Static Analysis of Chassis Frame of Battery-Operated Three-Wheeler

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Abstract— Battery operated three-wheeler or electric tricycle is raising commercial and passenger transport form in India. The Chassis refers to the lower body of the vehicle. The chassis frame is one of the principal part of an automobile usually made up of steel material. It serves as a backbone to vehicle which supports the all major parts of an automobile. The chassis frame should have enough strength to withstand against the various loads like static load, Inertia load, loads due to acceleration and braking. Also, chassis frame is to have adequate bending stiffness and torsional stiffness for better handling characteristics. This paper presents static analysis of chassis frame of L5 category battery operated three-wheeler. The chassis is modeled by using CATIA V5R20 software and the static analysis (FEA) is performed in ANSYS software. The parameters checked in static analysis are the deformation of chassis frame under maximum loading and maximum induced equivalent stress under static condition.

Keywords: Chassis frame, static analysis, FEA, Deformation, equivalent stress

I. INTRODUCTION

India is most crowded and densely populated country and ranked 2th place in highest population in the world following to the China. From the last two decades the population of petrol/diesel vehicle is also increased in local and commercial transport in every city in country. Because of this increased vehicle population most of the cities and town are highly polluted. The pollution is in terms of air and noise. [4] Now this pollution is started affecting to human life and environment in many ways like global warming, sea level increase, etc. So, a battery-operated three-wheeler is a one prime non-polluting and silent transport medium for urban and rural transport system to India which will be major substitute for petrol/diesel powered vehicles.

An automotive chassis is one of the important and integral part of any passenger/commercial vehicle. The chassis frame provides necessary supports to the various subsystem of vehicle like suspension system, braking system, steering system, etc. The chassis frame usually refers to lower body of the vehicle. The chassis frame is made up of long side members connected with series of cross members. Also, the member in vertical plane used to support steering system is important part of chassis frame. The chassis frame should have enough strength to withstand various static and dynamic loads conditions without undue deflection and distortion. [3] The weight of the chassis frame should be kept as minimum as possible without any compromising its strength and stiffness.

II. BASIC CALCULATION FOR CHASSIS FRAME

Design of chassis frame is one of the crucial steps in designing a vehicle. The chassis frame design exhibit outlook of vehicle which are like shape and size of vehicle, strength and safety of vehicle, stability of vehicle, etc. [5] The basic calculation of chassis frame gives the maximum stress generated under loading and the amount through which the chassis is going to deflect at static condition. Some input data is necessary to carry out this calculation are like,

The type of material and its grade is need to be fixed to incorporate its property values in calculation like Density, Yield strength, Modulus of elasticity, Poisson's ratio, etc.

Defining the overall dimension within which chassis frame is need to be designed.

The cross section and its dimension of defined material is required to select.

The overall dimensions of the chassis frame are given in following table

No.	Description	Dimensions (mm)
1	Overall length of chassis	2050
2	Overall width of chassis	1200

Table 1: Chassis dimensions of L5 category battery operated three-wheeler.

The loading on chassis consists of passengers including driver, seats, passenger, luggage, batteries. The weight of each component on chassis frame is given in following table.

No.	Component	Weight (kg)
1	Driver	68
2	Battery	70
3	Passenger	204
4	Seats	18
5	Luggage	40
6	Chassis and body	150

Table 2: Weight of the component

Material properties of chassis frame is given in following table.

Properties	Material
Grade	IS 2062
Modulus of elasticity (E)	200 GPa
Poisson's ratio (μ)	0.260
Density(ρ)	7850 kg/mm³
Yield strength	250 MPa
Ultimate strength	410 MPa

Table 3: Mechanical properties of material.

A. Calculation for Reactions:

Chassis is simply clamp with Twin fork shock absorber at front and rigid axle suspension (Leaf spring) at rear. So, Chassis is a Simply Supported Beam with uniformly distributed load. The total mass acting on chassis at static condition is 550kg. Taking factor of safety is 1.5 for this design, therefore the total mass becomes 825kg. So, the total load acting on chassis is 825×9.81= 8093.25N. As the chassis has two long members on which the total load is divided equally. Load acting on each long member is 4046.625N, Length of the Beam is 2050 mm. So, Uniformly Distributed Load is 4046.625/2050 = 1.97N/mm.

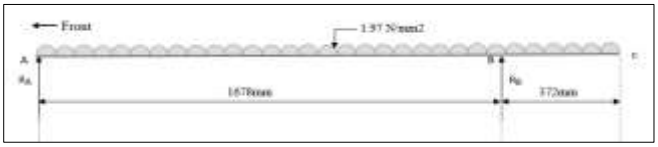

Fig. 1: simply supported beam carrying UDL

Calculating reactions at Support A and B, Taking moment about point 'B'

$(R_A \times 1678) – (3305.66 \times 1678/2) + (732.84 \times 372/2) = 0$

$\underline{R_A = 1571.59\ N}$

Now, taking moment about point 'A'

$(R_B \times 1678) – (3305.66 \times 1678/2) – [732.84 \times (1678+372/2)] = 0$

$\underline{R_B = 2466.90\ N}$

B. Calculation of Shear Force & Bending Moment.

Shear Force at $A_L = 0$
Shear Force at $A_R = 1571.59N$
Shear Force at $B_L = 1571.59 – 3305.66 = -1734.07N$
Shear Force at $B_R = -1734.07 + 2466.90 = 732.84N$
Shear Force at $C = 0$

Applying similarity of ΔPAD and ΔQBD

$$AD/PA = DB/QB$$
$$X/1571.59 = (1678-X)/2466.90$$
$$2466.90X = 2637128.02 – 1571.59X$$
$$\underline{X = 652.99mm}$$

Location D where Shear Force Changes Sign is <u>652.99mm</u> right to A.

C. Calculation of Bending Moment:

Bending moment at $M_A = 0$

Bending moment at $M_D = (R_A \times 652.9) – (1.97 \times 652.9 \times 652.9/2) = 606250.27$ Nmm

Bending moment at $M_B = (R_A \times 1678) – (3305.60 \times 839) = -136270.38$Nmm

Bending moment at $M_c = 0$

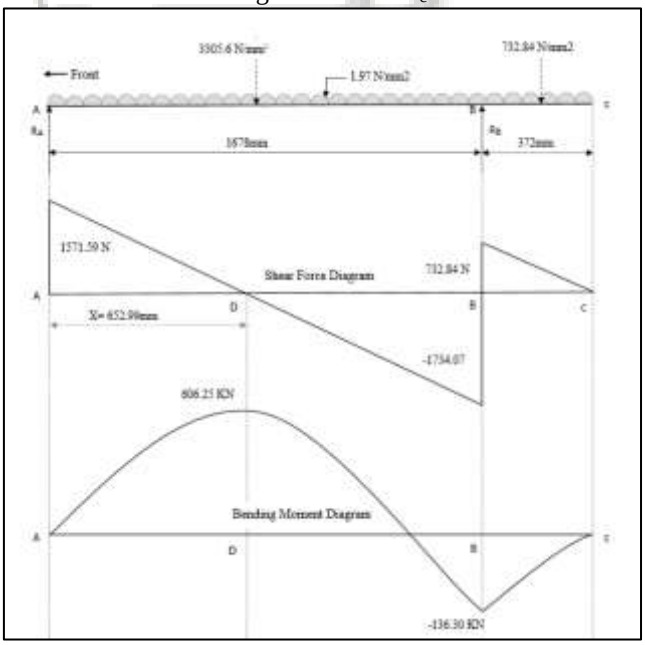

Fig. 2 Shear force and Bending Moment Diagram

D. Calculation of Moment of Inertia of Rectangular Section:

$$I = BD^3/12 – bd^3/12$$
$$I = (40 \times 60^3)/12 – (36 \times 56^3)/12$$
$$\underline{I = 193152mm^4}$$

E. Calculation of Section Modulus (z):

$$Z = I/Y = 193152/30$$
$$\underline{Z = 6438.4\ mm^3}$$

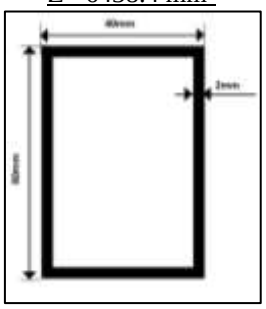

Fig. 3: Rectangular Cross Section

F. Calculation for Stress Induced in Beam (σ):

$$\sigma = M/Z = 606250.50/6438.4$$
$$\underline{\sigma = 94.16N/mm^2 < 250N/mm^2}$$

The induced stress value in beam is less than the permissible stress value, therefore the above design is safe.

G. Deflection of Chassis Frame(y):

The maximum deflection occurred in the chassis frame is calculated as follows,

$$y(EI) = (R_A \times X^3)/6 – (W \times X^4)/24 + [(W \times l^3)/24 + (R_A \times l^2)6] \times X$$

Put the value of x=0.823 in above equation.

$$\underline{y = 2.1mm}$$

That is within safe limit according deflection span ratio.

III. FINITE ELEMENT ANALYSIS OF CHASSIS FRAME

For carrying out the FE Analysis of chassis as per standard procedure first it requires to create merge part for assembly to achieve the connectivity and loading and constraining is required to be applied also idealization of parts is done on structure this will lead to faster analysis since the connected structure will not be physical but it will be a sketch with mechanical properties of mechanical structure. Procedure is followed in this section. [1]

A. CAD Model of Chassis Frame:

The CAD model of existing chassis frame is created using CatiaV5 R20 and it is imported in ANSYS as an external geometry file. The model is shown in Figure below.

Fig 4: CAD Model of Chassis Frame

B. Meshing of Chassis Frame:

The meshed chassis frame model has 61692 elements and 122990 nodes. The element is tetrahedral in shape. In order to get a better result, locally finer meshing applied in the region which is suspected to have the highest stress.

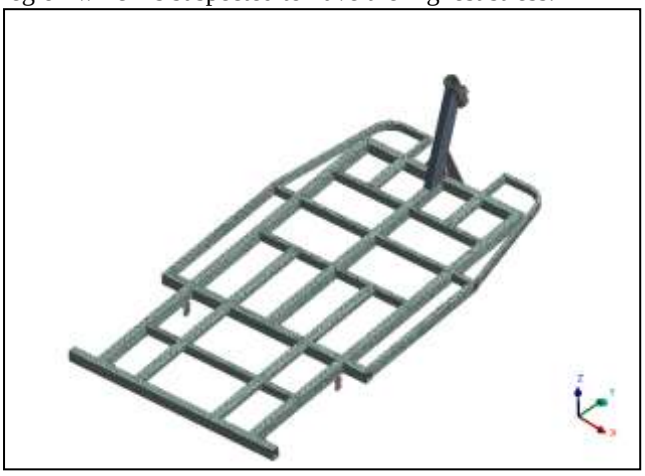

Fig. 5: Meshed Chassis Frame Model

C. Loading and Boundary Condition:

Loading involves application of various loads on chassis frame. In this case of chassis frame the load is applied vertically downward and the total load includes weight of driver, passenger, battery, luggage and weight of chassis itself. Boundary condition is nothing but the constraints given to chassis frame in order to restrict the movement of chassis part. In this case the boundary condition is given at two points, first is at neck point of front suspension assembly and second is given at rear leaf spring mounting points.

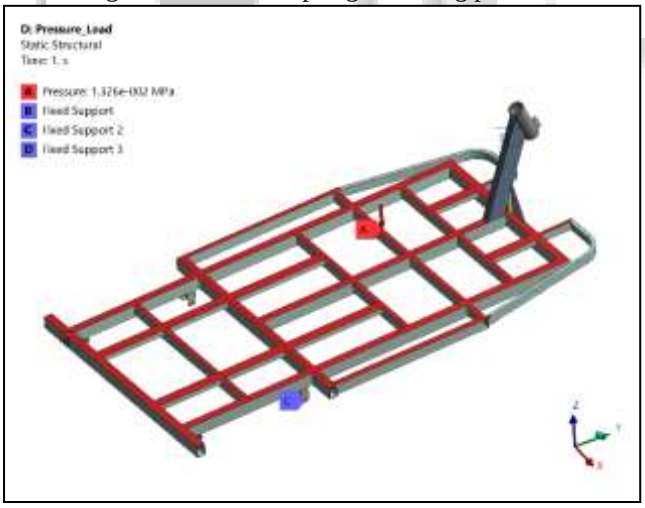

Fig. 6: Structural Load and boundary Condition for chassis frame

D. FEA Results:

Total Deformation: Following fig shows the total deformation of chassis frame under given loading condition. From the result it is observed that chassis frame got 0.764mm deformation

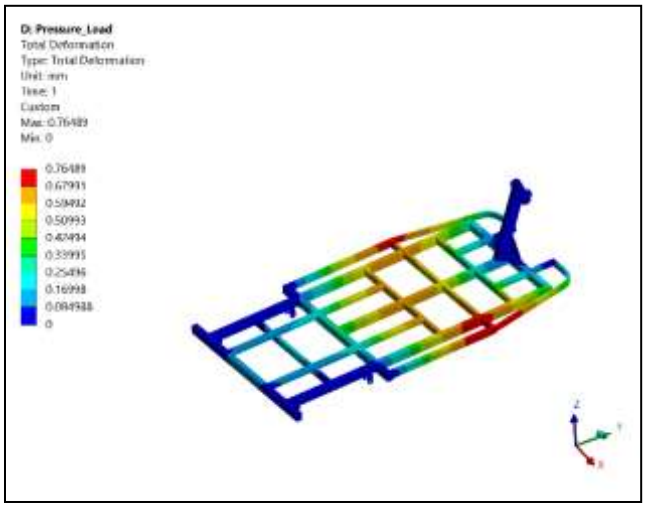

Fig. 7: Total Deformation of chassis under loading

Stress: The location of maximum Von Misses stress and maximum shear stress are at bottom of mounting bracket at front of chassis which is showed in figure below. The Von Misses stress magnitude of critical point is 137.33MPa.

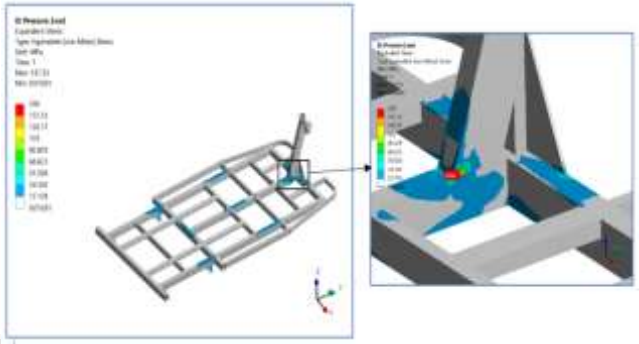

Fig. 8: Von Mises Stress Plot

IV. RESULT AND DISCUSSION

The battery-operated three-wheeler chassis was analysed theoretically by assuming the chassis as simply supported beam with uniformly distributed load provided by vehicle loading parameters like batteries, driver, passenger, luggage etc. and then the finite element method analysis was done with the help of Ansys FEA software. From above it was concluded that the total deformation occurs in chassis frame at static condition is 0.764mm. The highest stress occurred is 137.33 MPa by FEA software. The theoretically calculated deflection is 2.1mm and the maximum stress is 94. 16 MPa. The difference is caused by simplification of model and uncertainties of numerical calculation.

V. CONCLUSION

Results and methods presented illustrate how static structural analysis can be used to determine the chassis safety majors like deflection and stresses. The model of chassis is successfully designed and analysed. The design is done in Catia software; analysis is done by using ANSYS. Basic load calculations are carried out by using the concepts strength of materials and these results are compared with the results obtained through ANSYS. The FEA results and theoretical results are in closed agreement, and the design stresses are within the limits of strength of material.

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REFERENCES

[1] Vijaykumar V. Patel1and R. I. Patel, "Structural analysis of a ladder chassis frame", World Journal of Science and Technology 2012, 2(4):05-08 ISSN: 2231 – 2587.
[2] R. V. Patil, P. R. Lande, Dr. Y. P. Reddy, A. V. Sahasrabudhe, "Optimization of Three-Wheeler Chassis by Linear Static Analysis" Materials Today: Proceedings 4 (2017) 8806– 8815, Elsevier.
[3] Abhinn Bajaj, Shahnawaz Alam, Akshansh Uniyal, "Static and modal analysis of truck chassis", International conference on recent innovation in science engineering and management, ICRISEM-16, ISBN:978-81-932074-1-3.
[4] Amol Badgujar, P.A. Wankhade, "Static Analysis of Chassis Frame of Electric Tricycle", International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 5, May - 2013 ISSN: 2278-0181.
[5] Manish M. Patil, "Design and Development for Three-Wheeler Chassis", International Conference on Emanation in Modern Technology and Engineering (ICEMTE 2017), ISSN: 2321-8169, Volume: 5 Issue: 3, 210–217.

