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Design and Finite Element Analysis of Electric Vehicle Chassis

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***Abstract*: Electric vehicles are becoming more and more popular and need for efficient and reliable vehicles is rising. Chassis being the most vital part of the electric vehicle which accounts for the safety and life. 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 optimized design of chassis has been developed without compromising on adequate stiffness and strength. Various materials have been considered and evaluated. In this paper various chassis designs, design requirements and design of h-type (ladder) chassis of an electric vehicle chassis has been presented.**

Detailed CAD model of the chassis has developed based by reverse engineering the existing model, Finite element analysis has been performed to further optimize and enhance the chassis design. 3D CAD modelling has been performed in solidworks modelling software and Ansys workbench has been used for FE analysis. Analysis results and optimized design has been presented.

***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. Literature survey

A. *Ladder frame*

Ladder frame is the least complex and most established design. It comprises simply of two symmetrical rails, or shafts, and cross part interfacing them. This outline offers great shaft resistance in view of its constant rails from front to rear, however poor resistance to torsion or twisting if straightforward, opposite cross individuals are utilized.

B. *Backbone tube*

Backbone chassis is a kind of a car development chassis that is like the Body-on-frame design. Rather than a two-dimensional ladder compose structure, it comprises of a solid tubular spine (normally rectangular in cross segment) that associates the front and back suspension connection territories. A body is then put on this structure.

C. *Perimeter frame*

Like a ladder frame, however the centre segments of the frame rails sit detachable of the Front and back rails simply behind the rocker boards/ledge boards. This was done to take into consideration a lower floor container, and in this way bring down in general vehicle in traveller cars. Notwithstanding a brought down rooftop, the edge frame considers more agreeable lower seating positions and offers better wellbeing in case of a side impact.

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D. Superleggera

An Italian expression (signifying "super-light") for sports-auto development utilizing a three dimensional casing that comprises of a cage of narrow tubes that, other than being under the body, keep running up the fenders and over the radiator, cowl, and roof, and under the back window; it takes after a geodesic structure. The body, which isn't stress-bearing, is appended to the outside of the edge and is frequently made of aluminium.

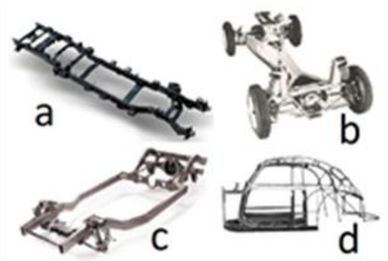

Fig. 1. (a) Ladder chassis, (b) Backbone chassis, (c) Perimeter Chassis, (d) Superleggera

3. Initial reverse engineered design of electric vehicle chassis

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

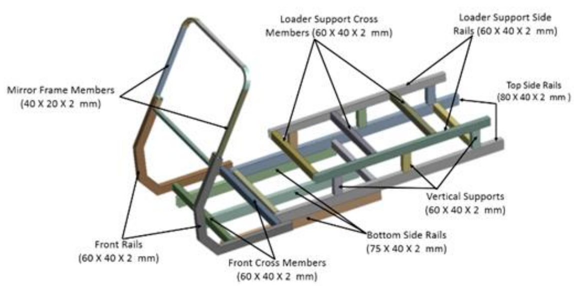

Fig. 2. Initial reverse engineered design of vehicle chassis

4. Modified and optimized design of electric vehicle

Various modifications of the chassis have been performed considering Design for manufacturing and design for assembly techniques. Some modifications have been performed based on FE analysis on the initial model. Chassis structure is modified by altering the double ladder chassis into single ladder chassis.

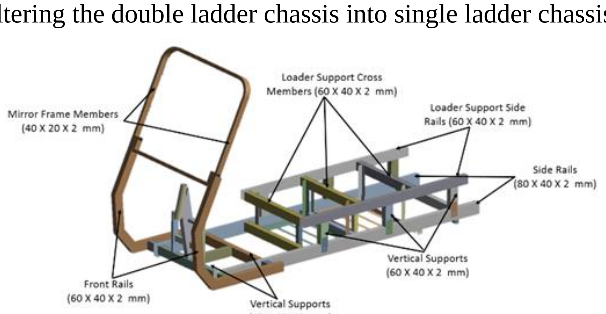

Fig. 3. Modified reverse engineered design of vehicle chassis

Altered the arrangement of cross rails, side rails and battery casing. Front suspension is made structurally strong by attaching.

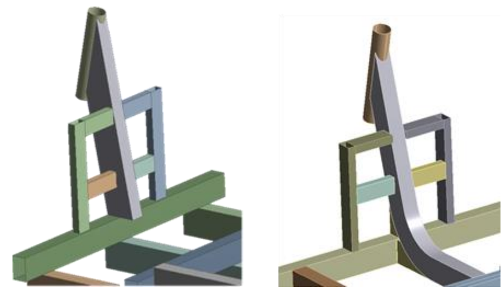
Fig. 4. Front suspension of existing vehicle and modified Front suspension of modified vehicle

5. Chassis beam calculations

Design calculations for chassis has been performed, reaction forces, bending moment, normal stress and deflection on the chassis have been calculated. H-type chassis has been considered, only half section is calculated since the chassis is symmetric.

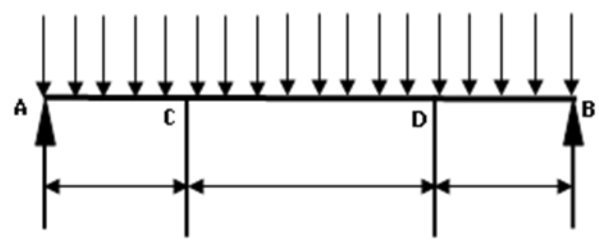

Fig. 5. Beam calculations

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’,
$R_c = w\,l\,(1-2c)/\,2b$
$= 3162.82$ N
Reaction Load at point‘d’,
$R_D = w\,l\,(1-2a)/\,2b$

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= 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 mm4

Section of Modules around the X – X Axis
Zxx = bh3 –b1h13 / 6h
= 7914.40 mm3

Stress developed on the beam
M = Mmax /z
= 122.08 N/mm^2
Maximum stress generated on the beam section is found to be 122.08 Mpa

6. Finite element analysis of electric three wheeler vehicle chassis

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.

A. Geometry model

Electric vehicle chassis geometry are modelled in CAD software by reverse engineering methodology. Chassis structure are modelled and tabulated in below tabular column.

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

B. 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/m^3
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

C. Finite element model of loader assembly

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

Fig. 6. FE model of the modified chassis

D. Loads and boundary conditions

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

Fig. 7. Load of 10,000 N (1 tonne) applied on the carrier

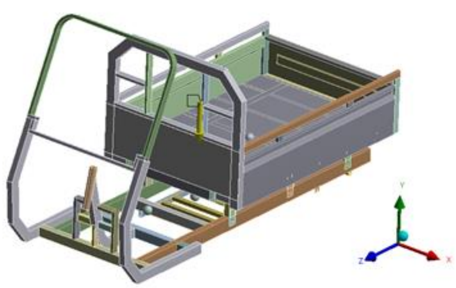

Fig. 8. Load of 1200 N applied on the front driver seat area

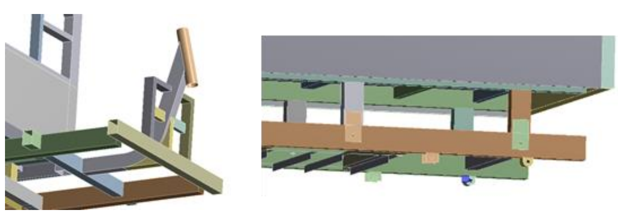

Fig. 9. Front suspension and rear leaf spring eyes surface are assigned as fixed support in all the directions

E. Bump analysis

In this analysis, acceleration of 3g is applied on the chassis of the vehicle including all load and boundary conditions considered in static structural case. Acceleration load condition is defined with respect to time (0.1 milliseconds) and profile of the load is shown below graph.

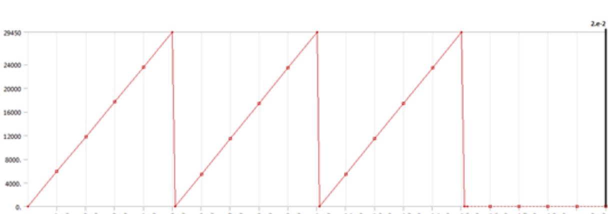

Fig. 10. Bump Profile applied on loader vehicle

7. Structural analysis results

Static structural analysis of the chassis is performed with the design load, stress and deflections obtained during the analysis are given below.

A. Modified chassis design results

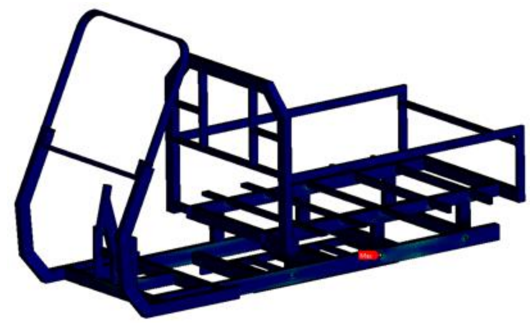

Fig. 11. Maximum equivalent stress was found to be below 240 MPa

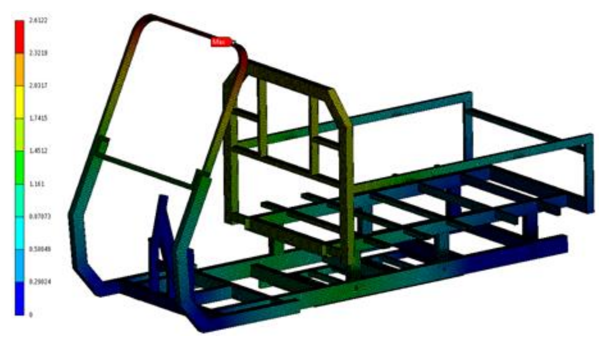

Fig. 12. Maximum deflection was found to be 2.61 mm

B. Bump analysis results

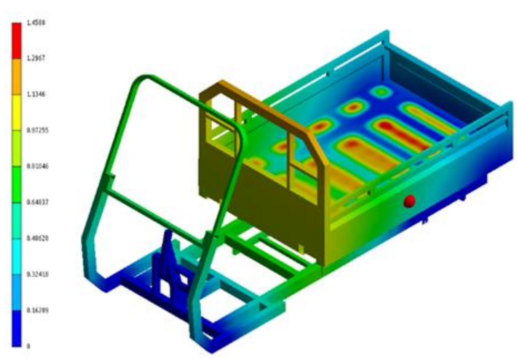

Fig. 13. Maximum deflection on loader frame was found to be 1.45 mm

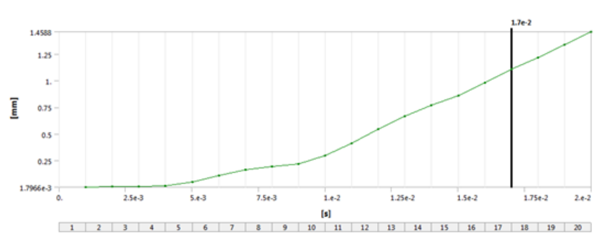

Fig. 14. Output Graphical representation of deformation w.r.t time

Table 3
Displacement data with respect to time

Time [s]	Maximum [MPa]
1.e-003	2.170
2.e-003	5.661
3.e-003	2.185
4.e-003	16.607
5.e-003	50.839
6.e-003	82.874
7.e-003	91.180
8.e-003	85.061
9.e-003	86.419
1.e-002	103.670
1.1e-002	118.440
1.2e-002	136.340
1.3e-002	152.910
1.4e-002	169.760
1.5e-002	191.670
1.6e-002	213.340
1.7e-002	225.630
1.8e-002	225.680
1.9e-002	216.720
2.e-002	203.000

Table 4
V_{on}-misses data with respect to time

Time [s]	Maximum [mm]
1.e-003	1.7966e-003
2.e-003	6.4046e-003
3.e-003	7.0067e-003
4.e-003	1.1963e-002
5.e-003	5.22e-002
6.e-003	0.11211
7.e-003	0.16323
8.e-003	0.19368
9.e-003	0.21909
1.e-002	0.29541
1.1e-002	0.41427
1.2e-002	0.54593
1.3e-002	0.66485
1.4e-002	0.76678
1.5e-002	0.85846
1.6e-002	0.97986
1.7e-002	1.1108
1.8e-002	1.2152
1.9e-002	1.3392
2.e-002	1.4588

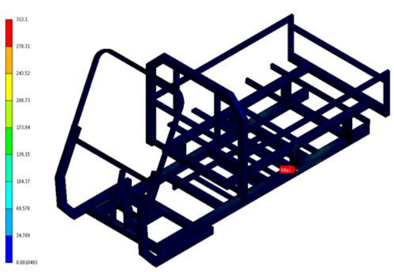

Fig. 15. Maximum equivalent stress on chassis structure is found to be 225.12 MPa

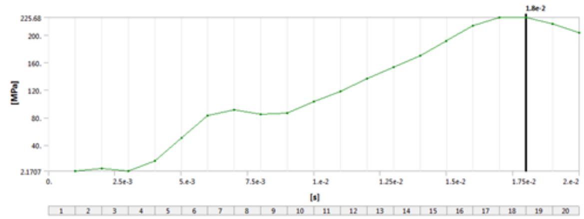

Fig. 16. Output Graphical representation of stress w.r.t time

Table 5
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

8. Conclusion

Various types of electric vehicle chassis designs have been studied and some changes in the existing model have been incorporated. Reverse engineering of the existing model is carried out successfully, design modifications have been performed. Detailed finite element analysis with bump analysis has been performed to evaluate the design. Analytical design calculations for the sections of the chassis have been performed to choose the correct channel for chassis. Considerable reduction in the weight of the chassis has been achieved and design has been validated by FE analysis.

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