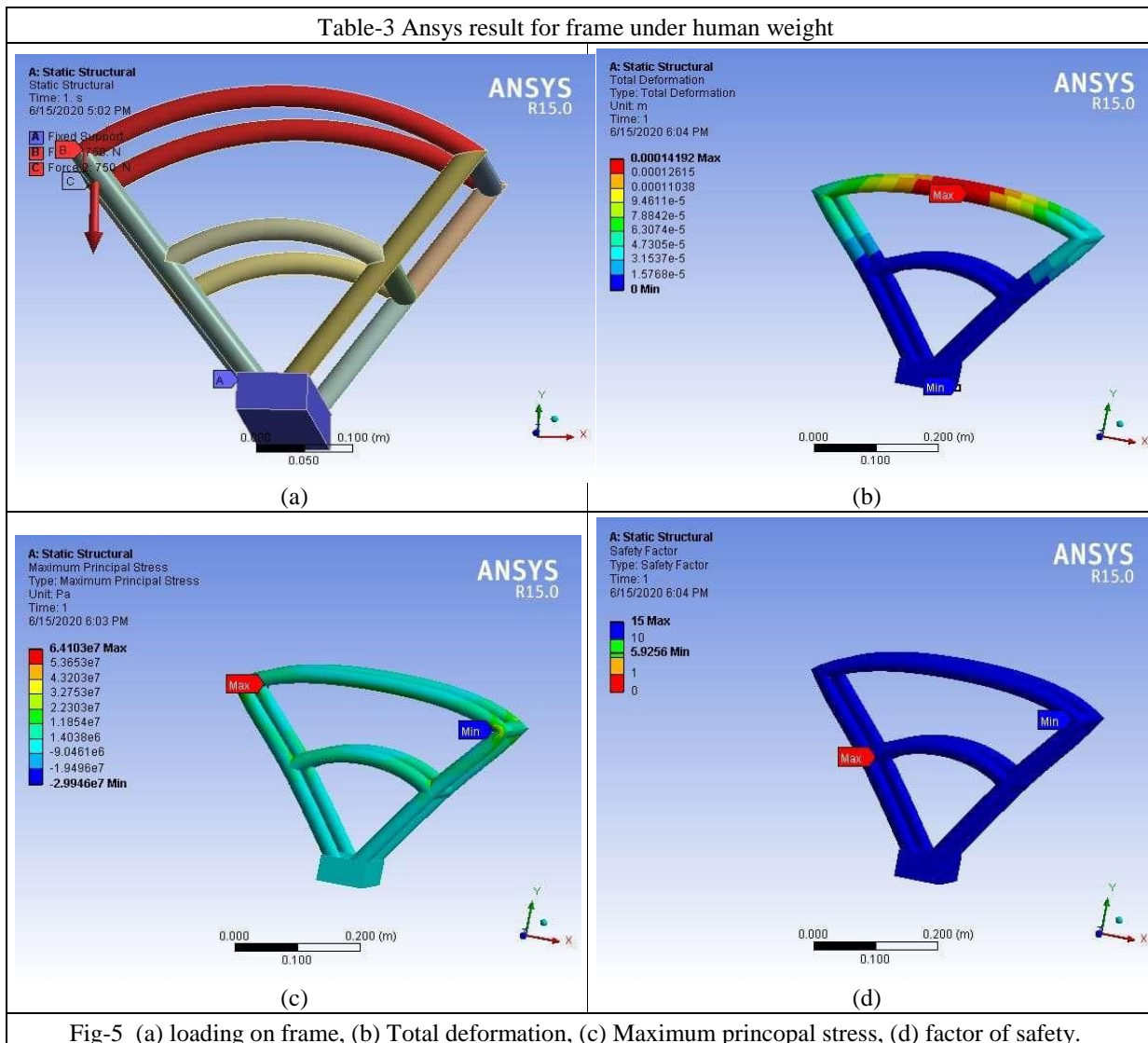
	0.30		
Density	7.85g/cc	Molybdenum	0.15-0.25
		Sulfur	0.040
		Phosphorus	0.035

V. ANALYSIS OF COMPONENTS:-

Analysis of components is done on ansys workbench. A linear static structural Analysis of frame and shaft was performed in order to assure for safe design. The frame geometry was designed on solid- works and was imported to ansys software. Engineering datas were updated as per the material selected and finally mesh was generated . The meshing was automatic but the size

was fine grade so as to get more converging results. Two cases were considered for the Analysis. The cases are mentioned below:-

- Analysis Of Frame Under Human Weight:- Human weight is considered to be action on the two top members of the frame which is about 1500N in total.



- Analysis of frame under the front Impact:-

In front Impact an impact force is made to act on the lower front portion of the frame. The Impact Force is calculate using second law of Newton i.e. ($F=ma$)and the force is about 2g.

Table 4 Results of Ansys in Front Impact in forward collision

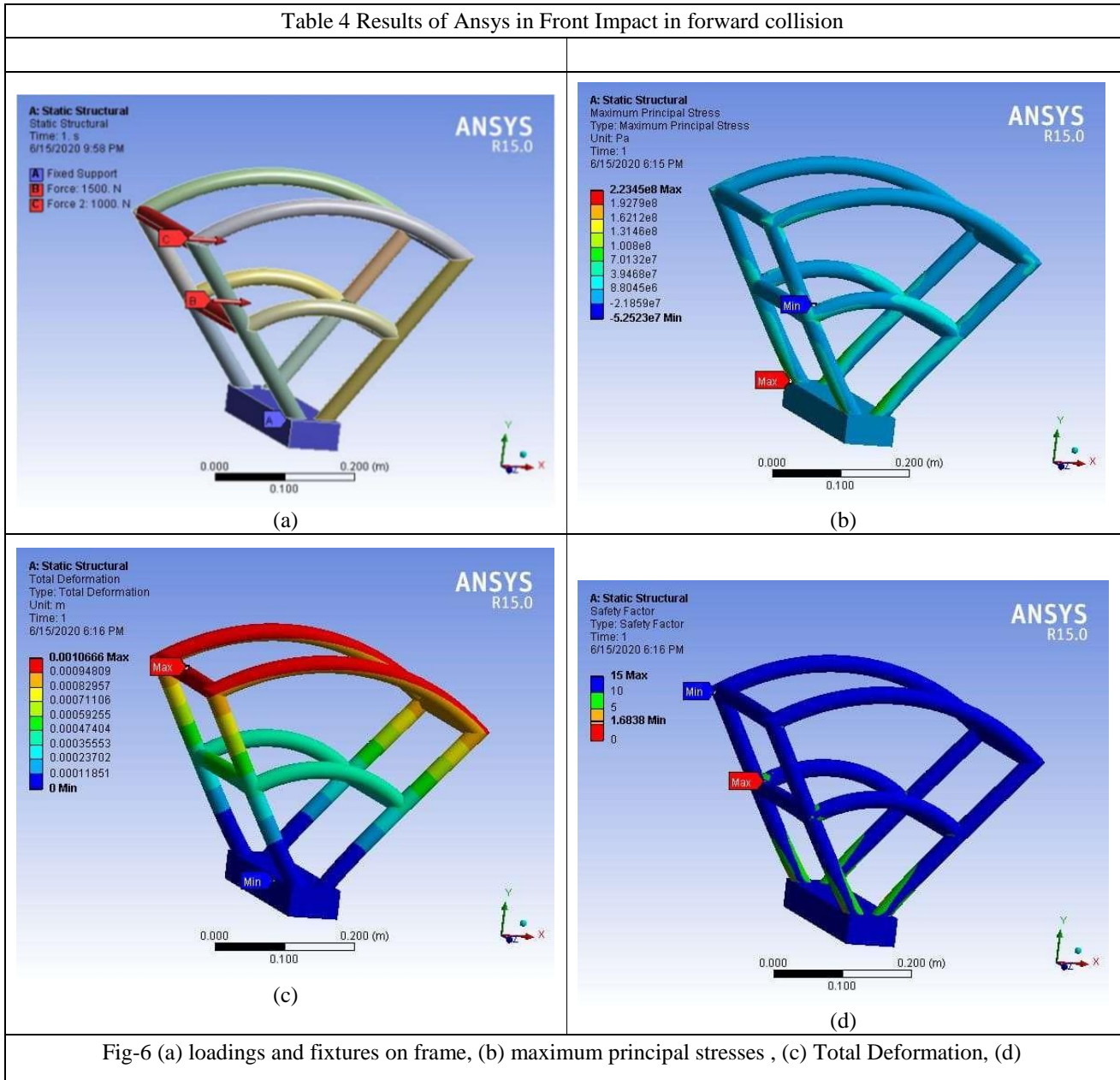


Fig-6 (a) loadings and fixtures on frame, (b) maximum principal stresses , (c) Total Deformation, (d)

- Analysis of shaft:-In Analysis of shaft, the shaft was modelled with theoretically calculated diameter with failure theory. And then analyzed on ansys using FEA with similar practical condition in static equilibrium. The weigh was put on the center

where wheels are mounted the fixed supports where selected where it was mounted on frame and the tension force on chain was also loaded on the shaft.

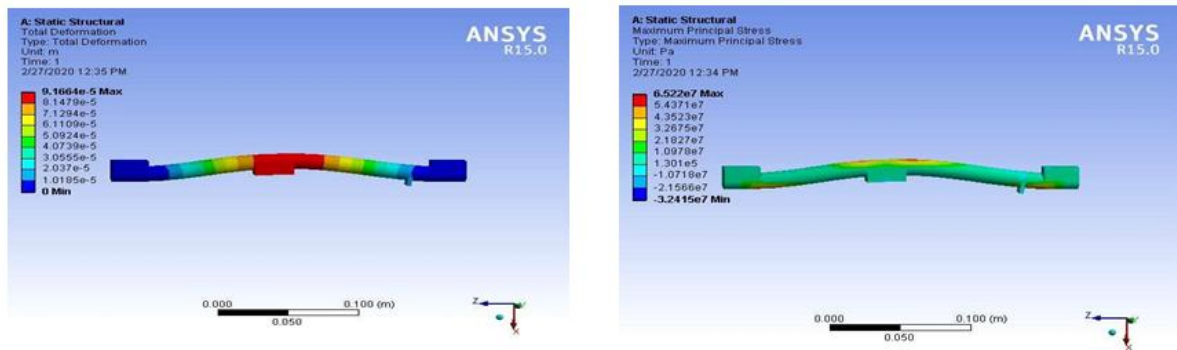


Fig-7 Structural Analysis of Shaft

- Result OfAnsys:-Finite element method was used to analyse the frame structure and shaft of the Unitrix on analysis software ansys workbench. Two cases were considered on the frame i.e sustainability of human weight and sustaining and the impact force imposed during crash. In the first case the axle was kept fixed and the members supporting seat were loaded with a force of 750 N on each member which gives a total of 1500 N.

In the second case the impact force was calculated by newton second law giving a force of 2000N acting on the lower front member while keeping axle fixed. In the analysis of shaft a shaft of theoretically calculated diameter was modelled and similar conditions were created and simulated using ansys workbench which aids in conformity of safe working of the component.

Si no.	Case	Maximum Principle stress	Total Deformation	Factor of safety
1	Loading Under driver weight	64.103 Mpa	0.14192mm	5.92
2	During Impact in forward collision	223.48 Mpa	1.066mm	1.68
3	Shaft	65.27 Mpa	0.09166	5.9

2. Components Of Mono-wheel bike:-

- DC Motor:-These are the prime movers and power converter in our Transmission line the Battery serve the purpose of energy storage whereas motor converts electrical energy into mechanical energy, transmitting it to wheels. In last decade, the development in electric vehicle technology has shifted our focus from ICE to Motors for their development and design as per electric vehicle performance. However, this project is functioning on a small 24V 350W motor to be used to power our e-bike. The motor size can however be increased considering cost opted for a small motor.
- Frame: Frame is the main part or structure on which other parts are fitted together, it also supports the motor ,So it is like the backbone of an E-bike, which carries and support whole load

including battery and all other parts. It also supports the driver in sitting comfortably. The frames are usually designed with powerful support , from that it can take up the load along with driver’s weight equally. It is made up of mild steel at defined Angles in the cross sections and is welded with specified thickness of metal sheets. The Alignment of frame has to be horizontal whether the frame is loaded or not.

- Battery:-Battery is one of the most important factor in consideration when upraise any E-bike. Range, Cost , Speed and Performance of the E-bike can be examine by which battery is used in this entire project .Generally , It is a device which produces Electrons through the Electro-Chemical Reactions & it also contains the Positive and Negative Terminals. Sealed Lead Acid Battery: A Sealed Lead Acid battery is a Re-chargeable Battery which can be

used in various electric vehicles now-a-days. The cells of the battery can have large amount of power to weight Ratio which means it has an ability to provide very high Currents. Battery's low cost and all these features, sum up the battery very captivating to use in such vehicles in which Motors are used to provide high current which is required by the motors. This battery is a lead acid battery which contains Sulphuric Acid's electrolytes congeal so that it won't spill out. Sealed Lead Acid Batteries are sealed partially, but it have air by chance gases are leaked suddenly as like by Overcharging the battery can make this happen.. These batteries can be used in small applications where they can roll down from upside. So basically, it means that the batteries with less weight holds up alot of Energy, which is very significant for E-bikes – and less weight means our E- bike can move more by charging the battery once.

Ultra-Capacitors can also be used for better performance in place of battery , but in our project, Sealed Lead Acid is used. Battery in order to reduce or maintain Cost and keep in mind other factors.

- Chain Drive:- It is an alignment of the links which adhered together with each other with the aid of the steel pins and this form of arrangement made up the chain like more surviving, hardened and provide enhanced way of conveying the Rotary Motion from one gear to another gear. For Chain Links, the chain drive has an impactful advantage which is, the chain drive can convey the Rotary Motion with the aid of 2 gears and chain over a distance whereas in order to convey motion, various gears have to be ordered in mesh in traditional.
- Sprocket:-Sprockets are the wheels with the teeth which can grip up the chain and sprockets are generally used to convey the rotatory motion between the shafts. In this, so many teeth

are present so it is totally different from the gears because the gear made up of only 1 or 2 teeth. Furthermore, they are also different from pulleys because pulley usually works in more smooth manner than sprockets.

- Motor Controller :-It is a device to control speed and torque of the motor. It can be done by changing the voltage and current in motor windings. Another way to achieve change is Pulse width modulation the speed and torque depends on the duty cycle of the voltage digital signals. Generally ,it can be structurised as type of motor being used for example-Alternating current, permanent magnet, servo, series etc. In this project, using a 250watt permanent magnet motor controller ,Generally a input is given to the motor controller using twister or a pedal throttle, which is an open system control system. This project need an electronic closed loop control system to process input to the controller as per the orientation of the vehicle. To process signal will be using a Gyroscope based microprocessor to take in of orientation and acceleration from Gyroscope and process output signals accordingly.

VI. ADVANTAGES:-

- It is very Easy to commute with low fatigue means with lack of energy.
- Cost of the Maintenance is low.
- Monowheel consumes very Less Energy.
- It is portable and it can be carried everywhere.
- Total Cost of the Monowheel unit is very low.
- Conveyable Batteries can be taken inside house.
- Due to compact size, it requires Less Parking space.
- Eco Friendly as it don't use any fossil fuels.
- It can be used for Short distance patrolling.

VII. LOAD ESTIMATION & CALCULATION:-

Table 6 Motor specification	
DC motor spec.	Value
Used for	Power train
Voltage	24 V
Current	14amp
Torque	15Nm
RPM	350RPM

Table 7 Vehicle Specification	
Maximum driver weight	100 kg
Desired top speed	12 km/h
Gross vehicle weight	25 kg
Radius of wheel/tire	5.5 inch=0.1397 m
Desired acceleration time	5sec
Maximum inclined angle	10 degree

By the second law of Newton's
 $F = ma \dots \dots \dots (1)$

Symbol	Data
V=20Km/h=5.56m/sec	Final velocity
U=0	Initial velocity
A=0.556m/s ²	Acceleration
T=10 s	time
Table 8 Data from Calculation.	

$F = (\text{Gross weight} + \text{driver's weight}) \times \text{Acceleration} \dots \dots \dots (2)$
 (from table 5)

In this equation:
 $V = u + at, \dots \dots \dots (3)$
 $(5.56 = 0 + a \cdot 10)$ so, $a = 0.556 \text{ m/s}^2$

Now Force, $F = 125 \cdot 0.556 = 69.5 \text{ N} \dots \dots \dots (4)$

Now Torque, $T = F \cdot r = 69.5 \cdot 0.139 = 9.70 \text{ N} \dots \dots \dots (5)$

Now $V = \omega r = 0.1397 \cdot 2 \pi \cdot N / 60 = 5.12 \text{ m/sec}$

Where $N = 350 \text{ rpm} \dots \dots \dots (6)$
 Power, $P = 2 \pi \cdot NT / 60 = 355.52 \text{ watt}$

VIII. DISCUSSION:-

The idea of monowheel is executed in keeping one and only factor and that is the problem of transportation.. The main motive is to get more space, when discuss about transport. This monowheel bike has the Payload capacity of

maximum 110 kg. Monowheel bike can go to the maximum speed of 19-21km/h. Working mode of the Battery is nearly about 3040minutes. The transmission system and steering system and self-balancing was analysed and as per the analysis the model was working with a better stability and control system as desired.

- Using the results which are illustrated in the paper, the overall design is safe, effective, lightweight and reliable for the needs.
- Analysis results also prove to be much safer, still various analyses such as fatigue test and buckling can be done for finding our unsafe or non-reliable result.
- Instead of the material AISI 4130 various materials can be used such as titanium, carbon fibre etc.
- The Titanium Alloy and Carbon Fibre restrain the design as it costly but it is compared to be much stronger than the material used. So depending upon the requirement the efficient one can be chosen.
- Due to the choosing of AISI 4130, the loading conditions have been restricted, so if any other stronger material has been chosen the loading conditions can be expanded.

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