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Electric Vehicle Chassis Design and Structural Analysis by using CAD and CAE Techniques

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***Abstract*: Electric drive vehicles are becoming an attractive alternative to combustion engine cars with global gradual fossil fuel prices rise. To meet the performance requirements of the automobile market which is dominated by engine based vehicles, EV's design has to be light weight, durable and have long range. Chassis of the vehicle has considerable weight apart from batteries. A light weight and optimised design of chassis has been developed without compromising on adequate stiffness and strength. Various materials have been considered and evaluated. With the advancement of CAD & CAE tools design process has been simplified and virtual validation of the design can be carried out. Chassis is modelled in Solidworks, Finite Element modelling (meshing) is carried out in Ansys Workbench and analysed using Ansys Solver.**

***Keywords*: Electric Vehicle, Chassis Design, Design for Strength, CAD-Solidworks, CAE, Ansys Workbench**

1. Introduction

The expanded capabilities of future engineers will help the zap of transport implies utilized in India. The capability of jolt is colossal, zap can enhance the air quality and create new business openings in India. With adequate capabilities, Indian engineers can build up claim items for neighbourhood organizations. The items for electro-portability exits, yet are not constrained to electrical vehicle design, fabricating, charging, and infrastructure. Different open doors exist likewise in administrations identified with electro-versatility, for example, web search tools for charging stations, vehicle-to-vehicle correspondence, and other administration related smart phone and portability. Critical open doors exist, especially in light weight vehicles, for example, three wheeler auto-rickshaw and bikes. Electrical vehicles are blasting in Western Countries, California and Norway being the early connectors for the zap of transport. Nations with vast cities and high populace thickness have begun to think about electrical vehicles as an answer for air quality issues in their significant cities. China has been a trailblazer in jolting bikes utilized in substantial cities.

So also, it is likely Indian vehicles will charge in not so distant future. Zap of electric vehicles will have significant effect in the smart cities arranged in India. Chassis of auto is the foundation of vehicles and incorporates the primary part frameworks, for example, the axles, suspension and is typically subjected to the weight of lodge, its substance, and inertia forces emerging because of harshness of street surfaces and so forth (i.e. static, dynamic and cyclic loading). The stress investigation is critical as it will assist us with analyzing the most extreme load that can be connected on the vehicle. The load point is therefore imperative with the goal that the mounting of the segments like motor/batteries, suspension, transmission and more can be resolved and improved.

2. Baseline design of electric vehicle chassis

Existing electric vehicle chassis structure is reverse engineered by using tools like rulers, vernier callipers, and laser measurement tool. Measurements are converted into three dimensional CAD design geometry.

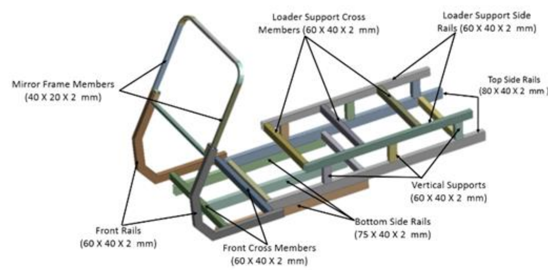

Fig. 1. Baseline design of vehicle chassis

3. Modified and optimized design of electric vehicle

Chassis structure is modified by altering the double ladder chassis into single ladder chassis. Altered the arrangement of cross rails, side rails and battery casing. Front suspension is made structurally strong by attaching.

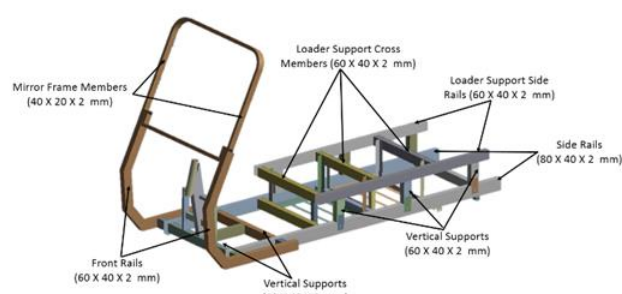

Fig. 2. Modified design of vehicle chassis

Fig. 3. Front Suspension of existing vehicle

Fig. 4. Front Suspension of modified vehicle

4. Calculations

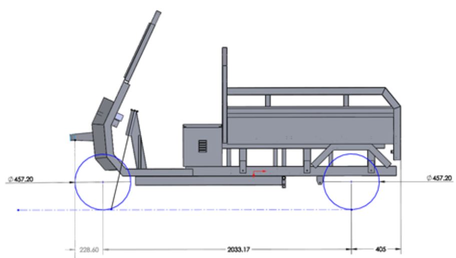

Fig. 5. Chassis beam calculations

Length of the beam (L) = 2527.00 mm
Side bar of the chassis (a) =228 mm
Rear Overhang (c) =405 mm
Wheel Base (b) = 2033.17mm
Material of the chassis, E = 200000 N/mm^2
Poisson Ratio = 0.3
Capacity of Vehicle = 9810 N
Capacity of Vehicle with 1.25% = 12262.5 N
Weight of body and differential = 2746.8 N
Total load acting on chassis = 15009.30 N
Load acting on the single frame = 7504.65 N

Calculation for Reaction:

Consider chassis of the vehicle a simply supported beam with uniformly distributed load.
Load acting on entire span of the beam is 58860 N.
Length of the Beam is 2527 mm.
Uniformly Distributed Load (w) is 7504.65 / 2527 = 2.97 N/mm
Reaction Load at point 'c',
Rc = w l (1-2c)/ 2b
= 3162.82 N
Reaction Load at point'd',
RD = w l (1-2a)/ 2b
= 4335.83 N

Calculation for Shear Force and Bending Moment

Shear Force calculation

V1 = W x a
= 678.89 N
V2 = Rc – V1
= 2489.92 N
V3 = Rd – V4
= 3133.07 N
V4 = wc
= 1202.76 N

Bending Moment calculation

M1 = -wa2/2
= -77597 N-mm

M2 = -wc2/2
= -243559.60 N-mm

M3 = RC ((RC/2w)-a)
= 966200.98 N-mm

Calculation for Stress Generated

Maximum bending moment generated
Mmax = 966200.98 N-mm
Moment of Inertia around the X – X Axis

Ixx = bh3 –b1h13 / 12
= 316576 mm^4

Section of Modules around the X – X Axis
Zxx = bh3 –b1h13 / 6h
= 7914.40 mm^3

Stress developed on the beam
M = Mmax /z
= 122.08 N/mm^2

5. Finite element analysis of electric three wheeler vehicle chassis

Table 1
Dimensions of channel

S.No.	Part Name	Dimensions
1	Front Mirror Frame	Rectangular Box Channel - 40 x 20 x2 mm
2	Front Dome Frame	Rectangular Box Channel - 60 x 40 x2 mm
3	Driver Seat	700 x 310 x 370 mm
4	Front Suspension	Ø44 mm pipe
5	Loader Frame	Rectangular Box Channel - 60 x 40 x2 mm
6	Battery Frame	L Angle - 30 x 30 x 5 mm

For carrying out the finite element analysis of chassis as per standard procedure first we need to cleanse the geometry to achieve the connectivity. Procedure is followed in this section. Cross section of the channels used in the chassis frame are 80 x

40 x 2 mm and 60 x 40 x 2 mm.

Geometry Model:

Electric vehicle chassis geometry is modelled in CAD software by reverse engineering methodology. Chassis structure are modelled and tabulated in table 1.

Engineering Material Data:

The material used for the required chassis cross rails, side rails are rectangular box channels with dimensions of 80 * 40 * 2 mm and 60*40*2 mm. The research was conducted to choose the best possible material. The choice of material was limited to steel as per SAE rules. The material was selected on the basis of cost, availability, performance and weight of material. The reasons for using rectangular box channel which has excellent bending and torsional characteristics. Shows Mechanical properties of Steel rectangular channel.

Table 2
Engineering material data

S. No.	Structural Steel Parameters	Value	Units
1	Density	7850	Kg/m3
2	Young's modulus	200.0	GPa
3	Poisson's ratio	0.3	-
4	Yield stress	250.0	MPa
5	Ultimate Tensile Strength	310.0	MPa

Finite Element Model of Loader Assembly:

- Chassis frame structure are assembled with rectangular box channels of standard sizes and are modelled shell elements.
- Bolt connections are represented as rigid elements.
- Welded joints are represented as permanent joints by assignment of bonded contacts.
- Driver seat mass, batteries mass, loader capacity load are modelled as lumped mass at their respective centre of gravity points.

Fig. 6. Mesh Model of Reverse engineered model

- Number of Nodes 113565
- Number of elements 102945
- Aspect Ratio (Average) 1.0833
- Jacobian Value (Average) 1.0689

Loads and Boundary Conditions

- Standard Earth Gravity (9806.6 mm/s2) is applied in Gravity direction over the entire Geometry.
- Front suspension and rear leaf spring eyes surface are assigned as Fixed support in all the conditions.
- A Load of 10,000 N (1 tonne) applied on the carrier
- A Load of 1200 N applied on front driver seat area
- A Load of 300 N each applied on battery cases

Fig. 7. Load of 10,000 N (1 tonne) applied on the carrier & Point Mass of 120 kg applied on the front driver seat area

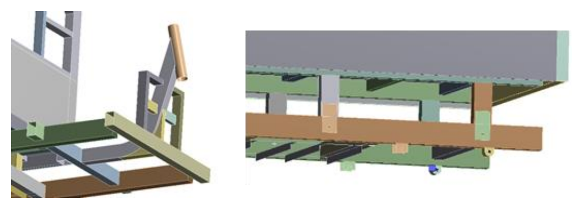

Fig. 8. Front suspension and rear leaf spring eyes surface are assigned as fixed support in all the directions

6. Structural analysis results

A. Initial reversed engineered chassis Results

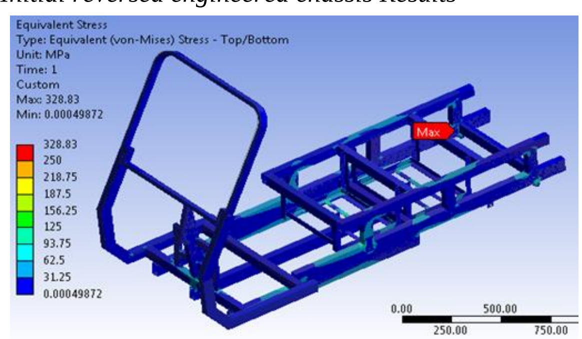

Fig. 9. Maximum equivalent stress was found to be 328.83 MPa

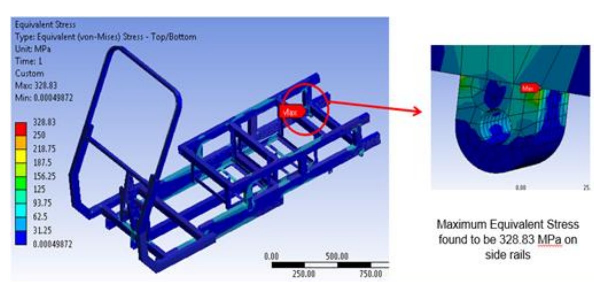

Fig. 10. Maximum equivalent stress was found to be 328.83 MPa

Equivalent stress distribution for the existing chassis during the static structural analysis is given below. Maximum stress of 308 MPa is observed at the rear suspension mounting Location but this is because of sudden transition from mounting location to tube the value can be ignored. It is a stress Concentration.

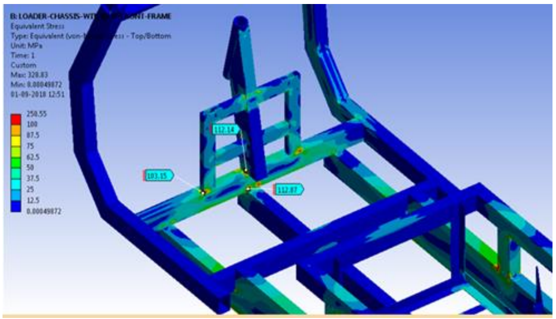

Fig. 11. Maximum equivalent distribution plot near front suspension location

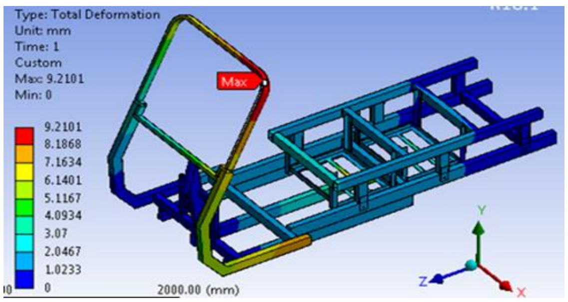

Fig. 12. Maximum deflection was found to be 9.21 mm

B. Modified Design chassis Results

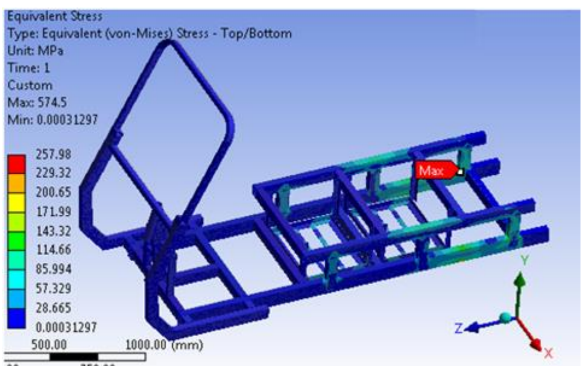

Fig. 13. Maximum equivalent stress was found to be below 240 MPa

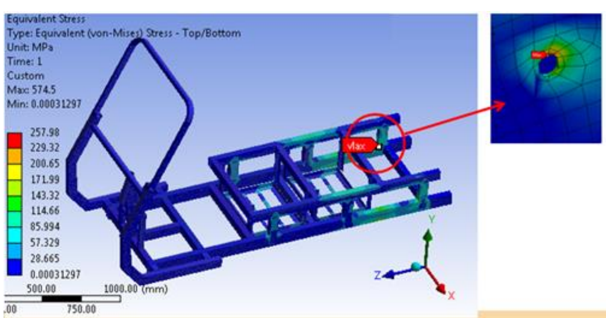

Fig. 14. Maximum equivalent stress was found to be 328.83 MPa

Maximum stress of 274.46 MPa is observed on the rear side of the frame as shown in the figure below. This is due to the reason of rigid connections are assigned in that location, which makes the elements stiff resulting in higher stresses. Hence stress generated at joint locations are neglected and stresses at other locations are taken in to consideration.

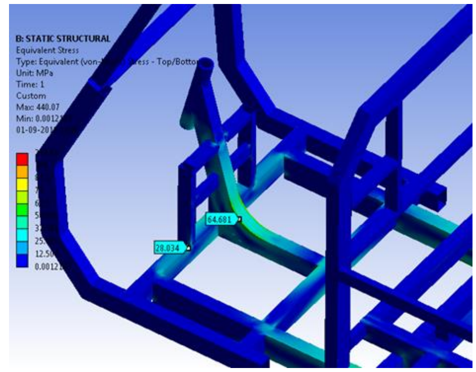

Fig. 15. Stress distribution at front handle location, stress has decreased in modified Design

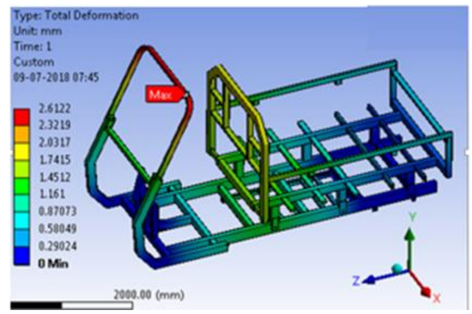

Fig. 16. Maximum deflection was found to be 2.61 mm

Table 3
Weight reduction tabular column

S. No.	Initial Weight of Loader chassis (kgs)	Optimized Weight of Loader chassis (kgs)	Change in weight (kgs)
1	118	86	32

7. Conclusion

Electric Vehicle Chassis has been developed based on the existing model. Reverse Engineering for the existing model has been carried out and 3D CAD model has been developed. Analytical Calculations for h-frame chassis with loads and boundary conditions have been performed to validate the design. Mesh model for the chassis is prepared in Ansys Workbench mechanical module. While geometry operations are performed in Geometry module of Ansys workbench. Detailed structural analysis for the Chassis has been carried out, considering self-weight of chassis, battery weight, driver weight, pay load and other miscellaneous weights and stress distributions, deflections obtained on the chassis have been reported. Design modifications and weight reductions for the existing chassis have been performed and on the stress and deflections obtained in analysis. Detailed CAD for the modified design has been prepared and structural analysis has been performed. Maximum stress and deflections obtained on the modified chassis well within the yield of the materials used. A Robust chassis for an Electric three wheeler chassis has been designed, analyzed and optimized.

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