International Journal of Pure and Applied Mathematics
Volume 119 No. 7 2018, 2231-2239
ISSN: 1311-8080 (printed version); ISSN: 1314-3395 (on-line version)
url: http://www.ijpam.eu
Special Issue
ijpam.eu

STRUCTURAL AND MODAL ANALYSIS OF SCOOTER FRAME

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ABSTRACT –

This project discusses the stress and deformation developed in chassis during the different load cases and identifying the failure modes by the modal analysis. It starts from the benchmark study of different scooter frame in the aspect of material selection, mechanical properties and the sections used in it (usually circle section is preferred because of its easiness of manufacturing ,even load distribution for different load Cases and some other geometrical reasons) Then Structural and modal analysis of frame under the various load consideration It involves 3d Modeling in Pro-E, Meshing in Hyper mess and analysis in ANSYS.
Thus the aim of the project is following:

a) To validate the Frame design i.e. stress and deformation calculation using FEA and suggest the design recommendations
b) To do Bench mark study of the frame structure, load characteristics, metallurgical and mechanical properties of the scooter frame members.
c) Identify critical stress areas and suggest for design improvement from the Modal analysis by identifying the different mode shapes and Natural frequency of the frame.

I. INTRODUCTION

The two-wheeler chassis consists of the frame, suspension, wheels and brakes. The chassis truly sets the overall style of the two-wheeler. Automotive chassis is the main carriage systems of a vehicle. The frame serves as a skeleton upon which parts like gearbox and engine are mounted. It can be made of steel, aluminum or an alloy. It is essential that the frame should not buckle on uneven road surfaces and that any distortions which may occur should not be transmitted to the body. The frame must therefore be torsion resistant[1-4].

The frame consists mostly of hollow tubes and serves as a skeleton on which components like the gearbox and engine are mounted.

Suspension The frame also serves as a support for the suspension system, a collection of springs and shock absorbers that helps keep the wheels in contact with the road and cushions the rider from bumps and jolts.

Wheels Motorcycle wheels are generally aluminium or steel rims with spokes, although some models introduced since the 1970s offer cast wheels. Cast wheels allow the bikes to use tubeless tires, which, unlike traditional pneumatic tires, don't have an inner tube to hold the compressed air.

Brakes The front and rear wheels on a motorcycle each have a brake. The rider activates the front brake with a hand lever on the right grip, the rear brake with the right foot pedal. Drum brakes were common until the 1970s, but most motorcycles today rely on the superior performance of disc brake.

II .METHODOLOGY OF THE STUDY:

Take the benchmark of different scooter frame for the Tube thickness, Tube diameter and mounting position brackets along with thickness. Collect the material property of the Frame and its allied parts. Carry out the design calculations and assume the required parameters. Model the frame structure in the PRO ENGINEER for different dimensions. Finite Element Meshing of these models to be carried out in HYPERMESH. The elements properties can be defined either in the HYPERMESH or in the ANSYS.
In this project I have defined the elements and load parameters at hyper mesh itself[5-8].
These meshed models are taken in to the ANSYS solver for solving. Record the results and analyse the same

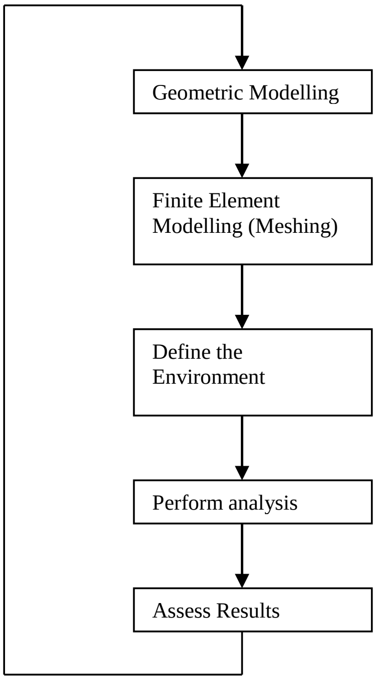
A. Development Of 3d Models - Computer Aided Design (Cad)

Creating an accurate geometric model is the first key step in a finite element process. It stands to reason that if the geometric model does not accurately represent the physical object, the analysis will be incorrect. Many CAD models work fine for the design and drafting but they do not have the quality required for FE meshing operations. So a special care must be taken during the modelling of the model in the meshing point of view.

B. Fundamentals of fea (finite element analysis)

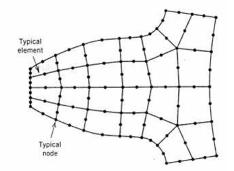
The FEA process is a method of analysing a part or assembly to ensure performance integrity over the product's lifetime. FEA allows engineers to simulate structural behaviour, make design changes and see the effects of the design changes quickly or even automatically. This process is a computer simulation of the make them and brake them or build them and bust them process in which a physical prototype is built and tested, and then rebuilt and tested as often as necessary until an acceptable design is created. This physical process can be costly and time consuming. But FEA does not replace testing. FEA supports and enhance testing. It especially helps to reduce the number of still necessary-physical tests. FEA and testing should be used together because each has unique strengths[9-15].

All types of finite element analyses involve the same basis steps as described



Furthermore the shape function which can be linear or non linear of an element influences its ability to represent displacements or stresses that vary over the element edges or surfaces and thus contributes directly to the quality of the analysis results[16-23]. The choice of a proper finite element is crucial for simulating correct structural behaviour.

Meshing is the process of subdividing the geometry in to a series of discrete elements. It is done to represent complex geometry and provide more elements in regions of interest, which for example are those where, stress gradients or structure born noise are greatest



III. BASICS OF FE THEORY

A.Determination Of Natural Frequencies And Mode Shapes

Assuming a harmonic solution $\{x\} = \{\phi\} \sin \omega t$ and determining its first and second derivatives the following forms are obtained from the upper equation

$$-\omega^2 [M] \{\phi\} \sin\omega t + [C] \{\phi\} \sin\omega t = 0$$

$$([C] - \omega^2 [M])\{\phi\} = 0$$

Setting $\omega^2 = \lambda$ the eigenvalue problem reduces to

$$[C - \lambda_i M] \{\phi_i\} = 0$$

with

$\{\phi_i\}$ = a eigenvector (or mode shape) corresponding to an eigenvalue λ_i

{The natural or characteristics frequency)

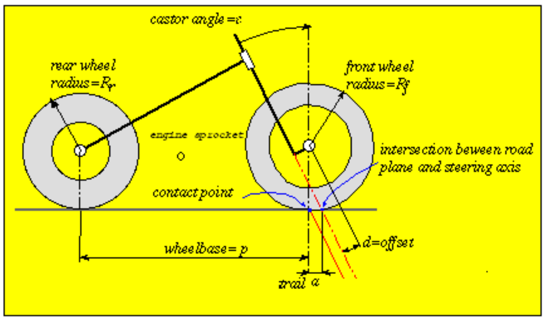
For each eigenvalue, which is proportional to a natural frequency, there is a corresponding eigenvector or mode shape. The eigenvalues are related to the natural frequencies according to

$$f_i = \sqrt{\lambda_i} / 2\pi = \omega_i / 2\pi$$

Due to the orthogonality of the calculated modes, none of the modes is affected by any other mode. That means that each mode is characteristic by itself, it cannot be described by a linear combination of the rest of modes. Each mode shape is similar to a static displaced shape as there are displacements and rotations for each node. However, there is one important difference between a mode shape and the static displacements: the scaling. In static analysis the displacements are the true physical displacements due to the applied loads. Since there is no applied load in normal mode analysis, the mode shape components can all be scaled by an arbitrary factor. Normally this scaling is done so that the maximum displacement in any mode is 1.0

IV.GEOMETRY, DESIGN AND MANUFACTURING CONSTRAINTS:

A. Target Specification:-



Wheel base	1310mm
Ground clearance	150mm
Seat height with cushion	760mm

Seat base height	660mm
Vehicle power	1200watts
Battery	24Ah x 4Nos
Engine	75cc
Castor angle	25 degree
Trial	Approx. 10mm
Offset	42mm
Weight of frame	12 kg (1.6mm thick) 14 kg (2mm thick)
Wheel centre to shock absorber mounting angle	20degree
Ground clearance	Approx, 150mm

B. Strength and stiffness requirement:

It is governed by static & dynamic loads acting under various conditions like high speed cornering, driving over irregular roads and driving over bumps and potholes. Apart from the above, there are other loads like rider and pillion, fuel tank and other vehicle parts. The frame stiffness shall be such that the deflection is minimum during various operating conditions. Typical values of frame stiffness are taken from benchmark vehicles and further fine-tuned based on vehicle handling simulation using multi-body software like ADAMS. Inadequate frame stiffness leads to vehicle instability in cornering and affects handling and manoeuvrability. The strength of frame shall be such that there is minimum permanent deflection during operating conditions. In order to ensure that, finite element analysis is done and the stress levels are calculated. The strength of the frame [frame tubes] is fixed at a value that is more than the stress value obtained during analysis[24-29].

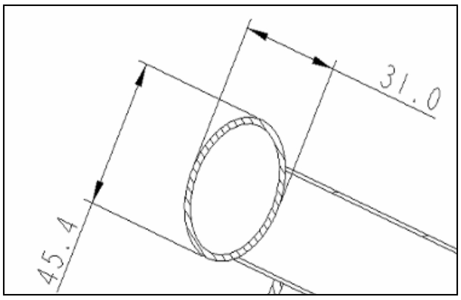
C. General stiffness requirement for motorcycles and scooters

Class of vehicle	Units	M/c (Domestic)	M/c (Urban)	M/c (Racing)	**Scooterette**
Vertical stiffness	N/mm	2000	3000	4000	210
Lateral stiffness	N/mm	180	230	350	230
Torsional stiffness	Nm/deg	600	600	1000	600

V. STRUCTURAL AND MODAL ANALYSIS OF SUSPENSION FRAME USING ALLOY STEEL

A. Material properties

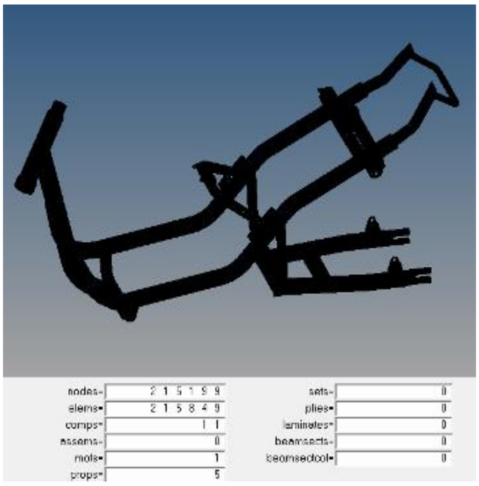
Young's Modulus (EX) : 205000N/mm2
Poisson's Ratio (PRXY) : 0.29
Density: 0.00000785 kg/mm3
Ultimate tensile strength : 520 N/sqmm
Yield strength: 360 N/Sqmm
STD : IS – 3074 ; CEW 1 steel tube for Auto motive
Main tube outer diameter: 48mm ;Thickness :3mm
Long member : Refer below for elliptical section dimensions
Section: Elliptical & circular; Thickness: 1.6mm & 2mm
Dimensional details of elliptical section:



Section modulus of elliptical section (2mm thick) :1.697e03 & 2.12e03
Section modulus of elliptical section (1.6mm thick) :1.41e03 & 1.71e03
Section modulus of circular section (1.6mm thick) ;od 41mm:1.9e03

A. Meshing In Hyper mesh

The following are the no of elements and the nodes crated for the different models
(For both elliptical and round long member) after the meshing



Sno	Model Name	No Of Elements	No Of Nodes
1	Scooter frame-elliptical long member	215849	215199

2	Scooter frame-round long member	213387	213011

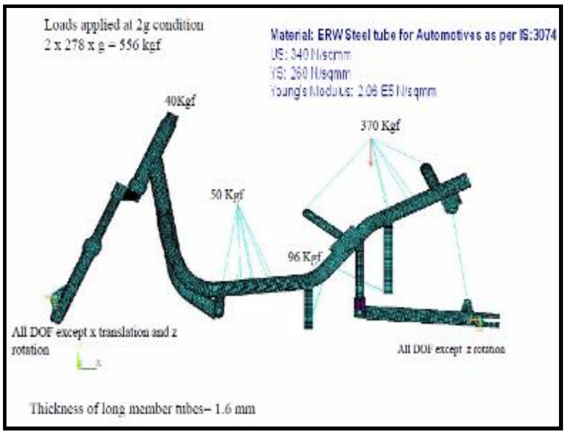
following are the properties of the elements selected for meshing

Element Type:
SHELL 181
MPC 184

B. SHELL 181 Element Descriptions

SHELL181 is suitable for analysing thin to moderately-thick shell structures. It is a four-noded element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z axes. The degenerate triangular option should only be used as filler elements in mesh generation[30-33].

VI. LOAD AND BOUNDARY CONDITION

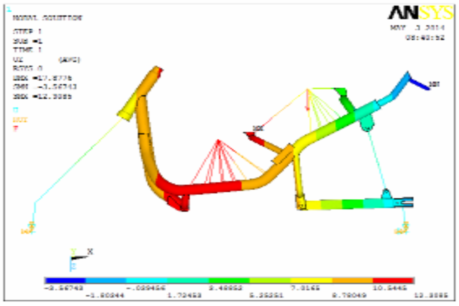


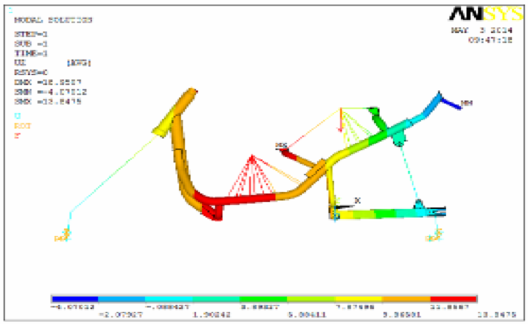
The above load condition established by Considering the 2 person with 103kg is sitting at rear and a kit having 25 kg is travelling in the scooter. 30% of load from rider mass distributed to handle bar/head tube area as a thumb rule of the design. battery mass 45kg totally 278 kg and in 2g condition 556 kg

Degrees of freedom are fixed at front and rear Wheel centre positions. The same environment created and analysed in the ansys for the various thickness and sections of the frame configuration[34-36].

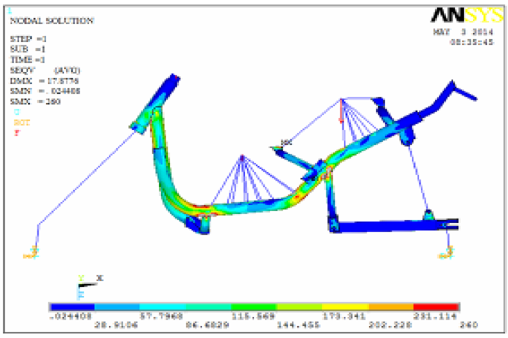
VII ANALYSIS RESULT

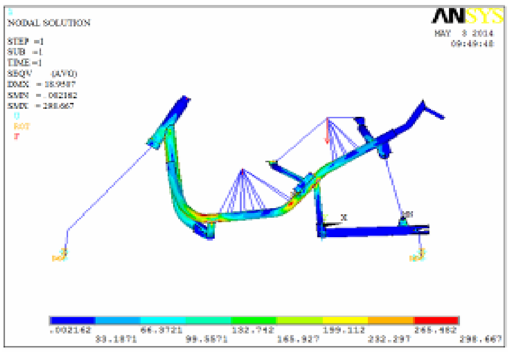
A Displacement plot





B . Von Misses stress plot



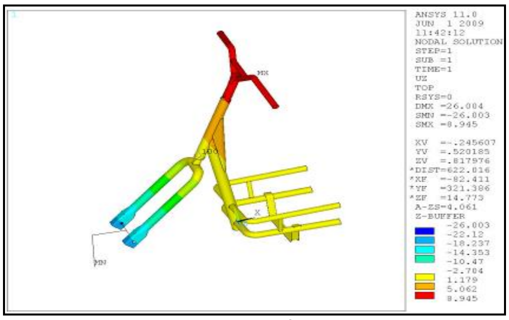


Summary of Vertical and Lateral load results

	Stiffness		vertical Load	Lateral load	Max. vertical displacement (mm)	Max. Lateral displacement (mm)	Von misses stress (Mpa)
Model	Vertical (N/mm)	Lateral (N/mm)					
New model-1.6mm thick. Elliptical	358.7	238.3	556	166.8	15.5	7	355
New model- 2 mm thick. Elliptical	444.8	222.4	556	166.8	12.5	7.5	260
New model-1.6mm thick. Round	308.9	256.6	556	166.8	18	6.5	450
New model- 2 mm thick. Round	397.1	238.3	556	166.8	14	7	300

VIII. FRAME ANALYSIS UNDER THE CORNERING LOAD

This study conducted to analyze the lateral stiffness of the frame particularly from the front cornering load. As a thump rule 10% of overall load can be taken as a applied load.

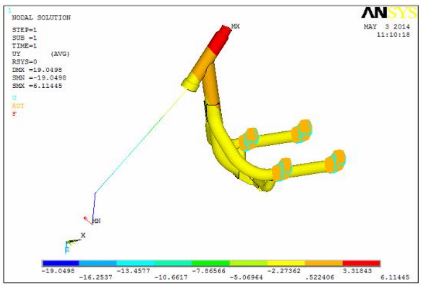


Bench mark frame

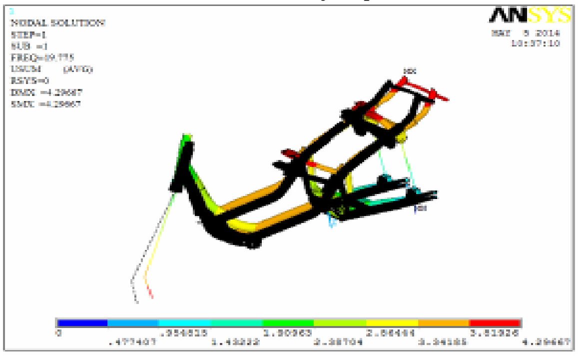
Bench mark frame subjected for cornering load as shown above and verified against the values of FEA. To validate the correlation %

	maximum disp. Measured at lab (mm)	maximum disp. Measured at FEA (mm)	Correlation %
Deflection (mm)	12	9	75 %

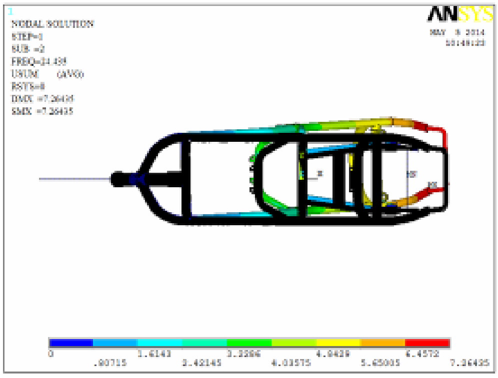
Deflection under Corner Load –FEA



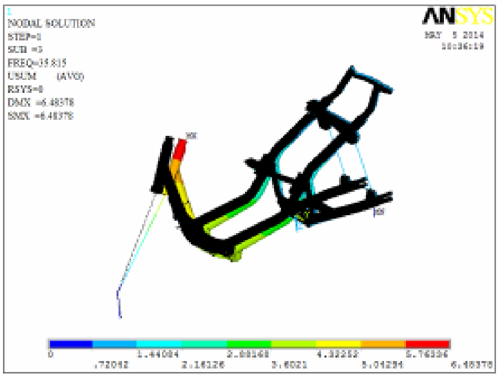
IX Modal analysis plot



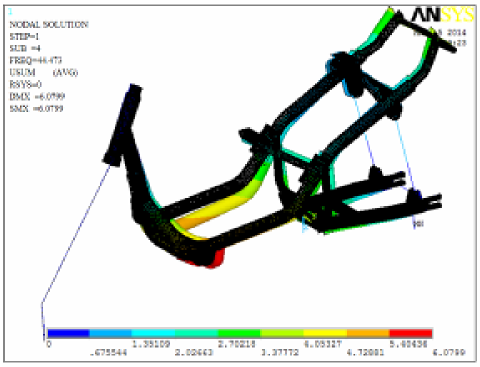
Mode-1



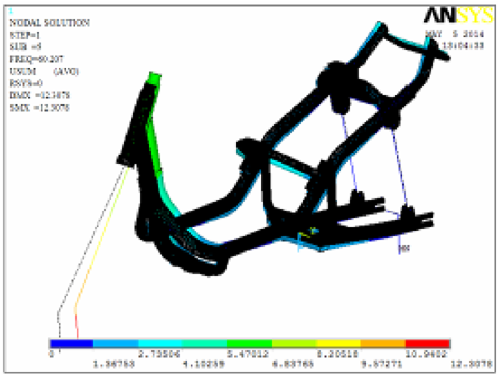
Mode-2



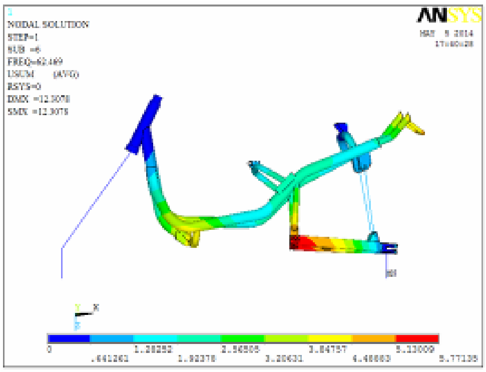
Mode-3



Mode-4



Mode-5



Mode-5

The above shown results are for the frame made of elliptical 2mm thick long member
Similar results are observed in all the other 3 cases like circular1.6mm thick,eliptical 1.6 &2mm thick longmember.

MODE NO.	MODAL FREQUENCY (Hz)			
	CIRCULAR 1.6 mm	ELLIPTICAL 1.6 mm	CIRCULAR 2 mm	ELIPTICAL 2 mm
1	9.445	10.0539	9.8453	10.3855
2	16.595	16.69	15.92	15.992
3	16.853	17.485	17.277	17.834
4	23.162	23.095	22.516	22.448
5	37.263	38.927	38.04	39.625
6	46.867	45.403	48.71	47.294

All four combination modal analysis results shows that, there is no much variations in the natural frequency. And they are not matching with the engine fundamental firing frequency orders. And Human is sensitive in the frequency band of 4 -9 Hz. And the result shows , observed frequencies are not harm to the human body also placed in the com fort level.

IX.CONCLUSIONS

Thus a scooter frame is designed for elliptical and round cross section with in the specified Geometrical boundary condition

The same were tested and verified with Finite element analysis for vertical and lateral load condition . Bench mark study for both material selection and behavior of frame under the various load condition studied. The generated shear stresses are less than the permissible value so the design is safe. Design improvements are made in order to meet the maximum targeted stress value of 300 MPa and vertical displacement less than 18 mm based on the bench mark study.

The usage of elliptical cross section thus increase the vertical stiffness also improves the manufacturability aspects in terms of pipe joints welding.

Lateral stiffness is very much important for the cornering behavior of the vehicle.

We should also ensure that the lateral stiffness is well in the acceptable level

For that lateral loading analysis and modal analysis has done.

In lateral load condition the frame is having sufficient stiffness also the stress induced in the sections also within the limit by comparing with bench mark data collected

From modal analysis the Identified natural frequencies for different mode shapes are not equal to the single cylinder engine's fundamental firing frequency orders
also not sensitive and in comfort zone with respect to the sensitive human body frequencies.

Henceforth I propose the elliptical cross section for hybrid scooter as the hybrid scooter frames are subjected to both statically mounted battery and engine loads.

As part of cost elliptical sections are costly also not widely used in automotive industries and I hope it could be compensate during the mass production of the vehicle

X. SCOPE FOR FURTHER WORK

- The natural frequency of vibration obtained can be further used in the system analysis of the complete assembly as a whole considering all the components of the motorcycle.

- As a scope for the further work on this project a complete harmonic analysis of the assembly can be carried out to determine the vibration characteristics of the motorcycle assembly under the influence of engine disturbance, human weight and road condition.

- The vibration experienced by the rider through the handlebar and the footrest can be studied and suitable modifications can be made in the components of the motorcycle to bring the range of the vibration under the comfort zone.

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