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RESEARCH ARTICLE OPEN ACCESS

Chassis Design of Self Balancing E-Bike

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Abstract:

In this ever growing scenario of the world with growing population and also vehicles, the problem persists more importantly for handicapped people to drive their vehicle on these overcrowded roads and ever increasing traffic.A chassis frame is designed to advocate this problem. Chassis is an important part of an automobile which supports the body and different parts. The function of the chassis is to withstand maximum load. It should be rigid enough to withstand twist, shock and vibration. As this is the electrical vehicle we designed the chassis that has high strength to weight ratio. In this paper a chassis of a two-wheeler electrical vehicle was designed and design parameters were optimized. At the first a line diagram of the chassis was drafted based on vehicle requirements like vehicle ergonomics, aesthetics, and space requirements.For optimization of design parameters thickness of the rod, outer diameter of the rod and yield strength of the material were taken as the design parameters and optimization of design parameters was done so that a chassis was designed that has high strength to weight ratio. Factor of safety of the chassis was taken as the strength of the chassis which was obtained from static structural analysis. Results obtained from the static structural analysis were used for optimization of design parameters to get high strength to weight ratio of the chassis. Conclusions were drawn based on the results obtained so that optimal design parameters were used to build a chassis that has high strength to weight ratio. Designs are analyzed using Finite Element Analysis (FEA) software and performance characteristics are parametrically and structurally optimized.

Keywords **— Chassis, shocks and vibration, optimization, FEA.**

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1. INTRODUCTION

Automotive chassis is a skeletal frame on which mechanical parts like engine, axle assemblies, brakes, steering etc, are fastened. Automotive chassis or automobile chassis helps to keep an automobile rigid, stiff and unbending. Chassis ensures low levels of noise, vibrations and harshness throughout the automobile. The chassis is considered to be the most significant component of an automobile. Automotive frames are basically manufactured from steel which holds the body and engine of an automotive vehicle. It provides strength needed for supporting vehicular components and payload placed upon it. At the time of manufacturing, the body of a vehicle is flexibly molded according to the structure of chassis.Automobile chassis is usually made of light sheet metal or composite plastics

Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic metals. Because of their low specific gravities, the strength to weight ratio of these composite materials are markedly superior to those of metallic materials. As the prices of the fossil fuels are soar increasing, electric driven vehicles became alternate source in automobile industry. Many of the automobile industries all over the world are doing research and development in building electric vehicles. In the automobile industry quality is the main issue which retains the brand value of their industry. Two wheeler vehicles have become the way of the life for many people in many of the countries like India. As there is shortage of the fossil fuels and increase in the prices of the fuels, people find it difficult to maintain the two-wheeler vehicle. So, two-wheeler vehicle driven by electrical motors finds solution for the problem due to fuels. In electrical vehicle, energy usage is most important. Like petrol and diesel engines electric motors may not produce more power, torque and speed. In order to perform better with electrical vehicle design of the frame plays the major role. That means the chassis of an electrical two-wheeler vehicle should have high strength to weight ratio.

Chassis is a skeletal frame that supports all the components like motor, suspension, tires, brakes etc. It is the most significant component that provides strength and stability to the vehicle. Automobile frame provides strength and flexibility to the automobile. The chassis structure must support the vehicle components and distribute the longitudinal, lateral and vertical loads. Many factors like material selection, strength, weight and stiffness are considered for the design of chassis. The main objective of the chassis is to provide connection between the front and rear suspension without permanent deformation. In this study Double Cradle chassis is designed, analysed and optimized. Tubes are used to build the chassis. Tube cross-section and material property play a major role in maintaining strength and weight of the vehicle. So, outer diameter, thickness of the tube and yield stress of the material is taken as the input design parameters. All the design parameters were chosen in three levels each based on the manufacturing conditions in the market. Strength to weight ratio is the output parameter of the chassis obtained for the different level of experiments. The factor of safety is taken as the strength of the chassis which is obtained from static structural analysis.

2. PROBLEM STATEMENTS

The energy storage and usage demand is increasing day by day. Hence the usage of electric vehicle is increasing. Chassis is the backbone of any vehicle. Therefore proper design and fabrication of Electric Bike chassis is required.

The arrangement of gyroscope (for Self-Balancing), Battery, Motor and Controller and various other components in a constrained space of a motorcycle frame is becoming a challenging task. Therefore, the design of the chassis is important to ensure enough space is given to mount all the peripherals well.

In India, cities are experiencing excessive traffic and noise pollution, leading to inexorable air pollution from the last few years.

3. OBJECTIVES

- We required chassis with such a design that will be appropriate for the installation of gyroscope and battery mounting in self-balancing e-bike.
- To provide better stability to the motorcycle at high speed, high strength and rigidity by using Double Cradle Chassis Building an electric bike will help in saving fossil fuels.
- Easy on the pocket and quick charge on the go vehicle
- Eco-friendly and energy-efficient bike.

4. Methodology

4.1 Designing
Frame

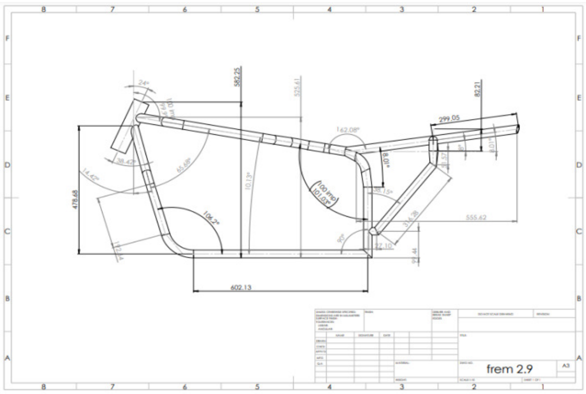

Fig 1. Chassis Design

A double-cradle frame uses two tubes running beneath the engine in order to support it instead of one steel tube on a single cradle frame.The construction handles heavy forces generated during hard braking and Provide stability at high speed. Since there are two loops on each side, "double" + "cradle" means double cradle. It is also called a feather bed frame because it is more comfortable to ride like a featherbed compared to the conventional flat frame.Double Cradle frame has high pressure bearing capacity. It is not expensive as Single Cradle. The Double Cradle frame is able to handle stress in any situation better than a single cradle.

Advantages of Double cradle chassis:-
1. Support battery swapping,
2. Protect battery in case of any accident,
3.Provide more rigidity and strength to Frame,
4.Vehicle remains more stable at high speed, etc.

Specifications	Value
Rake Angle	26^0
Steering Angle	35^0
Wheelbase	1617.61 mm
Ground Clearance	270 mm
Trail	92.79 mm
Turning Radius	1974.7371 mm

Brake Design:

1. Rear/ Drum Brake

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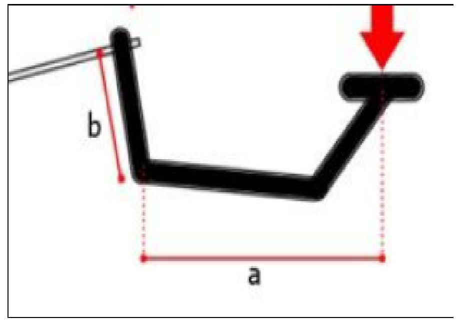

Fig 2. Brake Pedal

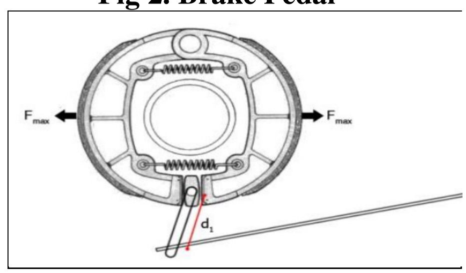

Fig 3. Drum Brake

Maximum Brake Torque T max = 197.77 N-m.

1. **Front Disc Brake**

A conventional Disc Brake system consists of a brake disc, two friction pads, and brake caliper.

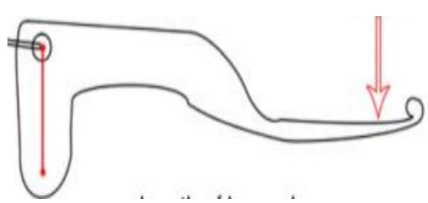

Fig. Brake Lever

L1 = Length of Lever from Pivot Point
L2 = Distance between Pivot Point and Piston
L2/L1 = 6.28
Fbp =Force output of the assembly
Fd = force applied to the Lever by the driver

Assume,
Fd = 45N
Fbp = Fd X L1/L2
= 282.6 N

A) The Master Cylinder

Diameter of Master Cylinder Dmc = 12mm
Area of Master Cylinder Piston = Amc = π Dmc2/4
Pressure Generated by Master Cylinder = Pmc = Fbp / Amc

Pressure Generated by Master Cylinder =2.5 MPa

B) The Calliper

Diameter of calliper Piston (Dcal)
= 28mm
= 0.028 m
Area of calliper Piston (Acal)
= π Dcal2/4
= 6.1575 x 10-4 m^{2}.
Pressure Transmitted to Calliper (Pcal) = Pmc
= 2.5 MPa
Linear Mechanical Force Generated by Calliper (Fcal)
=PcalxAcal
= 1537.5 N
Clamping force is equal to twice the linear Mechanical force
Fclamp = 2 x Fcal

Fclamp = 3075 N

C) The Brake Pad

The frictional force is related to calliper clamp force is as
F frictional = Fclamp x µbp
= 1230 N

F frictional = 1230 N

µbp = Coefficient of friction between the brake pad and the Disk

D) Disc

Torque Tt = Ffractional x Reff
= 140.22 Nm

Torque Tt =140.22 Nm

Torque on Tyre (Tt) = Torque on wheel (Tw) = Torque on Rotor (Tr)

E) The Tyre

Force reacted on Ground
Force on Front tyre Ffront = Tt / Rfront = 467.4 N
Force on Rear tyre Frear = Trear / Rrear = 197.77 / 0.31 = 637.99 N
Total Braking force reacted between vehicle and the ground
Ftotal =Ffront + Frear= 467.4 + 637.99 = 1105.39 N

Ftotal = 1105.39 N

F) Deceleration of Vehicle

Av = Ftotal / mv
= 1105.39/110

Av = 10.049 m/s^2

G) Breaking Distance of Vehicle

D = V2/2Av
= 14.1662/(2 x 10.049)
= 9.9848m

D = 9.9848m

H) Braking Time of Vehicle

T = V x mv / Ttotal = 14.1667 x 1 10/1105.39
= 1.409 sec

T=1.409 sec

Weight Distribution with Rider

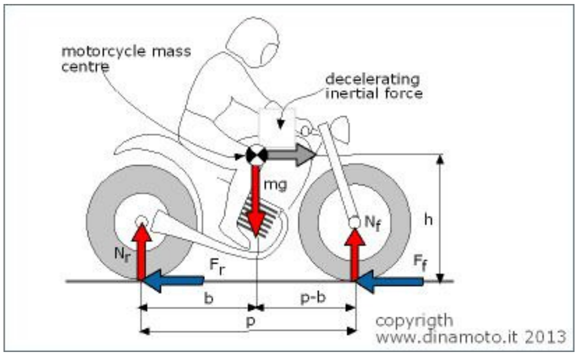

Fig4. Weight Distribution

C.G. from ground (with rider)(H)=780.51mm
C.G. from front axle (X)=792.98 mm
Wheelbase (WB)=1617.61mm
Distance of rear axle from C.G
(Y)=824.63 mm
Weight of bike with rider
(W)=1765.8N
Vertical Force at front axle
=W*y/WB
=1765.8*824.63/1617.67
=900.1747 N

Vertical Force at front axle=900.1747 N

Force at rear axle =W*x/WB
=1765.8*792.98/1617.61
=865.625 N

Force at rear axle =865.625 N

Steering Design:-
Weight distribution is the apportioning of weight within a vehicle. Typically, it is written in the form x/y, where x is the percentage of weight in the front, and y is the percentage in the back.

weight distribution directly affects a variety of vehicle characteristics, including handling, acceleration, traction, and component life. For this reason weight distribution varies with the vehicle's intended usage.
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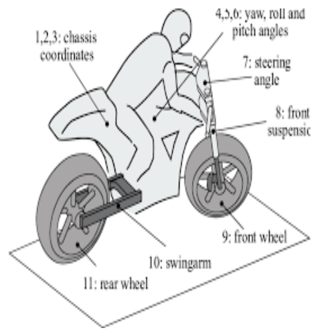


Fig5.Steering

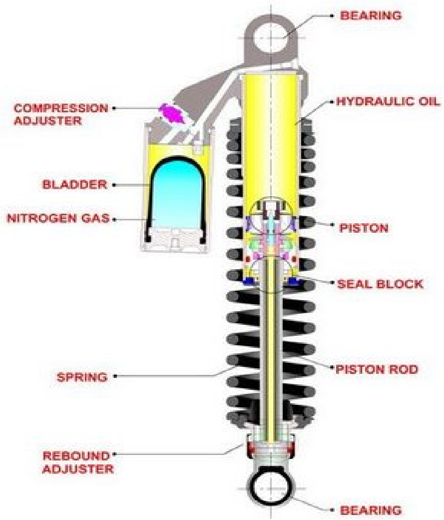
Dimension of Front wheel radius(R) =311.15 mm
Rake Angle (δ) =26^0
Fork Offset (f) =53 mm
Wheel base (WB) =1617.61 mm
Steering angle=35^0

Trail (T) = (Rsin (δ)-f)/ cos (δ)
=92.79 mm

Trail (T) = 92.79 mm

Wheel flip flop factor (I),
Head tube angle (h) =90-δ
=64^0
I=T*sin(H)*cos(H)
=36.559
Turning radius (r)
r=WB/sin(90-wheel angle)
=1974.7371 mm

Turning radius (r) = 1974.7371mm



Suspension:

Fig6. Shock Absorber

A shock absorber or damper is a mechanical or hydraulic device designed to absorb and damp shock impulses. It does this by converting the kinetic energy of the shock into another form of energy which is then dissipated. Most shock absorbers are a form of dashpot.

Purpose of shock absorber:
(i) To control the vibrations on springs.
(ii) To provide a comfortable ride.
(iii) To act flexible and to be rigid enough.
(iv)To resist the unnecessary motion of the spring

Suspension Calculation:

Material: Steel(modulus of rigidity) G = 78500
Mean diameter of a coil D=62mm
Diameter of wire d = 8mm
Total no of coils n1= 18
Height h = 220mm
Outer diameter of spring coil D0 = D +d
=70mm
No of active turns n= 14
Weight of bike = 110kgs
Let weight of 1 person = 70Kgs
Weight of 2 persons = 70×2=140Kgs
Weight of bike + persons = 250Kgs

Parameters	Values
Dimension of Front wheel radius(R)	311.15 mm
Rake Angle (δ)	26^0
Fork Offset (f)	53 mm
Wheel base (WB)	1617.61 mm
Steering angle	35^0
Trail (T)	92.79 mm
Turning radius (r)	1974.7371 mm

Rear suspension = 65%
65% of 250 = 162.5Kgs
Considering dynamic loads it will be double W = 325Kgs
= 3188N
For single shock absorber weight = w/2= 1594.125 = W
We Know that, compression of spring (δ) = K(X-X0)
C = spring index
=D/d
=7.75
= 8
(δ) = K(X-X0)
= 282.698
Solid length, Ls=n1×C=144 mm
Free length of spring,
Lf=solid length maximum compression + clearance between adjustable coils
= 469.1027 mm
Spring rate, ΔF= K(X-X0)
=1.1(3.572)
= 3.93 N
Pitch of coil, P= 26
Stress in helical spring is calculated by
τ = Kw x 8 x FD /π d3
Buckling of compression spring by share stress is X =499.519 mm
Values of buckling factor KB = 7.5 (For hinged and Spring for steel material)

Spring Stiffness K = 0.05(For hinged and spring)
Bucking Factor for hinged end and built- in end springs
Wcr = 5.719×0.05×469.102=134.139N

Dynamic Impacts of Vehicle:-
Weight transfer from rear axle to front axle
Weight transfer(WT)=av*H*Ft/(g*WB)
=546.3538 N
During braking,
Force on Front axle,
= 900.1747+546.3538
=1433.5343N

Force on Front axle = 1433.5343 N

Force on Rear axle,
865.625-546.3538=319.2712N

Force on Rear axle = 319.2712 N

Material Selection
Material IS 3074: 2005 Gr CEW 2 AD
Chemical Discipline: Group Metal and alloys
Spectro Test: Low Alloy Steel

ELEMENT	REFERENCE	OBSERVER RESULT	MU[+/-]%
C%	0.25 Max	0.0635	0.0014
Mn%	1.60 Max	0.222	0.0570
S%	0.040 Max	0.0054	0.0004
P%	0.040 Max	0.0134	0.0001

Mechanical discipline: group mechanical properties of metals

Parameters	Permissible	Observed result
Thickness [mm]		2.00
Area [mm2]		24.96
Gauge length[mm]		50.00
Yeild load [KN]		9.20
Ultimate load[KN]		10.40
Final length[mm]		59.19
Yeild strength [N/mm2]	450 min	368.59
Ultimate tensile stress [N/mm2]	550 min	416.67
% Elongation		18.38

5.2 Analysis

Structural analysis software from ANSYS provides the ability to simulate every structural aspect of a product, including linear static analysis that simply provides stresses or deformations, modal analysis that determines vibration characteristics, through to advanced transient nonlinear phenomena involving dynamic Analysis.
Various loading conditions like static loadings were carried out on the chassis with the help of software like ANSYS. They found that the stresses were maximum at joint locations, and the values of stresses were less than permissible yield stresses, as a result the design was safe. It was found that the values of stresses were less than the permissible yield stress values that meant the design was safe. CAD model of existing chassis has been prepared in Solidworks.

Stress Cases	Von Mises Stress (MPa)	Maximum permissible stress (MPa)	Factor Of Safety
Axial tension and Compression	41.842	220.8	5.276
Bending	41.842	243.2694	5.184
Bearing	41.842	276.4425	6.606
Shear	41.842	147.436	3.532

A general-purpose commercial finite element code, ANSYS is applied to conduct the static simulations. A full 3-D solid model is constructed for the static test simulation. Mixed type of elements which contain quadrilateral as well as triangular elements, have been used in analysis.

The sensitive regions have been re-meshed considering the shape and size of the parts. From the analysis total deformation and von-Mises stress were determined and are shown in the figures

Total Deformation

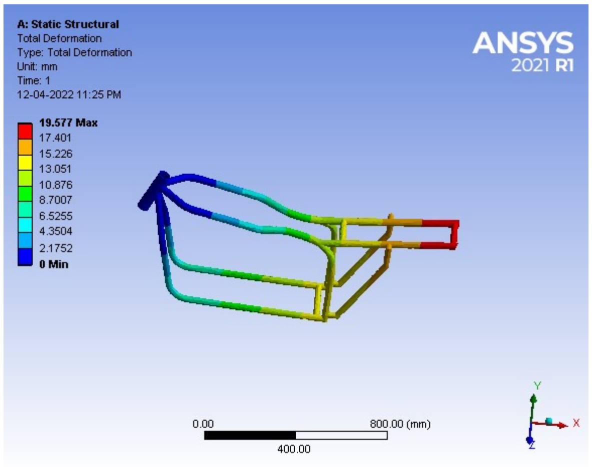


Fig6:Total Deformation

Total deformation is the deformation option that you can see all the deformation results related to your model, in three coordinates(X, Y, and Z). Direction.
In directional deformation, you can select a coordinate (X, Y, or Z) to see the deformation result of your physical model in this direction

Von-mises Stress

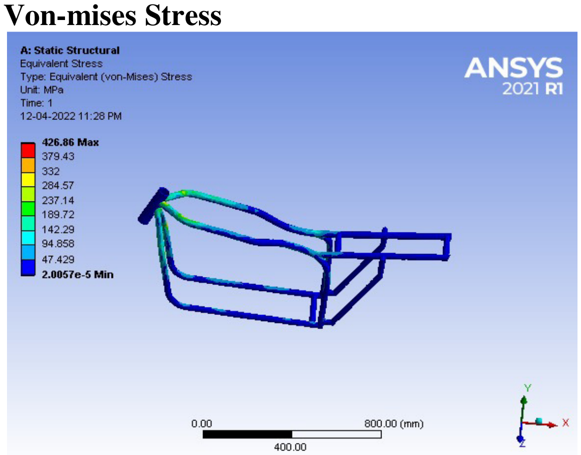


Fig7 : Von Mises Stress Analysis

The von Mises' theory states that a ductile solid will yield when the distortion energy density reaches a critical value for that material. The von Mises stress (σVM) represents the equivalent stress state of the material before the distortional energy reaches its yielding point. The von Mises stress is used to predict yielding of materials under complex loading from the results of uniaxial tensile tests. The von Mises stress satisfies the property where two stress states with equal distortion energy have an equal von Mises stress.

5.3 Manufacturing

Fig8. Cutting

Cutting: The above image shows the cutting process of CWE 2 pipe.

Fig9. Bending

Bending: The above image shows the CNC Bending done for CEW 2 pipe. It can produce high-efficiency, high-precision, and high-standard work pieces to meet customer needs.

Fig. Welding

Welding : The above image shows the CO2 welding process done on Chassis.CO2 provides very deep weld penetration, which is useful for welding thick material.As the diameter of the wire is small, the welding current density is high and thus the deposition rate is big.Good concentration of the arc realizes deep penetration.The deposition efficiency is high and formation of slag is little, which makes it unnecessary to remove slag after each pass.The arc generation rate is high, thereby lowering the welding cost and making the process to be more economical.

6. CONCLUSION:

- A frame design was adopted to provide not only better strength and rigidity but also better component mountings.
- A FEA model was created and analysis of the frame was carried out with various load cases. It was clear from the analysis that the displacement during worst load cases was well within limits.
- The essential components like the battery pack and the motor are safe from the critical forces acting on the frame.

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