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Crash Analysis for Optimum Design of ATV Frame

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***Abstract*:- All Automobile components are based on their quality of design. The structural member and base frame stand on the important place when considering the strength and efficiency of vehicle. ATV is different kind of vehicle where structural rigidity of frame is most crucial factor. In order for frame to be efficient series of test must be conducted for inspection of the same. During considering the design one must also consider various parameters like Steering geometry, Suspension Geometry and Crash Analysis for Optimum Design. Crash is highly collateral, transient dynamics portent during which some areas of frame undergo plastic deformation and absorb a substantial amount of energy. Hence the structure frame should be designed to optimize its crash deformation along with safety of driver. This paper focuses on crash analysis using Hypermesh and also design parameters of the same. Using the same mentioned software various graphs are plotted for ensuring stability of the frame. Being the spine of the ATV, its main functions is to carry load and other system under operating conditions.**

Keywords: Chassis, Steering Geometry, Suspension Geometry, Crash Test, Rigid Body

1 INTRODUCTION

Driver safety is the foremost concern in any motorsport event. Considering the accidents, it was observed that most of the injuries were due to head on collision. ATV competition organizers expects the team to build an ATV from zero stage, following the rules specified by the governing bodies. The work focuses on safety of vehicle at the student level. The model of the frame is prepared according to the specifications in rule book with help of CATIAV5. The calculations necessary for the forces to be applied on the roll cage include basic mechanical formulae like bending moment, force calculations and mass energy conversions. This basic force analysis can deliver results for structural rigidity but when it comes to considering of all the parameter including driver safety the advance type of analysis is put to use using Hyper Mesh. This frame model is analyzed considering AISI 4130 as a best suited material for the frame. Hyper Mesh is a high-performance finite element pre-processor to prepare even the largest models, starting from import of CAD geometry to exporting an analysis run for various disciplines. The main parameter considered for analysis are mesh sizes, mesh type and the order of element and various iterations were made considering these parameters. The model was further optimized for weight reduction. The simulation results were compared with analytical results and a convergence graph was obtained to justify the design

2 LITERATURE REVIEW

Crash Analysis of Vehicle, Akshay Lokhande, Abhijeet Darekar, Sanket Nimbalkar, Abhishek Patil, Sinhgad Academy of Engineering, Maharashtra, India.

From this Paper, it is clear that frame of a any vehicle is a integral part when considering static and dynamic operating conditions. Here the model is prepared in a 3D software using various functional parameters. This model is further uploaded on a Ansys workbench for static evaluation of force and displacement vectors. The chassis forms the backbone of vehicle as its main work is to carry all the system and parts effectively. It must also withstand static and dynamic loads without undue deflection or distortions. The crash analysis simulation and results can be used to assess both the crashworthiness of designed chassis and to investigate ways to improve design. It is an essential part of design cycle and can reduce the need for costly destructive testing program. The concept of Finite Element Analysis of chassis has been highlighted in this project. The chassis is designed using Creo2.0 and then the analysis is done with the help of analysis software Ansys and then after comparing the optimum design is selected.

Crash Analysis on Conventional Type Chassis, Arko Banerjee, SRM Institute of Science and Technology, Chennai, Tamil Nadu.

The phenomenon of a vehicle crash is a nonlinear transient dynamics phenomenon. This report presents, crash analysis of a conventional type chassis structure design of 252kg was performed by using FEM. During a chassis crash lot of the members will have a plastic deformation and would absorb a lot of energy, thus crash test analysis plays an important role in testing the vehicles safety. As the chassis is the Backbone of the Vehicle it should be able to withstand static and dynamic loads without much mechanical distortions. Crash analysis simulation used to regulate better methods to design a chassis and also reduces the need of costly physical destructive testing programs. The Chassis has been designed in Solid works 2017 and the analysis has been done with the help of analysis software Ansys.

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A Review on Design & Analysis on Of All Terrain Vehicle Chassis, Shubham Kapadne, Ajay Anap, Nikhil Jagdale, Aditya Bhutada, PCET's Nutan Maharashtra Institute of Engineering and Technology, Pune, India.

According to writer's view, improvements in structural component design is often achieved by a trial and error method guided by the engineer. Despite the designer's experience, it must remain a fundamental aspect in design. Such an approach is likely to allow only marginal product enhancements. The different turn of mind that could optimize structural design is needed and could be given by structural optimization methods linked with finite elements analysis. This method is briefly introduced and applications are presented and discussed with the aim of showing their potential. A particular focus is given to weight reduction in automotive chassis design applications.

Design and optimization of Double wishbone suspension system for ATVs, Shantanu Garud, Pritam Nagare, Rohit Kusalkar, Vijay Singh Gadhave, Ajinkya Sawant, Dept of Mechanical Engineering, RMDSSOE, Pune, Maharashtra, India.

According to author's perspective, ATV means All-Terrain vehicle which is also known as quadricycle or quad bike. It's designed in such a way that it can handle an irregular terrain. Suspension system is one of the most essential sub-system of an automobile. Its elementary function is to isolate driver from shocks and bumps and maintain the contact between road and tire. Various forces act on suspension system of ATV. It carries out optimize computing for the suspension-based system on the target of minimizing the weight and cost. MSC are is used ADAMS software is used for simulation of double wishbone suspension geometry. While simulation of suspension geometry the parameters considered for the result purpose are camber angle, caster angle, king pin inclination, scrub radius, roll steer, percent Ackerman. Objective is optimizing the front upper control. A-arm is converted into single member and the optimization result improves the suspension system performance in a certain extent. CATIA is used for modelling and after the modelling geometry is imported in ANSYS for structural analysis for finding out stress and deformation results of parts.

Design and Manufacturing of steering system for ATV, Mr. Kartik Gavhale, Ms. Nishigandha gurav, Prashant Zaware, D Y Patil School of Engineering Academy, Ambi, Pune, Maharashtra, India.

Steering system is used to steer the vehicle according to need of the rider. In order to design a steering system, it is important to recognise and compensate the forces on basis of track. Steering system of an ATV needs to be efficient as well as the parameters like rigidity, weight, spaces must be within the design and stress limits. While designing a steering system of ATV, we need to consider an irregular terrain. All the forces and torque encountered during the run are considered in order to design the mechanisms which will sustain these irregular terrains. Need to frequently steer a vehicle in any direction makes it necessary for a mechanism to be responsive and also sustain the fatigue loads due to terrain. The steering wheel is designed considering the steering force. Some important parameters and values of the steering results are referred from this paper.

3 CRUCIAL CONSIDERATIONS AND GEOMETRIES FOR ATV FRAME DESIGN

First step of frame design is to know accurate positions of various points of different geometries and component mounting points in an infinite continuum besides given specifications. The frame provides required sustenance to the vehicle components placed on it. The frame should be strong enough to withstand shock, vibrations and hub to hub twist in case of ATV. The ATV chassis frame consists of side members attached with a support pillar. Stress analysis using Finite Element Method (FEM) and 3D cad software can be used to locate the critical point and mounting points respectively. These points are factors that may cause the fatigue failure. The magnitude of the stress is used to predict the life span and strength of the ATV chassis.

3.1 Suspension Geometry

In order to defy the bumps and jerks that usually occur in an off-road track, an integrated method of design is developed to obtain an optimized geometry of a system which contributes to the vehicle's handling and braking for a better safety driving, to keep the driver as isolated as possible from bumps, vibrations and give the drivers a drive experience. This geometrical system is termed as suspension system.

While designing the suspension system of vehicle, basic parameters considered are as follows:

Parameter	Specifications	Parameter	Specifications
Wheel Base	1040 mm	Tire Radius	280 mm
Track Width Front	980 mm	Tire Width	177 mm
Track Width Rear	940 mm	Sprung Mass	100 kgs
Shocker E2E Max T	22 inches; 6 inches	Up Sprung Mass	80 kgs

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Using above parameters basic suspension geometry is constructed on Catia and tested the same on Lotus Suspension Analysis (LSA) software. Using LSA initial outline is obtained and hard points are drawn and graphical and numerical values are determined. This modelling approach allows user to individual suspension models. The changes in camber angle, toe angle is displayed graphically against motions like rolling, bump, steering. Several parameters are considered to get the hard points of the suspension system like damping ratio, sprung and un-sprung weight, spring rate, camber angle, caster angle, roll Centre, wheelbase, track width, toe angle, ground clearance.

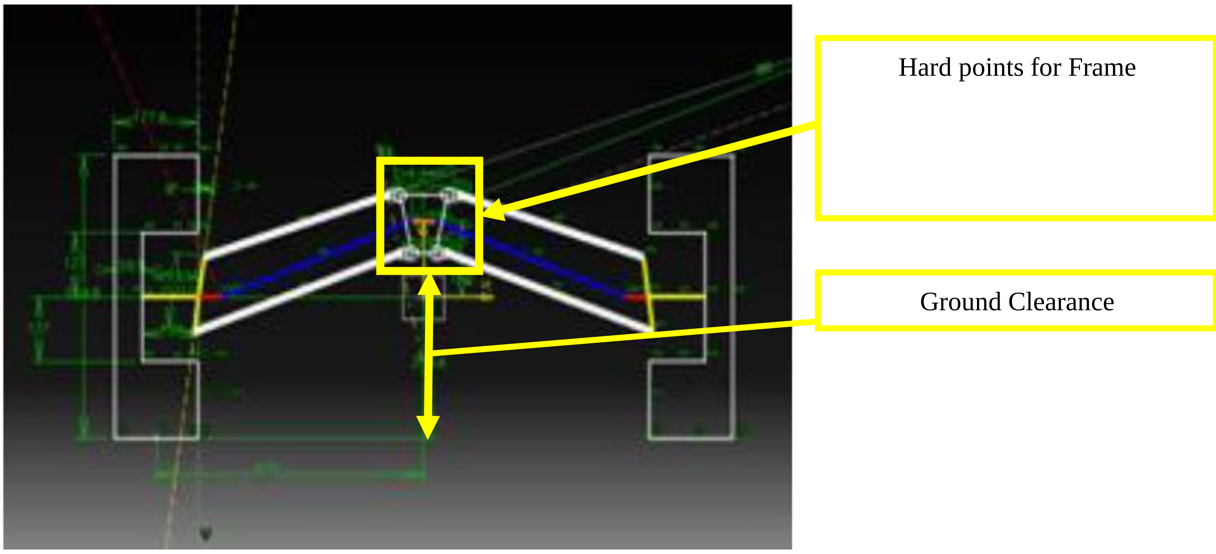
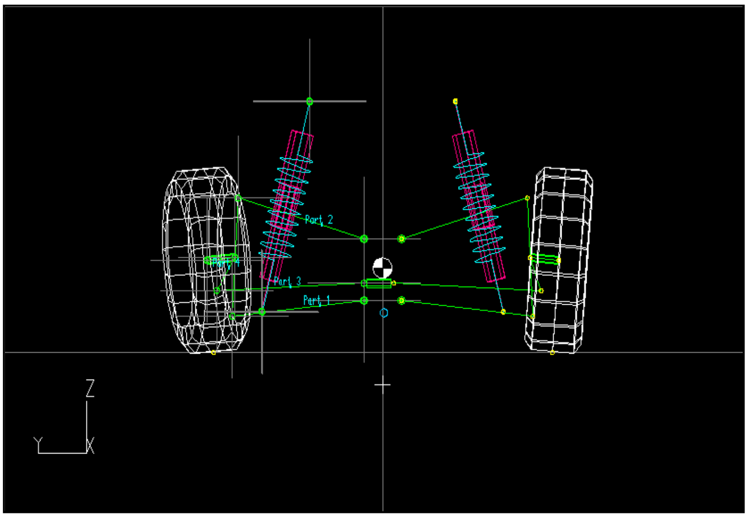


Fig-ICR of suspension geometry

So before designing in LSA, design considerations are as follows:

a) Kingpin and caster angle are kept in such a way that they can compensate each other and camber gain, by providing their individual function.
b) A positive king pin angle is kept to help in steering the vehicle.
c) Roll centre below CG to avoid jacking force.
d) Front ride frequency is greater than rear.
e) Roll axis inclined towards front to give under-steer characteristic.
f) Front double wishbone unequal parallel arm to have better traction during cornering.
g) We have taken Damper to lower wishbone for the front suspension and damper to upper wishbone in rear suspension system.

Thus, taking care of all these considerations and other minute details a model is drafted in LSA and following results with graphs are obtained. These properties are controlled by controlling the camber, caster, toe, kingpin angle etc



Numerical Results	
Camber Angle	4 Deg
Castor Inclination	0.48 Deg
King Pin Angle	3 Deg
Scrub Radius	90 mm
Toe In (Static Condition)	3.52 Deg

Fig-Simulation of suspension using lotus shark software

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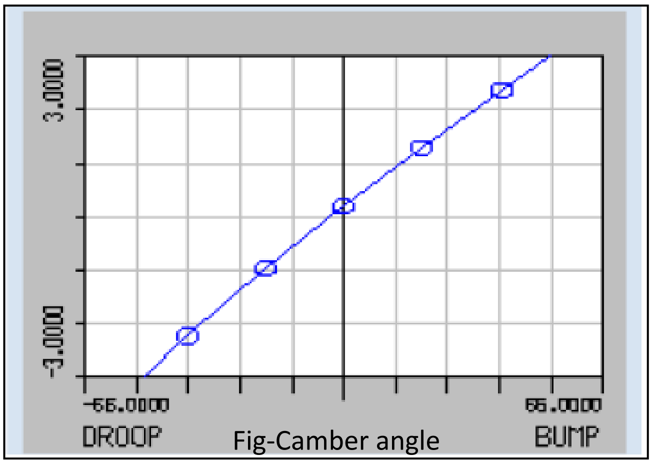

Fig-Camber angle

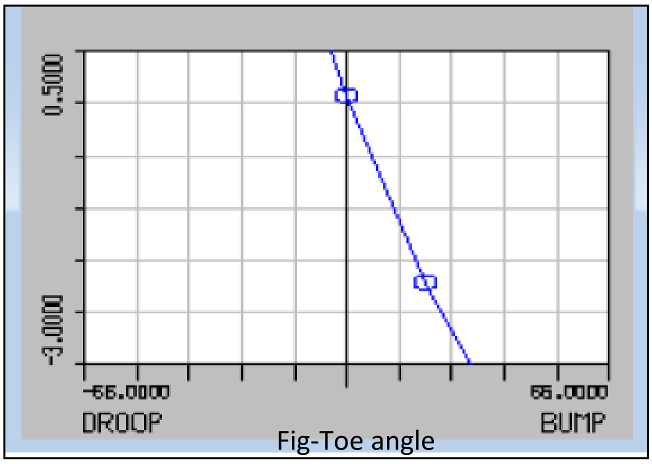

Fig-Toe angle

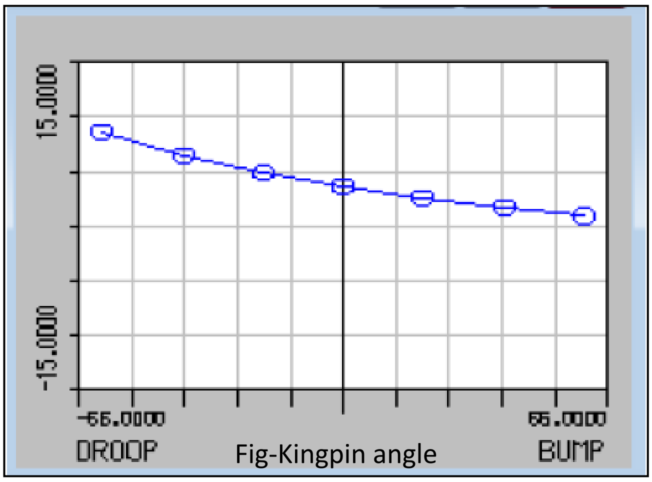

Fig-Kingpin angle

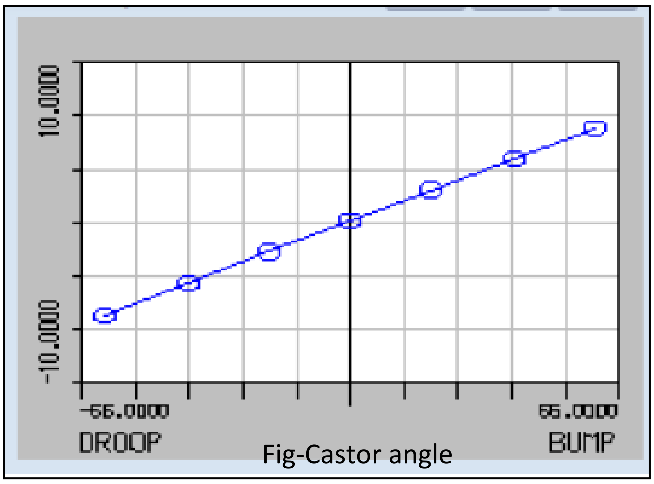

Fig-Castor angle

3.2 Steering Geometry

The basic aim of steering is to ensure that the wheels are pointing in the desired directions during static and dynamic condition. This is typically achieved by a series of linkages, rods, pivots and gears with precise alignment of these parts with each other. One of the fundamental concepts is that of caster angle of each wheel is steered with a pivot point ahead of the wheel this makes the steering tend to be self-centring towards the direction of travel.

Generally, Ackermann steering Geometry is best suited for ATV as efficiency of the same can be obtained up to 65 percent. Synthesis of a steering mechanism that exactly meets the requirements of Ackermann steering geometry is crucial part in steering system. It starts from reviewing of the four-bar linkage, then the number of points that a common four-bar linkage could precisely trace at most. After pointing out the limits of a four-bar steering mechanism, determination of turning geometry for steering wheels and proposed steering mechanism with incomplete noncircular gears for vehicle by transforming the Ackermann criteria into the mechanism synthesis is done. The pitch curves, addendum curves, dedendum curves, tooth profiles and transition curves of the noncircular gears are formulated and designed. Kinematic simulations are executed to demonstrate the target of design.

To determine efficiency of this Steering Mechanism a sketch is drafted either in AutoCAD or Catia V5. The Sketch is bound to fixed constraints and dimensions. Tie Rod length, Pivot to horizontal axis length, Tripod length are now determined using Trial and Error method or Gauss Seidel Method. The difference between total Wheelbase and obtained bisecting point of extended axis of both front tires from normal is used to find the Ackerman length difference value. This value is reduced from wheelbase length and divided by the same to calculate Ackermann Efficiency. When the efficiency reaches between 60 to 65 percent the symmetric value obtained for the tie rod and tripod length are considered to be optimum.

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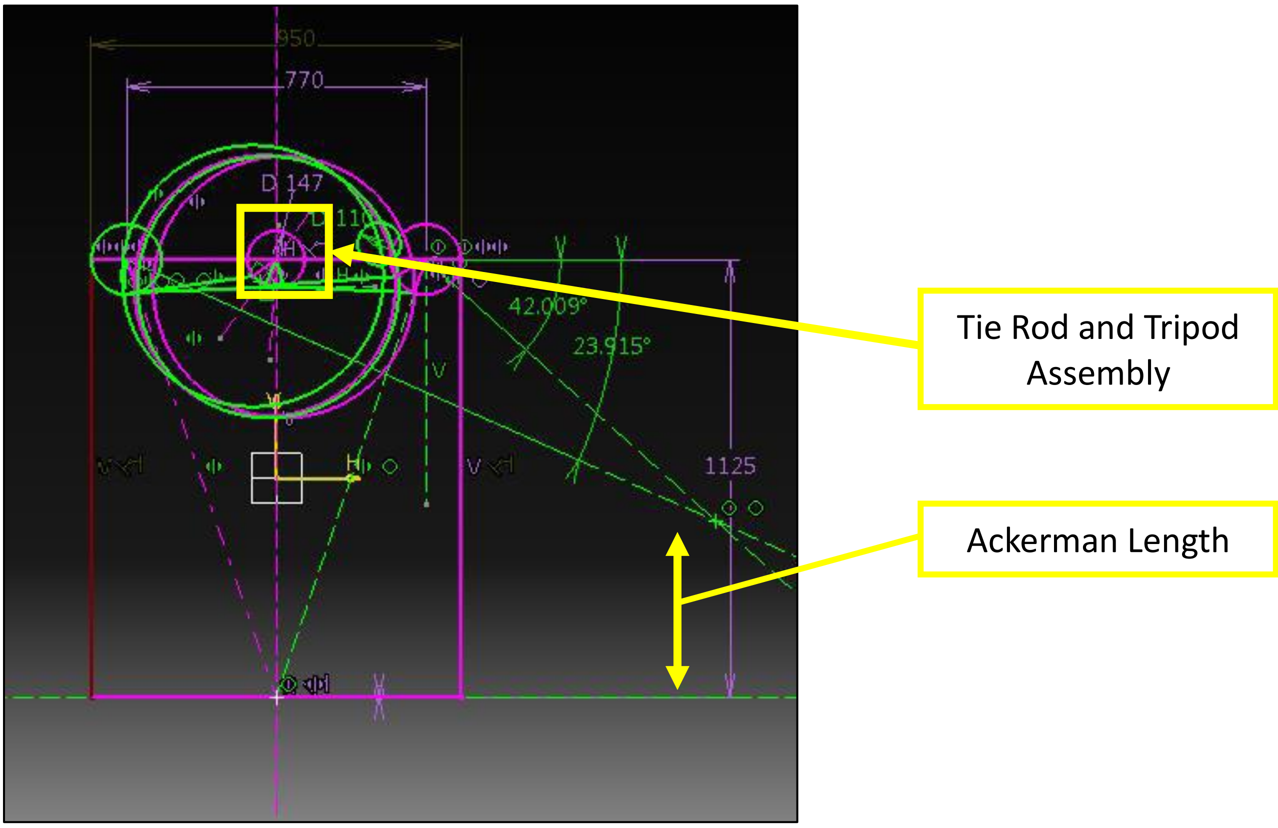

Fig-ICR of Akerman steering geometry

Obtained Steering Parameters and Values

Ackerman Angle	22.89
Radius of Gyration	395.15 mm
Moment of King Pin Inclination	10.898 Nm
Moment at Tripod	12.731 Nm
Steering Effort on Handle	45 N
Turning Radius along Ackerman Point	3.5 m
Mechanical Trail	19.53

3.3 Engine Mounting Points

Engine mounting points are easy to obtain but stands on an important ground for designing chassis. Weight of the engine is considered and placed approximately on the Center of Gravity Axis leaning towards rear side of the frame. Hard points obtained must be free from any clashing and flush from other systems and must provide enough room from intake and Exhaust Manifold. Generally, ATV customized engines have 5 mounting brackets on the body of which 3 are used. ***A*** mount which is front upper mount is located such that it provides clearance for exhaust manifold and minimum clearance between fuel tank mountings. ***B*** mount which is rear middle mount should be such that it gives clearance to intake manifold. ***C*** mount which is combination of two double parallel and coaxial mount is situated at bottom which also connects harness and earthing of and engine to a relay coil. All mounts are attached to frame via bracket and vulcanized hard rubber in between to damp vibrations.

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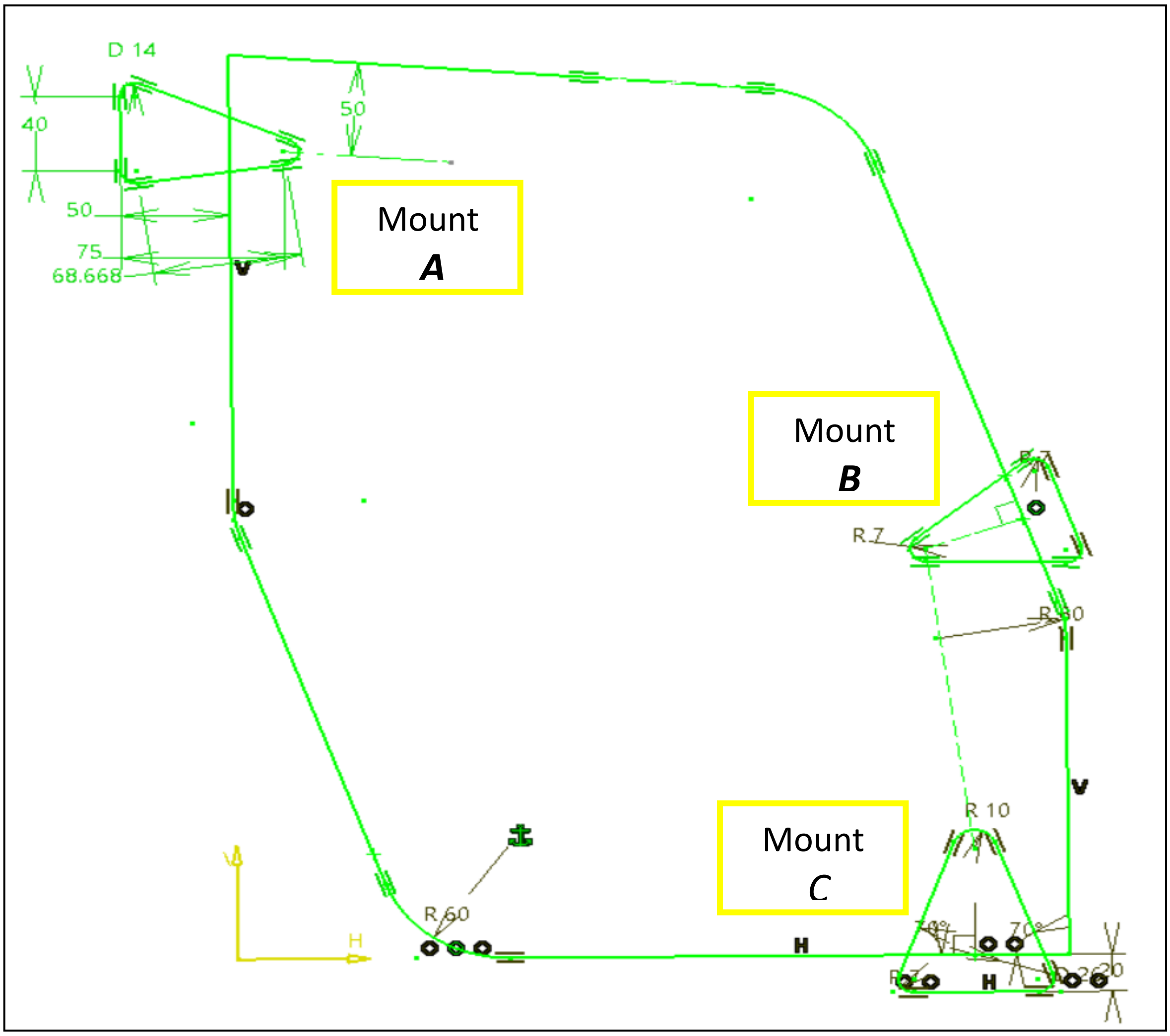

Fig: Engine Mounts

3.4 Material Selection

Material selection ATV frame is one of the key design decisions that has great impact on the safety, performance efficiency and reliability of the vehicle. It also decides the weight of the vehicle, fabrication processes and cost. The qualities of importance are yield strength, the strength to weight ratio and good weldability. For optimum strength it is better to have minimum carbon content of 0.18%. The materials selected for the study include AISI 1018, AISI 1020 and AISI 4130. Table 1&2 give the details of the chemical composition and Mechanical Properties of the materials.

Element (%)	**AISI 1018**	**AISI 1020**	**AISI 4130**
Carbon, C	0.15 – 0.20	0.17 – 0.230	0.28 – 0.33
Iron, Fe	98.81 – 99.26	99.08 – 99.53	97.03 – 98.22
Manganese, Mn	0.60 – 0.90	0.30 – 0.60	0.40 – 0.60
Phosphorous, P	≤ 0.04	≤ 0.04	0.035
Sulfur, S	≤ 0.05	≤ 0.05	0.04
Chromium, Cr	–	–	0.80 – 1.10
Molybdenum, Mo	–	–	0.15 – 0.25

Table: Chemical Properties of AISI 4130, 1018, 1020

Parameter	**AISI 1018**	**AISI 1020**	**AISI 4130**
Tensile Strength (MPa)	440	395	560
Yield Strength (MPa)	370	295	460
Poisson Ratio	0.290	0.290	0.295

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% Elongation	15	36.50	21.50
Strength to Weight Ratio	55-70	65-85	90-120
Modulus of Elasticity (GPa)	205	200	210

Table: Mechanical Properties of AISI 4130, 1018, 1020

The above materials have low carbon content, hence can be welded easily. However, AISI 4130 alloy steel is selected as it has high yield strength and strength to weight ratio than other materials. The AISI 4130 alloy steel also has very high tensile strength and resistance to corrosion as it contains chromium and molybdenum as strengthening agents. Cross section of the tubing plays an important role in design of the frame. The bending strength and ease of fabrication are considered while deciding the pipe cross section. It helps in reducing forces which are induced in the structure. Square and Circular are commonly used cross sections for ATVs. The Primary members of the chassis is kept 25.4 mm (1 inch) outer size with 2 mm wall thickness whereas the Secondary members is kept of 25.4 mm outer diameter with minimum wall thickness of 1.6 mm. Bending, and shear are predominant in the chassis. To select a suitable cross section tubing an arbitrary bending load of 800 N is applied to study the bending characteristics

Factors	**Square**	**Circular**
Bending Stress (N/mm^2)	392.93	287.19
Deflection (mm)	10.372	5.375

Circular Cross-sectional diameter of 25.4 mm is selected as it has uniform distribution of forces and high torsional rigidity which resulted in improving strength of Roll Cage. as there is less stress concentration and deformation as compared to square.

4. FRAME DESIGN

Integrating all the hard points and parameters frame is designed in CatiaV5 wireframe. Catia provides very flexible and easy user interface for design. Summing all the points the wireframe is created. The wireframe created is swept along spline with required diameter and later provided with thickness. Post processing puts together selecting and applying material for analysis purpose. Required mechanical properties are fed to the software for precise results.

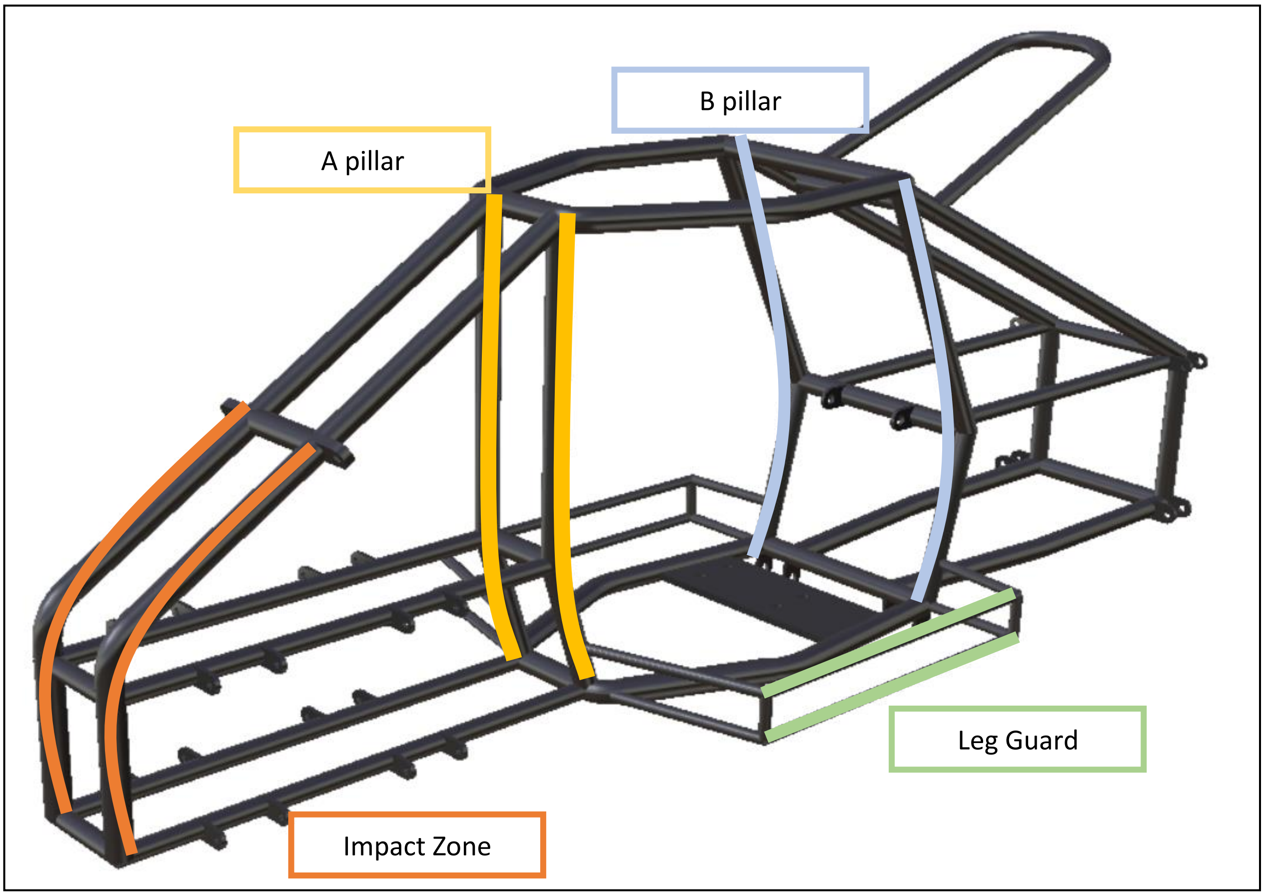

Fig-Frame isometric view

5. FRAME CRASH ANALYSIS

After the model of frame is completed on CATIA, the same is uploaded in hypermesh for mapped meshing. Hypermesh is a toll

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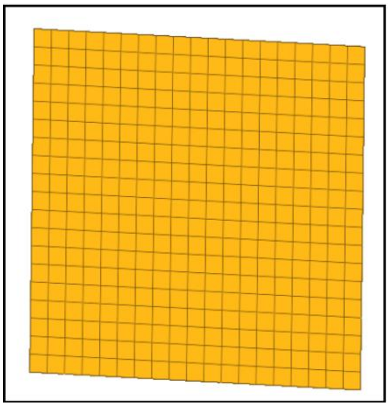
used to create linear and symmetric meshed structures to define force and displacement vectors. The model is uploaded on the same and mapped meshing feature is applied on the whole body for further analysis. Also, dynamic analysis is carried out by converting 3D model into singular line diagram. For the same, rigid body us considered to be a dash panel for impact. The body is divided into 100 elements and 121 nodes which is modeled by shell type meshing.



No of elements: 100
No of Nodes: 121
Weight of meshed model: 4.7 kg

The frame is also meshed by using shell type meshing consisting of 1741 elements and 3453 nodes. The base of the frame is fixed in all degree of freedom except the impact zone. The chassis is forced upon the rigid body with the velocity of 40 m/s. The results obtained are graphical and deformation observed is 83.60 mm.

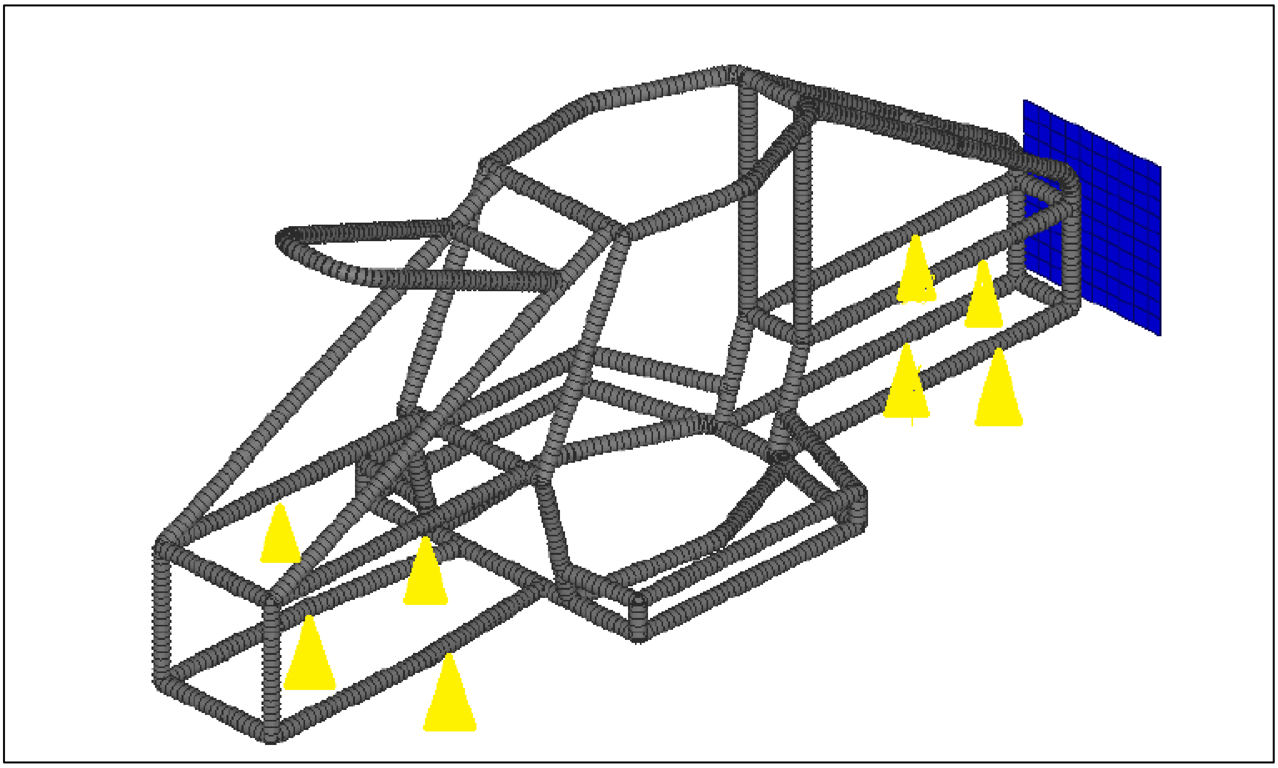


Fig-Meshed frame model in hypermesh

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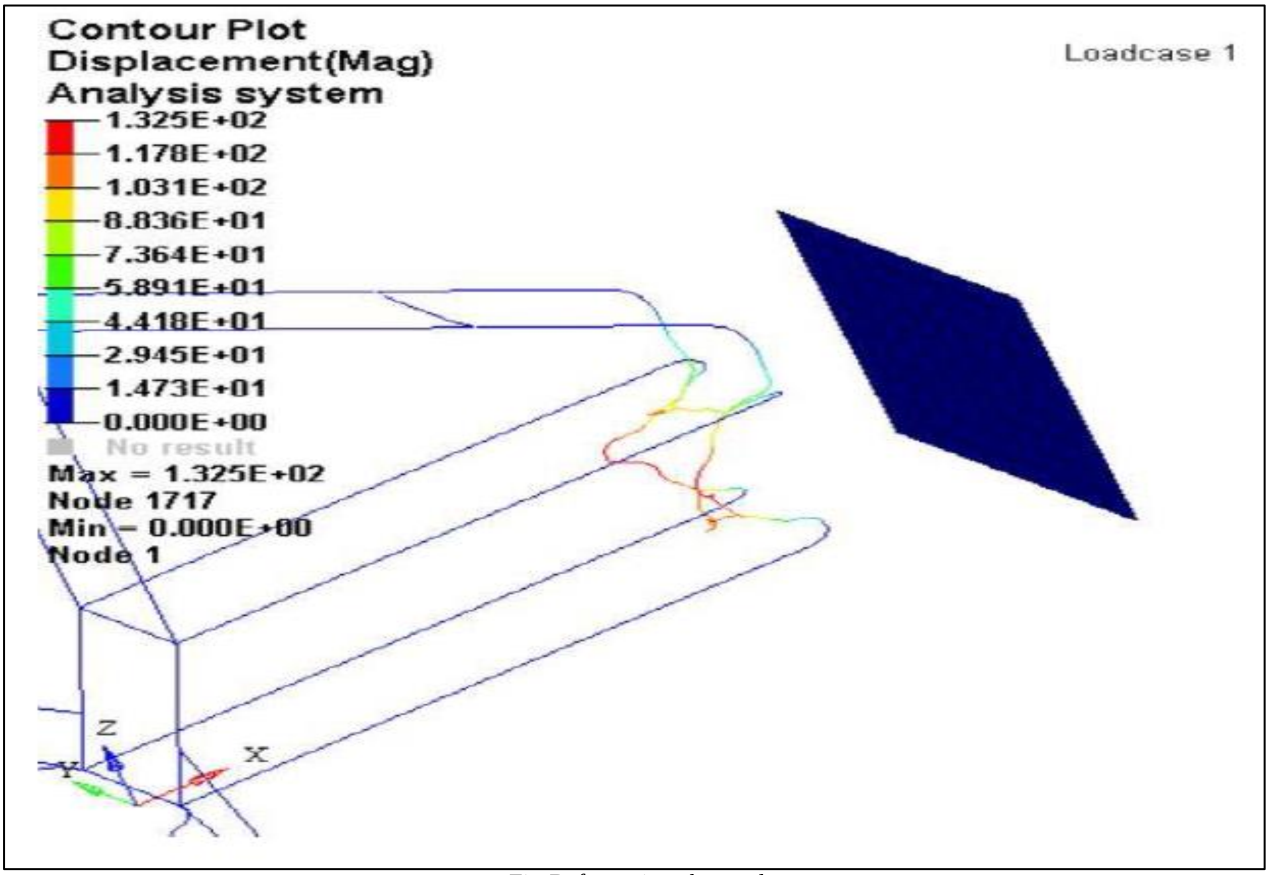

Fig-Deformation observed

10 GRAPHICAL RESULTS

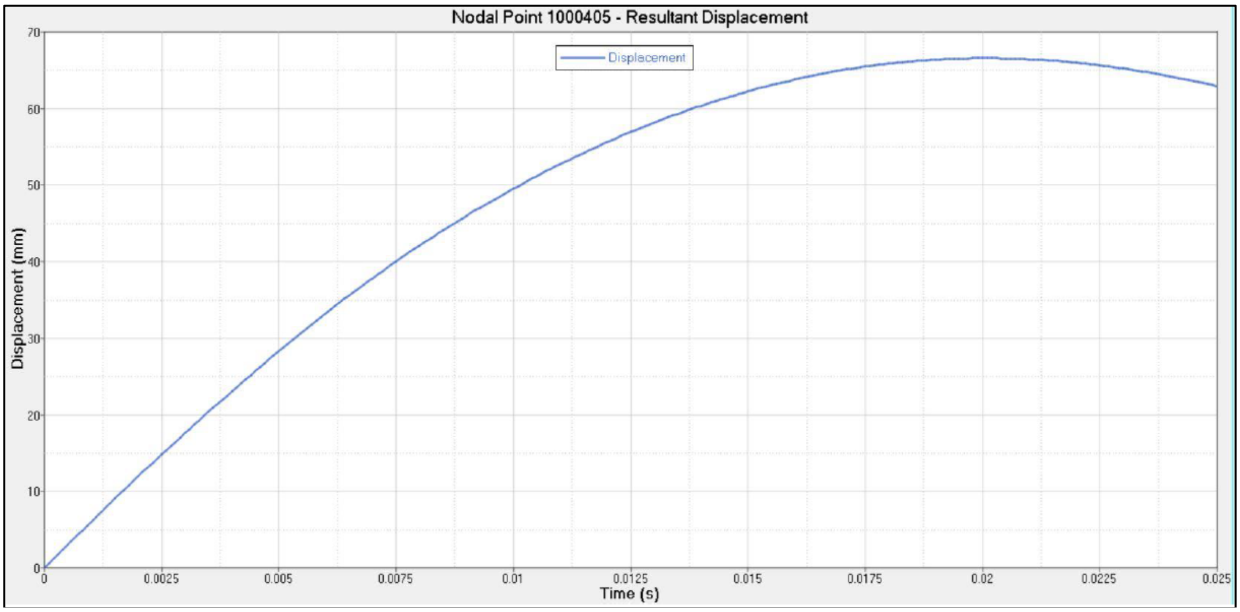

Fig-Resultant displacement

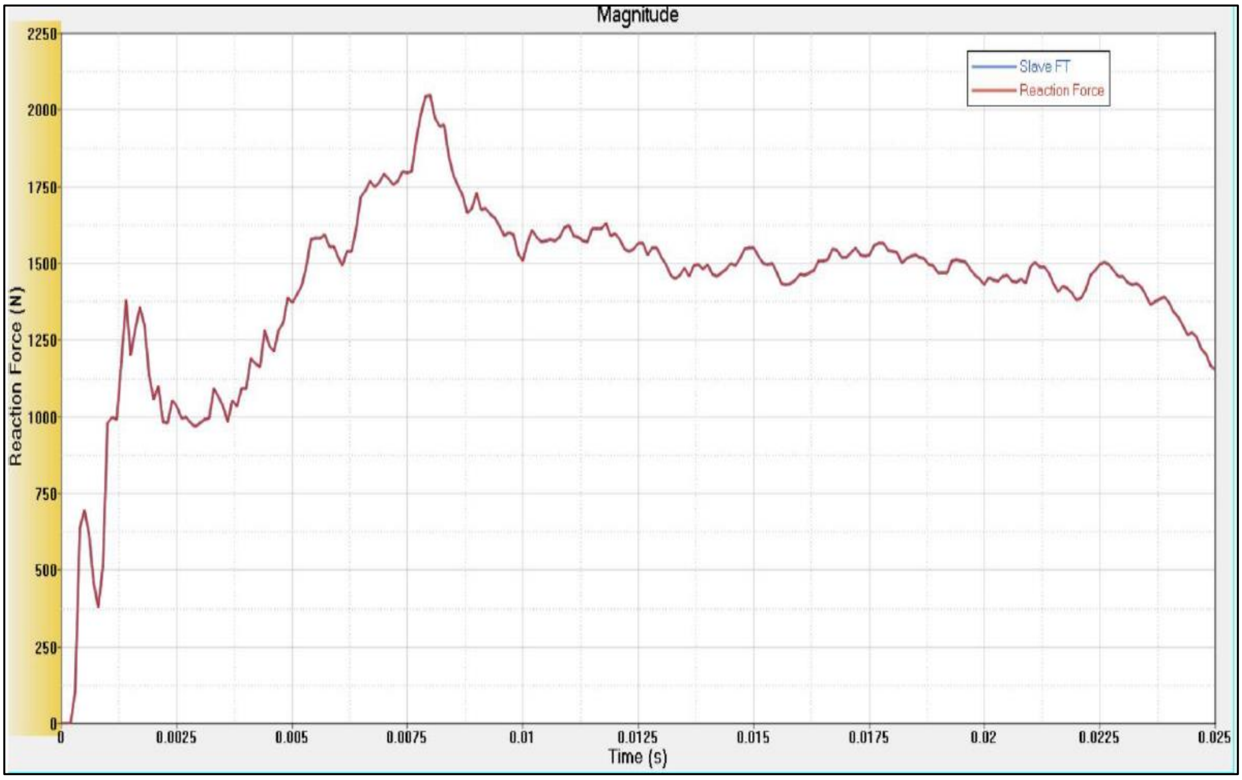

Fig-Resultant magnitude

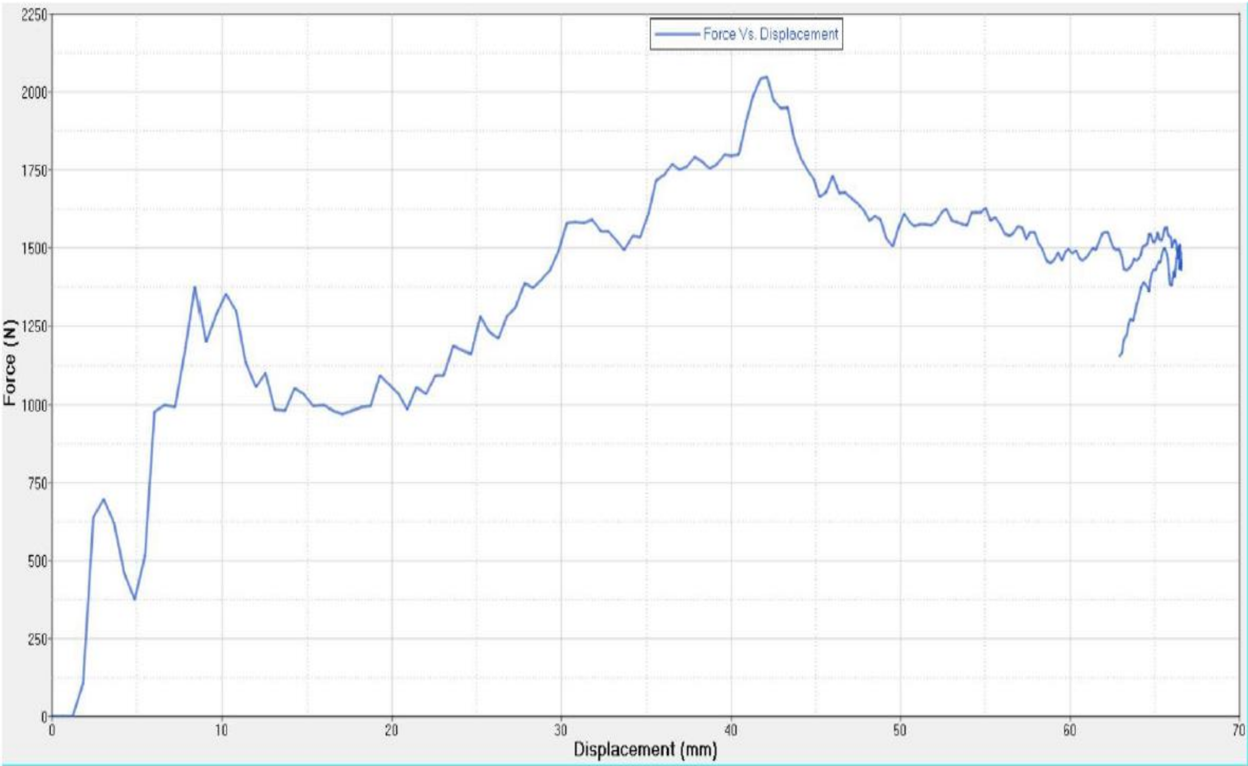

Fig-Force v/s Displacement

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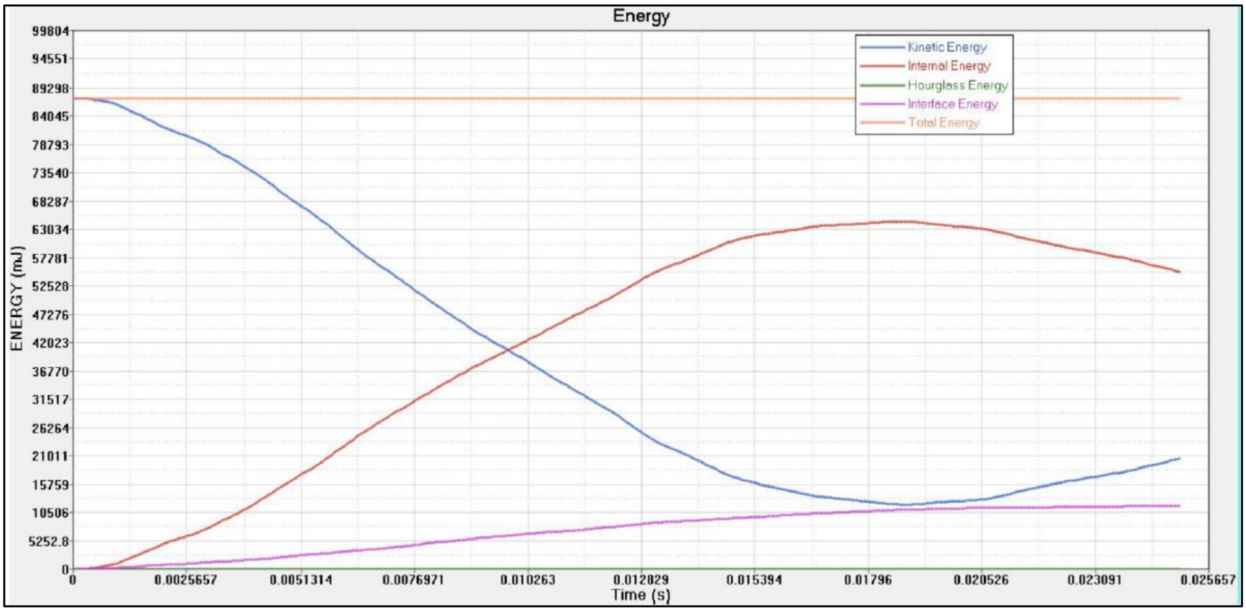

Fig-Energy Plot

Sr No	Parameter	Observation
1	Resultant displacement	67.63 mm
2	Resultant Magnitude Force	2103 N
3	Maximum kinetic energy	86.97 J
4	Reaction Force	2250 N

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