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Design analysis of electric two wheeler frame

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Abstract - The motorcycle frame is one of the major components. It provides vehicle rigidity and strength when the two wheeler, is in motion with any road condition. It links various parts of the vehicle system and holds them together. The present study frame modelling is done taking into account structural and ergonomics considerations. The design analysis parameters are dependent on loads acting on the frame. The load acts through suspension (both front and rear), steering, transmission system and other sub systems. The study includes the stress analysis of the designed frame using finite element analysis software (Autodesk fusion 360) for reduced weight without affecting structural strength. Results indicate that a reduction of 20kg (33% weight) can be achieved for a conventional available frame having 60Kg weight. This overall reduced the cost is achieved by selecting proper material and making changes in design. The designed frame can sustain a load of 300Kg / 2943N with safety factor 15.

Keywords :- Electric Vehicles; Motorcycle; Design; Chassis; Steel ASTM A913; Aluminum 7075.

A. Introduction

In today's world effects of pollution and global warming have become a serious concern which is impacting the life of common man. Despite lower contributors to green house gases among different sectors today transportation sector is looked with suspicion by the environment agencies and the government. Switching from Internal Combustion (IC) based power source to an alternative energy source is the only option as the fossils reserve are also on the verge of extinction. This will lead to a sustainable transportation system that will be environmentally friendly (Gupta *et al.*, 2018). The environment degradation problem is seen in big cities where the vehicle population is large. This large number also leads to noise and parking problems. These problems can be resolved by using battery electric vehicles (BEVs) along with shared mobility. Switching to cleaner energy source will not only be beneficial for the environment it will also be economically beneficial as compared to high prices of petroleum products. For many governments and vehicle manufacturers around the world, developing cleaner alternative fuel and power systems has become a priority. The power source of BEVs is rechargeable batteries, the range and the power of these vehicle are thus influenced by the battery chemistry and its capacity. In the present study analysis is made on bobber chassis which is a modified version of a Double-Cradle cruiser where extraneous parts are removed to simplify the design for reduced weight.

BEVs in India, came with challenges that might adversely affect the existing system of infrastructure. One issue is the availability of “electricity” (Chandra and Minal, 1984). The initial cost of electric vehicles is another factor that hinders in its wider adoption. India currently stands at forth position in car sales globally and common mans budget cars form the major portion of this sale. With the advancement in technology the EVs will be well adopted by the consumers as can be seen from the sales of OLA brand of two wheelers. Once consumers know the financial benefits involved with the usage of EVs pace of adoption will become fast. (Goel, Sharma and Rathore, 2021) (Khichadia, 2015)

BEVs have less components as compared to IC engine-based vehicles thus reduced weight inspires designers to relook the existing design. In the present research work is done on two-wheeler chassis design with a proper material selection for reduced cost. Findings of the study suggest that if correct material is selected for a properly selected chassis. Than the same can reduce the initial cost of electric two wheeler.

DESIGN PARAMETERS*:*

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If the light frame is to be achived than it should have advantages of both Chassis frame i,e trellis and perimeter frame. Light weight, more strength, with high stiffness factor are some of the advantages that are associated with trellis frame at the same time compactness, small wheel base and a small flex (that helps in high speed cornering) are the plus points associated with perimeter frame. A combined unit will thus have more stability and agility. The complete mass / weight of the system acts upon a point called as centre of gravity (CG). At this point gravitational force acts. (Amjad et al., 2011). Lower the CG more will be the vehicle stability. The distance between the axis of rotation of front and rear wheel is called wheel base. Longer wheel base has increases straight line speed while its shorter value help in cornering stability.

Trail increases the steering stability with reduced turning radius. This also helps in better turning to the driver during cornering. Angle between vertical axis drawn perpendicular and front forks is called rake angle.

STRUCTURAL ANALYSIS:

One part of Finite Element Analysis is Structural Analysis. Effects of steady loads and forces on a structure are measured through structural analysis. Steady inertia loads and time varying loads are also taken care of by this analysis. Time varying load are covered into approximated equivalent loads in a stationary condition. This analysis comprises of strains, stresses, forces and displacements in structures or its subparts under specified load. (Paramasivam, Subramanian and Mathai, 2020). Steady-state forces comprises of forces due to gravity or rotational velocity, displacements and temperatures for thermal strain.

The analysed chassis is opened in the fusion 360 software which is a cloud-based 3D modelling software, This is used for product design, manufacturing and structural analysis. The step format solid model is opened in fusion 360, and material (Steel ASTM A913 and Aluminium 7075) is specified.

Table 1: Vehicle dimensions:

Length	**2,240mm**
Width	800mm
Height	1025mm
Rider weight(assumed)	100kg
Battery weight and other components	40kg
Mounting points	6
Pipe Dimensions	21.3 mm x 2.3 mm and 26.9 mm and 3.2 mm.

Assumption made

.

Rider weight (W) = 100 kg. g = 9.81

Force acting on saddle pipes = ƅØ·˥

= 211Ø:/92

= 981N

So, 981N battery weight is acting on six mounting points(n) Battery Weight(w) = 40Kg

Force acting on battery mounts = ᒧ ØJ·Ø·˥

= 51Ø7Ø:/92

= 2354.5N

Saddle pipes takes forces equal to 1000N. A 2400N is acting on the mount. Single mount bears a force of 400N.

MATERIAL SELECTION:

This design demonstrated in Fig (1) and Fig (2) is developed with the pipes dimension: 21.3 mm x 2.3 mm and 26.9 mm and 3.2 mm. The materials used for the chassis is Steel ASTM A913 and Aluminium 7075.

The frame member on which the force acts and its point of application are two important parametes for analysis.

The geometrical and physical boundary conditions are different as such there are no standard range of values for forces acting on the frames (Rege *et al.*, 2017).

The data given below is considered for analysis of different forces acting on the frame of a two wheeler. The forces were first calculated in Newton then converted to G – Force. This is done by dividing the same with the weight of the vehicle. This gives us a standardized value. This will further help in comparing with forces that are acting on the frame of other vehicles

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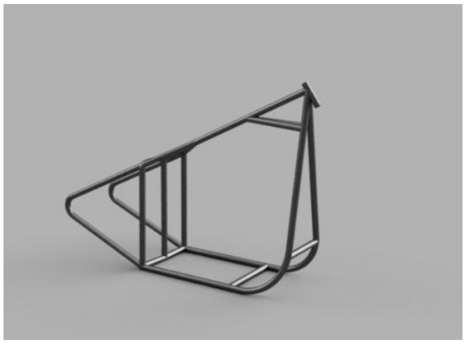


Fig (1): Steel ASTM A913 chassis

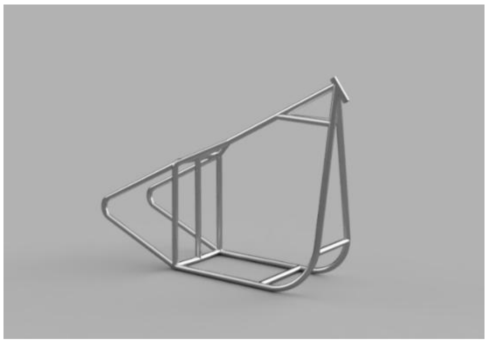


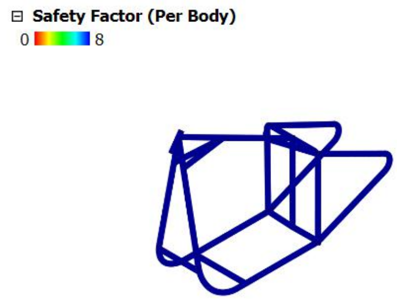
Fig (2): Aluminium 7075 chassis

ANALYSIS OF FORCE ACTING ON FRAME:

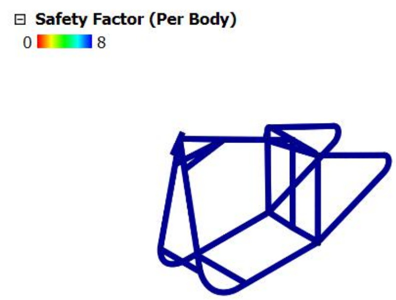
Vehicle and passenger weight.
The frame takes weight of all the components in down wards diection.(Patil and Chikkali, 2020)
Bump force:
When the two wheeler strikes a bumb or pases through rough tarrain a force will act on the frame.
Lateral force
While taking turns this type of force is generated. The force has the same value as that of centrifugal force produced during cornering.
Brake force:
Brake force is applied on the front of the frame. The same comes into play when brakes are applied. (Patel, Patel and Patel, 2012) .
Weight transfer:
This comes in play during acceleration and braking. The load from the rear is transferred to the front while braking and the opposite effect takes place while accelerating.
Impact Force:
When a sudden impact is made through any direction an impulse force is extended on the frame which is responsible for deformation.

SAFETY FACTOR ANALYSIS:

Safety factor analysis (Please check) is the ratio between the strength of the material and the maximum stress of that part. It indicates if the design is likely to survive unharmed, bend or break when subjected to the load.
Minimum safety factor on the legend will be 3 with maximum being 9. Table (1) shows the maximum and minimum values for safety factor analysis.



Fig(3):Steel chassis



Fig(4): Aluminium chassis

Table(1):

Material	Minimum	Maximum
Steel	14.98	15
Aluminium	6.29	15

Maximum stress for the test came out to be 15 whereas minimum 5.534 for steel
Maximum stress for the test came out to be 15 whereas minimum 4.627 for aluminium
The above analysis is done on 2943N load

VON MISES:

Von mises the value which is used to determine whether the material will yield or fracture. According to yield criteria if the von mises stress of a material under load is equal

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or greater than the yield limit under simple tension then the material will yield. Table (2) shows the maximum and minimum values for Von Mises

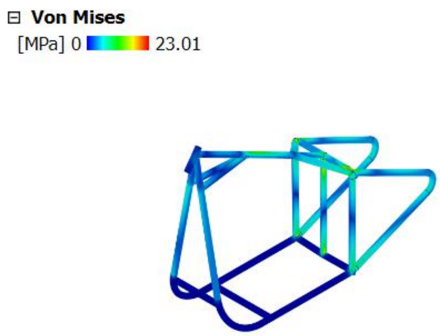


Fig (5):Steel chassis

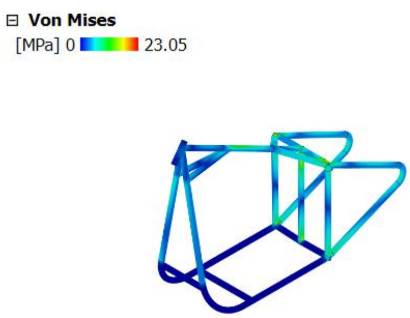


Fig (6): Aluminium chassis

Table (2):

Material	Minimum	Maximum
Steel	2.302E-13 MPa	23.01 MPa
Aluminium	3.044E-13 MPa	23.05 MPa

1st principle:

Table (3) shows the parameters for minimum and maximum values for the 1st principle

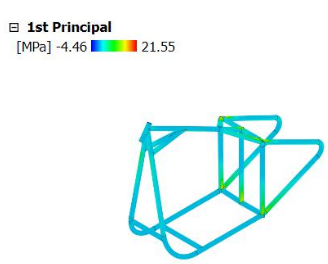


Fig (7):Steel chassis

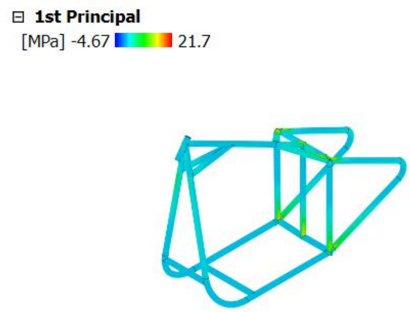


Fig (8): Aluminium chassis

Table(3):

Material	Minimum	Maximum
Steel	-4.457 MPa	21.55 MPa
Aluminium	-4.669 MPa	21.7 MPa

3rd principle:

Table (4) shows the maximum and minimum values for 3rd principle

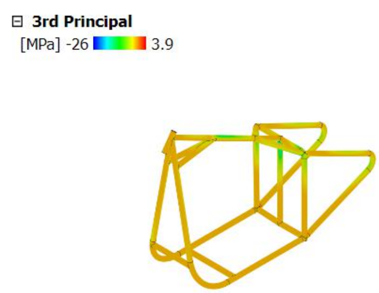
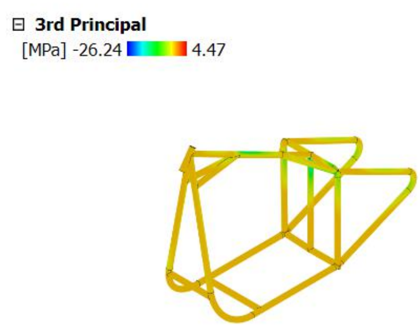


Fig (9):Steel chassis



Fig(10): Aluminium chassis

Table (4):

Material	Minimum	Maximum
Steel	-26MPa	3.905MPa
Aluminium	-26.24MPa	4.469MPa

The above analysis is done on 2943N load

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FINITE ELEMENT ANALYSIS:

According to (Yetmez, 2016) Finite element analysis (FEA) is applied for getting results.

Displacement Test Analysis:
It is a plot that shows the amount the model that is moved relative to the original position. Table (5) shows the different values and parameters for displacement test analysis

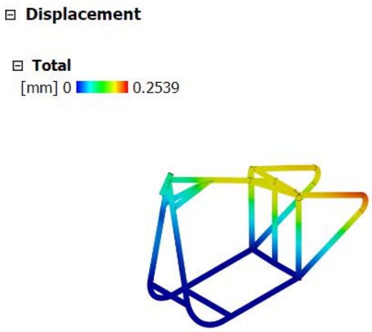

Fig (11):Steel chassis

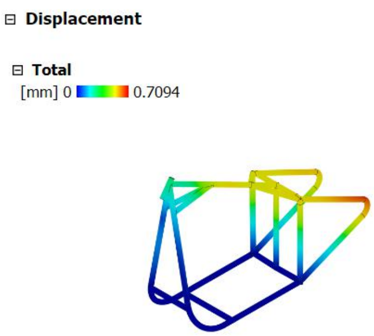

Fig (12): Aluminium chassis

Table(5):

Material	Minimum	Maximum
Steel	Total=0mm X= -0.219mm Y=-0.02109mm Z= -0.1352mm	Total=0.2539mm X= 0.01484mm Y= 0.1185mm Z=0.0267mm
Aluminium	Total=0mm X= -0.6119mm Y= -0.05875mm Z= -0.3775mm	Total=0.7094mm X=0.04171mm Y=0.3311mm Z=0.07454mm

The above analysis is done on 2943N load

Reaction Force:
It is a plot that shows values which are much higher and lower than the applied load

Table(6):

Material	Minimum	Maximum
Steel	Total= 0N X= -513.4N Y= -241.3N Z = -396.9N	Total= 878.3N X=305.7N Y=391N Z=595.8N
Aluminium	Total= 0N X= -533N Y= -240.1N Z= -389.9N	Total=902.1N X=308.9N Y= 386.7N Z= 616.6N

The above analysis is done on 2943N load

RESULT AND CONCLUSIONS**:**
The frame is prepared by design software taking into account the design requirements of a two wheeler. A bobber two wheeler frame design was selected.
This design provided better strength, rigidity, good component mountings and freedom of design. An FEA model was created and an analysis of the frame was carried out with the load case. The analysis findings are that a reduction of 20kg (33% weight) can be achieved for a conventional available frame having 60Kg weight. This overall reduced the cost is achieved by selecting proper material and making changes in design. The designed frame can sustain a load of 300Kg / 2943N with safety factor 15.

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