Design Development, Analysis and Fabrication of a Modified Three wheeled Vehicle.

Kiran Kumar.S, K.S Sridhar, G.S Ravi

Abstract

Three wheeled vehicles (TWV) particularly recognised as Auto Rickshaws are commonly preferred for public transportation in many developing countries such as India, Thailand and other places. It is also a form of novelty transportation in many eastern countries. These vehicles are usually built for economic reasons and being light in construction. In the present work an attempt is made to design a Tadpole type configuration TWV (2 wheels in the front and 1 wheel at rear) using CATIA V5. Finite Element model is developed using hypermesh software simulation system, and mode shapes are extracted to study the natural behaviour and response of the vehicle. The vehicle is fabricated as per the proposed design using an 8.65 kW engine to drive the vehicle. The other components, viz steering mechanism, brakes, stub axles, seats, foot rest, fuel tank, battery box, control pedals, cables, clamps, hinges, etc. are designed and fabricated for the vehicle. The maximum stress and deflection are determined by structural analysis method which also enables to recognise the critical regions in the design, under individual static loading conditions ranging from 1g force to 4g force. It is also noticed that the maximum stress values are well within the allowable limits. This modified design approach leads to producing a light weight vehicle along with new frame design and seating arrangements. This configuration type TWV with rear wheel drive and front wheel steering also overcomes the drawbacks of vehicle lateral instability in terms of vehicle rollover which otherwise is prevalent in Delta configuration type (1 wheel in front and 2 wheels at rear) TWV.

Keywords: Tadpole and Delta Configuration type Three Wheeled Vehicle, Design and Analysis (static and modal), Fabrication.

1 Introduction

Three wheeled vehicles (TWVs) have a single wheel at the front and two at the rear (Delta configuration) whose mechanics is similar like a motorcycle and the rear axle is similar like a car. TWVs can also have two wheels at the front and one wheel at the rear (Tadpole configuration). For a Delta configuration type of TWV (Passenger Auto Rickshaw), an attempt to make a right U-turn even at moderate speeds is dangerous and leads to vehicle roll over. Further, in the event of application of brake at high speeds it results in poor dynamic behaviour of the vehicle.

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The present paper discusses the work carried in terms of concept design, modelling, linear static analysis, dynamic analysis (modal) and fabrication of a Tadpole configuration type TWV. In this present work a modified tadpole configuration type TWV is proposed, tailor made parts are designed and fabricated. The proposed TWV also overcomes the drawbacks present in the delta configuration type TWV.

2 Literature Review

Technical papers related to the subject matter of this work are studied to understand various designs available and the areas involved in the subject. Prof Patrick J Starr [1] discusses regarding the vehicles that participate in solar car racing having three wheels, arranged one at the rear and two in front. A crucial vehicle property is the location of centre of gravity (CG) of the vehicle. If the CG location is proper, the vehicle will be stable, if the CG is in the wrong place, the vehicle may exhibit with unstable behaviours. Components should be arranged to achieve and obtain a specified location of the CG, it is also crucial that designers should understand how the location of the CG can influence vehicle stability.

Keith J Wakeham [2] introduction to different type of frames used in chassis design, among them the space frame design was considered as one of the best chassis methods which yield good results for, weight holding, torsional rigidity and impact protection. Space frame is also simple to design making sure that it has nodes where the tube ends meet and not having parts subjecting to bending loads and reasonable effort to build.

Dr R Rajappan and M Vivekanandhan [3] In the truck chassis different failures occur due to static and dynamic loading conditions. In this work static and dynamic load characteristics have been analysed using FE models. The F.E model of chassis is constructed and is meshed with appropriate shell elements, stress concentration areas are identified, vibration, natural frequency and mode shapes are extracted and analysed. The model is simulated considering the effect of bolted and riveted joints. Modal updating of truck chassis model is carried out by adjusting the properties such as mass, density and poisson’s ratio. Finally modifications are made to update the F.E truck chassis model which is proposed to have reduced vibration, improved strength, and optimized weight of the truck chassis.

Lars Hollmotz, Steffen Sohr and Heiko Johannsen [5] The CLEVER (Compact Low Emission Vehicle for Urban Transport) project task is involved in finding solutions for the increasing mobility challenges by developing a new type of a small vehicle, which serves as an alternative to traditional cars and an improvement in urban transportation, although it minimises the environmental impacts caused by increased mobility. Various requirements like customer, environmental and safety requirements are recognised.

3 Work Carried Out

3.1 Modeling of Three wheeled Vehicle

3.1.1 Frame

Different ideas came up in mind when it came for designing of frames, however after referring the literatures, space frames found to be suitable for the type of vehicle and importantly the configuration. The frame is designed suitable for a tadpole configuration type TWV, meant to carry one driver at front and a pillion rider. Fig (1) shows the frame modeled in CATIA.

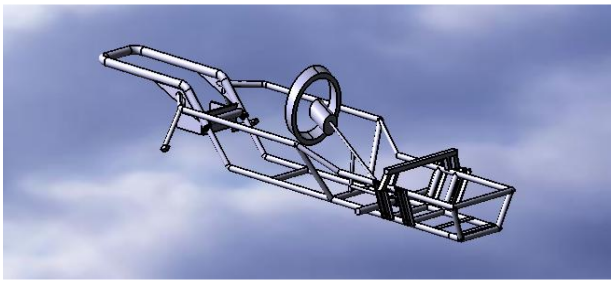

Fig (1) Frame model.

3.1.2 Assembly / Full Model

After individual part modelling, the A arms are assembled to the frame, stub axle to the arms, engine to the frame, other accessories like seats, fuel tank, foot rest, battery box etc are modeled and assembled. It is as ashown in fig (2).

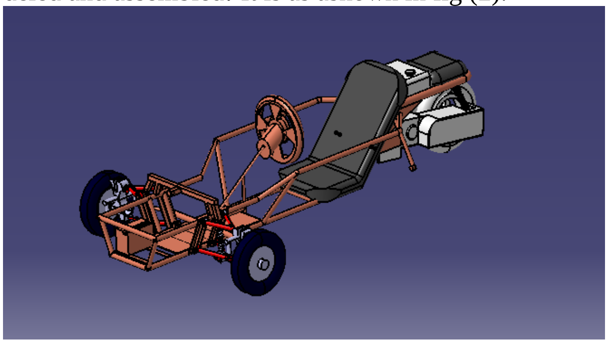

Fig (2) Full TWV model.

3.2 Fabrication of TWV

The vehicle is fabricated as per the proposed model. Steel pipes are selected to fabricate the frame and other structural parts. The operation involved are cutting, milling, bending, grinding, edge preparation, welding, threading, drilling, painting, etc. Fig (3) shows the fabricated model and its specifications are given in Table 1.

Fig (3) Fabrication model of TWV.

Table 1. Vehicle Specifications.

Description	**Measure**
Total mass of the Vehicle	160 kg
Track width	1240 mm
Wheel Base	1820 mm
Sprung Mass	140 kg
Unsprung Mass	35 kg
Distance from CG to front tyre	754 mm
Distance from CG to rear tyre	1066 mm
CG height in z-axis	343 mm
Engine	4S, 165CC, 8.65KW

3.3 Analysis

3.3.1 Modal Analysis using Finite Element (FE) Method

The TWV model is exported into the hypermesh simulation system, quad, tria, tetra, penta and hexa elements are used in the meshing process, Table 2 shows the material properties assigned to the model. The free-free boundary condition is adopted in order to obtain the natural frequencies and mode shapes. Fig (4) shows 1st mode shape of the three wheeled vehicle model without external loads or any forces applied, ten mode shapes have been extracted along with resulting frequency and displacement magnitude for each mode and the modal analysis details are seen in the succeeding results and discussions section.

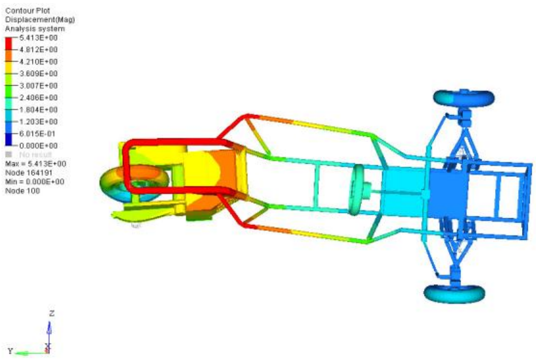

Fig (4) Modal analysis

Table.2 Material properties

SN	Material	Elastic modulus (N/mm^2)	Poisson's Ratio	Density	
				Ton/mm^3	Kg/m^3
1	Steel spring	207000	0.295	7.8 x 10^{-9}	7.8 x 10^{-3}
2	Tire rubber	30	0.45	8.61 x 10^{-10}	8.61 x 10^{-4}
3	Steel	200000	0.303	7.9 x 10^{-9}	7.9 x 10^{-3}
4	Engine material	200000	0.303	2.11 x 10^{-9}	2.11 x 10^{-3}
5	Aluminium	70000	0.33	2.7 x 10^{-9}	2.7 x 10^{-3}
6	Steering wheel	70000	0.33	7.5 x 10^{-10}	7.5 x 10^{-4}

3.3.2 Linear Static Analysis by Finite Element Method.

Fig (5) shows the TWV model fixed in all degrees of freedom near the tyre contact patch. Here static load of 1g (i.e 9810 mm/sec^2) acceleration is applied in Z-direction. The linear static analysis is applied to analyse displacements and stresses, the applied static load range is 1g and incremented up to 4g.

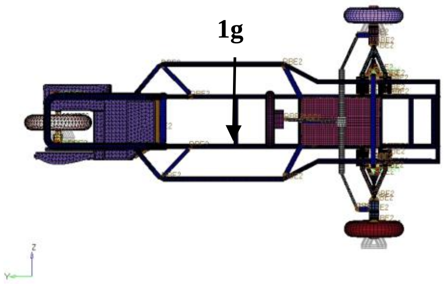

Fig (5) Application of Static load.

4 Results and Discussions

4.1 Linear Static Analysis

4.1.1 Displacement contour for static load of 1g.

For the static load condition, the displacement contour has been obtained. It is found that maximum displacement occurs at the rear end of the vehicle which can be visualized from the red coloured portion indicating maximum value of 5.69 mm and is as shown in the Fig (6).

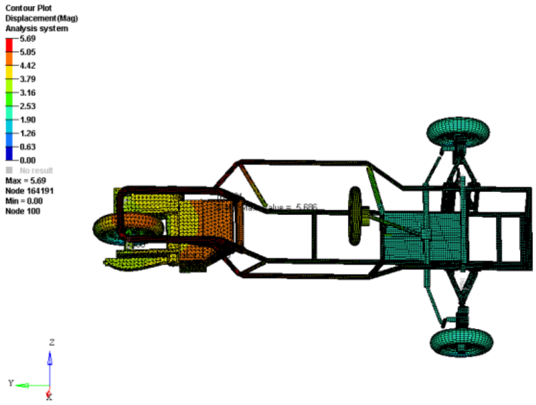

Fig (6) Displacement contour for static load of 1g.

Table.3 shows the maximum displacement values and increase in percentage for each load case ranging from 1g to 4g.

Table.3 Displacement magnitude description.

SN	Static load (m sec^{-2})	Displacement (mm)	Percentage increase (%)
1	1g	5.69	100
2	2g	11.37	50.0
3	3g	17.06	33.35
4	4g	22.74	24.98

4.1.2 Stress contour for static load of 1g.

Fig (7) shows the stress contour for the static load of 1g. It is found that maximum stress occurs at the front portion of the vehicle near the A arm connecting region, which can be visualized from the red coloured portion indicating maximum value of 88.24 N/mm^2.

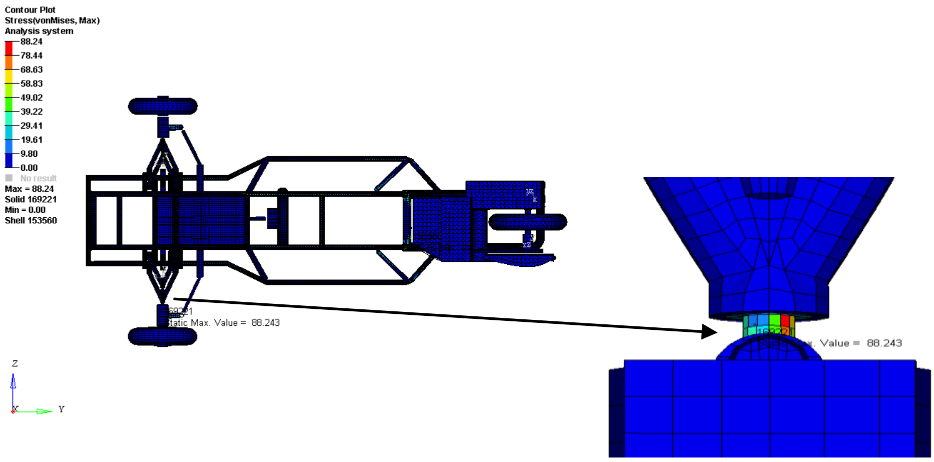

Fig (7) Stress contour for static load of 1g.

The material is ductile and maximum distortion energy theory (vonmises) is considered for determining the failure criteria, the allowable stress for the material is 205 MPa and yield stress of 410 MPa. It is seen that the maximum stress occurs at the front side of the three wheeled vehicle (near the A arm connection). The maximum stresses for each load case found over the entire three wheeled vehicle is well within the allowable limit. The stress values, FOS and increase in percentage for each case is tabulated in the Table. 4.

Table.4 Stress magnitude and FOS description.

SN	Static load (m sec^{-2})	Stress (N/mm^2)	Percentage increase (%)	FOS
1	1g	88.24	100	4.6
2	2g	176.49	50.0	2.3
3	3g	264.73	33.33	1.5
4	4g	352.97	25	1.1

4.2 Modal Analysis

There are ten natural frequencies calculated for the modal analysis. The resulting frequency and displacement magnitudes are tabulated in the Table.5 along with the mode shape description. It is observed that all the natural frequencies are below 50 Hz, varying from 8 Hz to 42 Hz. Normally, the operating frequency is related to dynamic forces induced by roughness of the road, speed breakers, engine, transmission., etc.

Table.5 Mode shape description and frequency.

SN	Modes	Mode shape Description	Result frequency from FEA (Hz)
1	1st mode	Lateral bending	8.29
2	2nd mode	Lateral bending	13.01
3	3rd mode	Longitudinal bending	14.42
4	4th mode	Axial bending	16.91
5	5th mode	Lateral bending	19.52
6	6th mode	Longitudinal bending	21.73
7	7th mode	Torsional	22.75
8	8th mode	Bending	32.24
9	9th mode	Bending(mixed)	40.52
10	10th mode	Combined torsion and bending	41.58

5 Conclusions

In the present work involving Design Analysis and Development of a Modified Three wheeled Vehicle, a Tadpole configuration type of three wheeled vehicle design development and analysis is carried out. The following conclusions can be drawn from the work;

- Structural analysis determines the maximum stress, maximum deflection and recognizes critical regions under individual static loading conditions from 1g force to 4g force.
- The maximum stresses for each load case found over the entire vehicle is well within the allowable limit.
- The dynamic characteristics such as, the natural frequencies and mode shapes of the vehicle has been determined.
- It is observed that all the natural frequencies of six global modes are below 22 Hz, varying from 8 Hz to 22 Hz.

- For the first five modes, the vehicle experiences global vibrations which include longitudinal, lateral and axial bending modes. In the sixth mode the vibrations found are of local mode occurring at 21.73 Hz.
- For a Tadpole configuration type vehicle, say the vehicle is driving at high speeds and brakes are applied suddenly to stop the vehicle, the weight transfer from rear to front is supported by two wheels in the front.
- The Tadpole configuration type with rear wheel drive and front wheel steering overcomes the drawbacks of vehicle lateral instability in terms of vehicle rollover which otherwise is prevalent in Delta configuration type of three wheeled vehicle.

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