Modal and Static Analysis of a Standard All-Terrain Vehicle Chassis

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***Abstract* - This is a special kind of four-wheeled vehicle used for recreational and exploration purposes. It is designed for off road usage and for endurance of a rough terrain. In many aspects it is similar to an All-Terrain Vehicle (ATV) except that it is much smaller in size and has safer rollover capabilities. Besides these any successful mini baja vehicle should also be easily transported, easily maintained and fun to drive. Our vehicle can navigate through almost all terrain, which ultimately is the objective behind the making of any all-terrain vehicles. We began the task of designing by conducting extensive research of each main component of the vehicle.**

***Key words* - Static analysis, Modal analysis, Finite element analysis , strength, Suspension.**

Nomenclature used:

1. FEA – Finite element analysis
2. Lbs - pounds force
3. in: Inches “: Inch
4. LFS: Lower Frame Side
5. Mpa – Mega pascal.
6. Gpa – Giga pascal.

I. INTRODUCTION

The objective of the study is to design and develop the roll cage for All - Terrain Vehicle. Material for the roll cage is selected based on strength, cost and availability. The roll cage is designed to incorporate all the automotive sub-systems. A software model is prepared in Solid works software. Later the design is tested against all modes of failure by conducting various simulations and stress analysis with the aid of Ansys Software. Based on the result obtained from these tests the design is modified accordingly. After successfully designing the roll cage, it is ready for fabricated.

The vehicle is required to have a combination frame and roll cage consisting of steel members. As weight is critical in a vehicle powered by a small engine, a balance must be found between the strength and weight of the design. To best optimize this balance the use of solid modeling and finite element analysis (FEA) software is extremely useful in addition to conventional analysis. The following paper outlines the design and analysis of the chassis design.

There are many ATV’s in the market, but they are not manufactured in India. These ATV’s are assembled here. So we are giving a cost effective design of an All Terrain Vehicle Frame. Since the chassis is the main part of an automotive, it should be strong and light weight. Thus, the chassis design becomes very important. Typical capabilities on basis of which these vehicles are judged are hill climbing, pulling, acceleration and maneuverability on land as well as shallow waters.

This is aimed to design the frame of an ATV which is of minimum possible weight and show that the design is safe, rugged and easy to maneuver. Design is done and carried out linear static analysis and modal analysis for the frame.

II. EXPERIMENTAL DETAILS

A. *Design Methodology*

The primary objective of the frame is to provide a 3-dimensional protected space around the driver that will keep the driver safe. Its secondary objectives are to provide reliable mounting locations for components, be appealing, low in cost, and low in weight. These objectives were met by choosing a frame material that has good strength and also weighs less giving us an advantage in weight reduction. A low cost frame was provided through material selection and incorporating more continuous members with bends rather than a collection of members welded together to reduce manufacturing costs. Catia V.0 and SolidWorks 2010 were used to model a frame that is aesthetically appealing and meets all requirements.

B. *Problem Definition*

The design and development process of the roll cage involves various factors; namely material selection, frame design, cross-section determination and finite element analysis. One of the key design decision of our frame that greatly increases the safety, reliability and performance in any automobile design is material selection. To ensure that the optimal material is chosen, extensive research was carried out and compared with materials from multiple categories. The key categories for comparison were strength, weight, and cost. Here we are going design the chassis for two materials namely AISI Steel 1018 and 4130 Chrome moly steel.

C. *Material Selection*

One of the key design decisions of our frame that greatly increases the safety, reliability and performance in any automobile design is material selection. To ensure that the optimal material is chosen, extensive research was carried out and compared with materials from multiple categories. The key categories for comparison were strength, weight, and cost. 1018 steel, 1020 DOM, and 4130 chromoly were first considered. In general in the design of mini all terrain vehicles, if the standard tube size of 1”x0.12” is not used, then the material has to have equivalent bending strength to that of 1018 steel in the standard tube size.

While the rules set many factors of the material’s geometry, there are many other limitations. These limitations include the method of fabrication and industry standards for the material. The frame will be built using a bent tube construction and MIG welded joints. MIG welding becomes difficult at wall thicknesses less than 0.035 inches. The tubing bender that will be used for the fabrication can bend a maximum of 1.5 inch diameter tube with a 0.120 inch wall thickness. It also requires that the tube have a minimum wall thickness of 0.055 inches. The geometry is also limited by industry standards. It is important to utilize commonly available tubing sizes and materials. Tubing is available in standard fractional sizes to the 1/8th of an inch: 1, 1.125, 1.25, 1.375, and 1.5. The wall thickness is limited to: 0.035, 0.049, 0.058, 0.065, and 0.083 inches. The most commonly available material for this type of tubing is “AISI 1018 grade Steel”.

Table 1:Material specification chart

Property	1018 1”*0.12”	1020 DOM 1.25”*0.065	4130 1.25”*0.065
Yield strength	365Mpa	539Mpa	670Mpa
Bending stress	2790Nm^2	3640Nm^2	3640Nm^2
Bending strength	391Nm	602Nm	747Nm
Weight	112lbs	82lbs	82lbs

Table 2:Mechanical properties of steel 1018

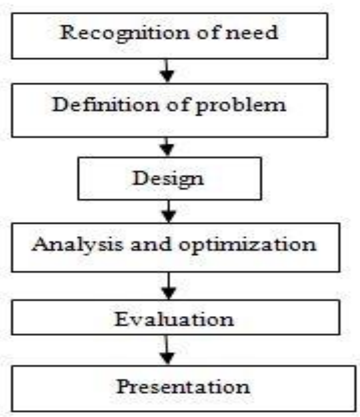
Properties	limits
Density (×1000 kg/m3)	7.7-8.03
Poisson's Ratio	0.27-0.30
Elastic Modulus (GPa)	190-210
Tensile Strength (Mpa)	560.5
Elongation (%)	28.2

Table 3:Chemical properties of 4130 chrome moly steel

Composition	**Element weight (%)**
Carbon (C)	0.28 - 0.33
Chromium (Cr)	0.8 - 1.1
Manganese (Mn)	0.7 - 0.9
Molybdenum (Mb)	0.15 -0.25
Phosphorus (P)	0.035 max
Silicon (Si)	0.15 - 0.35
Sulphur (S)	0.04 max

D. *Phases of design*

The complete design process, from start to finish, is highly iterative in nature and is as outlined in the flow diagram shown below. The process begins with recognition of a need and a decision to do something about it. After much iteration, the process ends with the presentation of the plans for satisfying the need



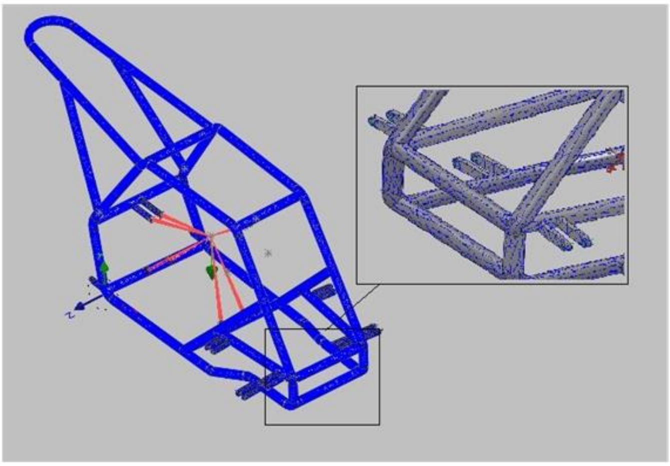


Fig.1 3D design of the chassis

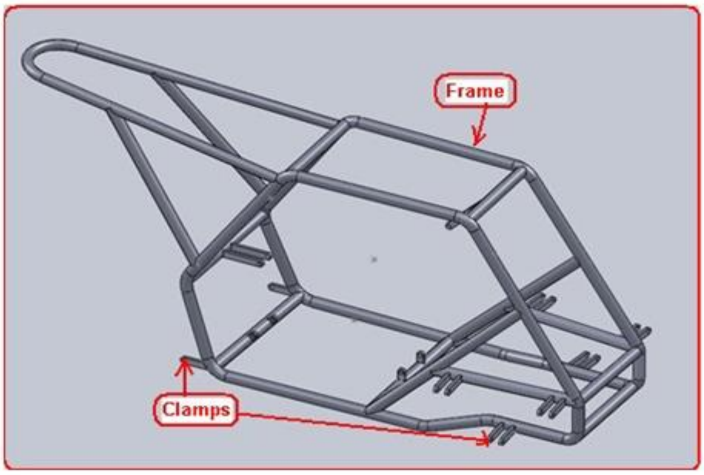


Fig.2 Mesh model of the chassis

E. Finite Element Analysis

After finalizing the frame along with its material and cross section, it is very essential to test the rigidity and strength of the frame under severe conditions. The frame should be able to withstand the impact, torsion, roll over conditions and provide utmost safety to the driver without undergoing much deformation. The solution of a general continuum by the finite element method always follows an orderly step by step process.

Step. 1. Discritization of structural domain
Step 2. Selection of a proper interpolation model
Step 3. Derivations of element stiffness matrices (Characteristic matrices) and load vectors.
Step4. Assemblage of element equations to obtain the overall equilibrium equation.
Step 5: Solution of system equations to find nodal values of the displacements (field variable) Step 6: Computation of element strains &stresses from the known model displacements

F. Frame Design Static Analysis for AISI steel 1018

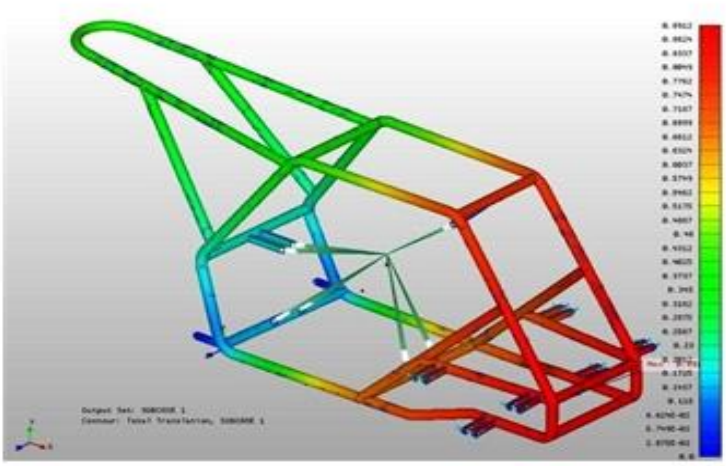


Fig.3 Displacement plot of the chassis is 0.8932mm

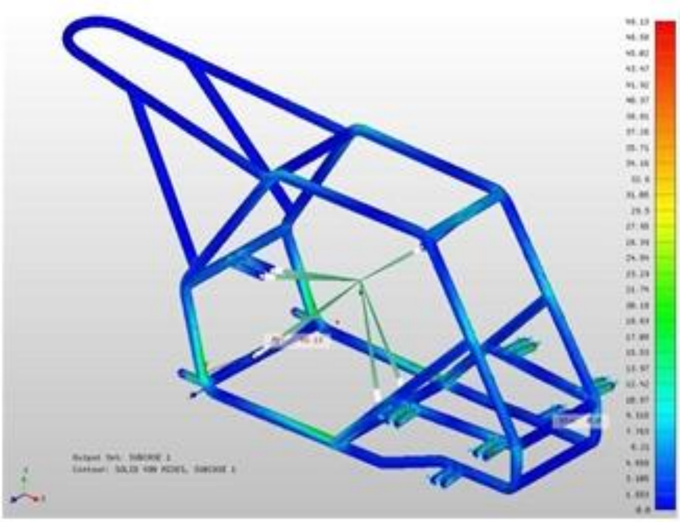


Fig.4 Von misses stress is found to be 48.19Mpa

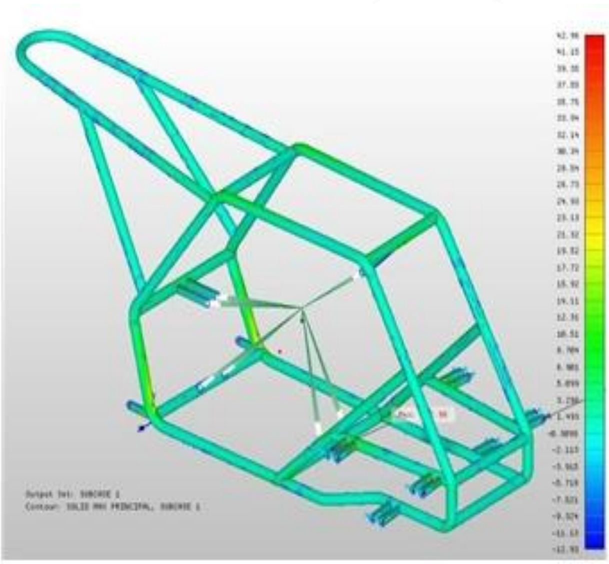


Fig. 5 First mode shape at 23 Hz

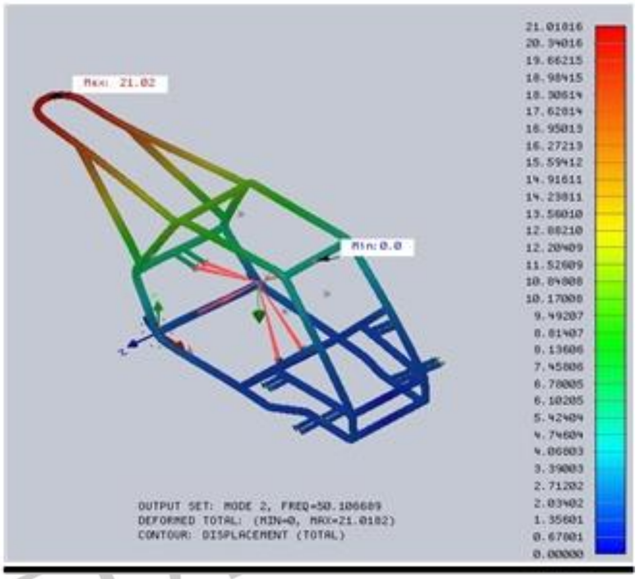
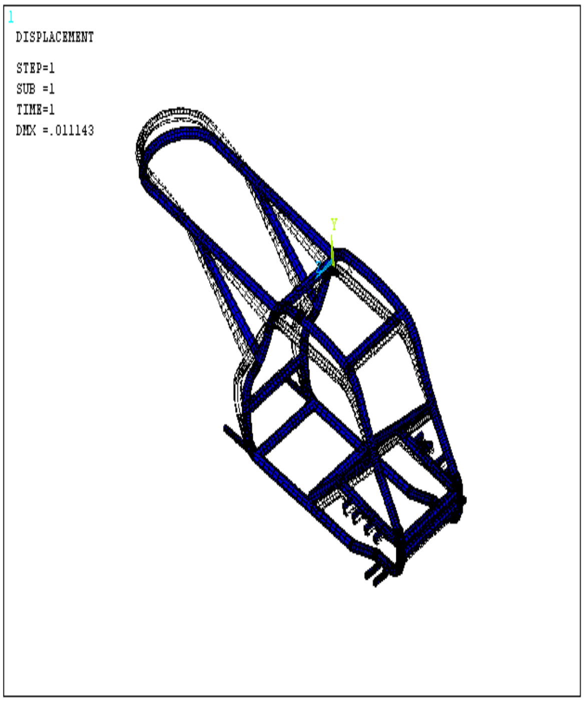


Fig.6 Second mode shape plot 50Hz

G. Static Analysis of frame for 4130 chrome moly steel



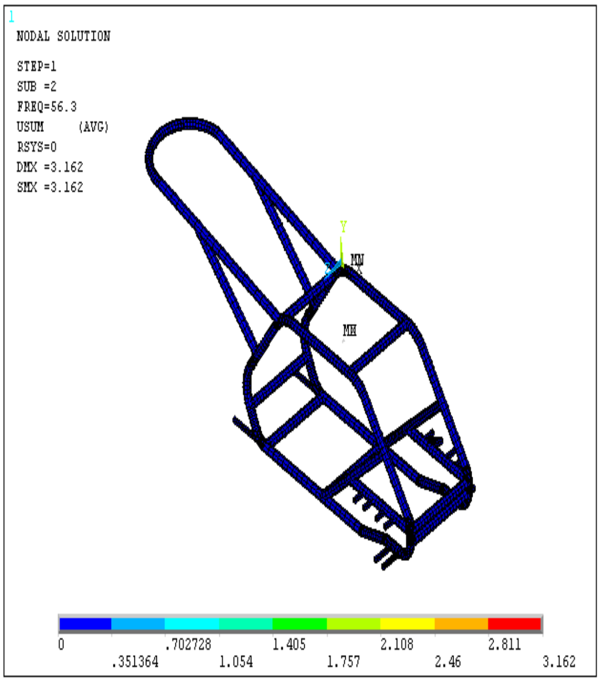


Fig.7 Displacement plot of chassis is 0.011mm

Fig.8 Maximum von misses stress is 39.27 Mpa

H. Modal Analysis of 4130 chrome moly steel

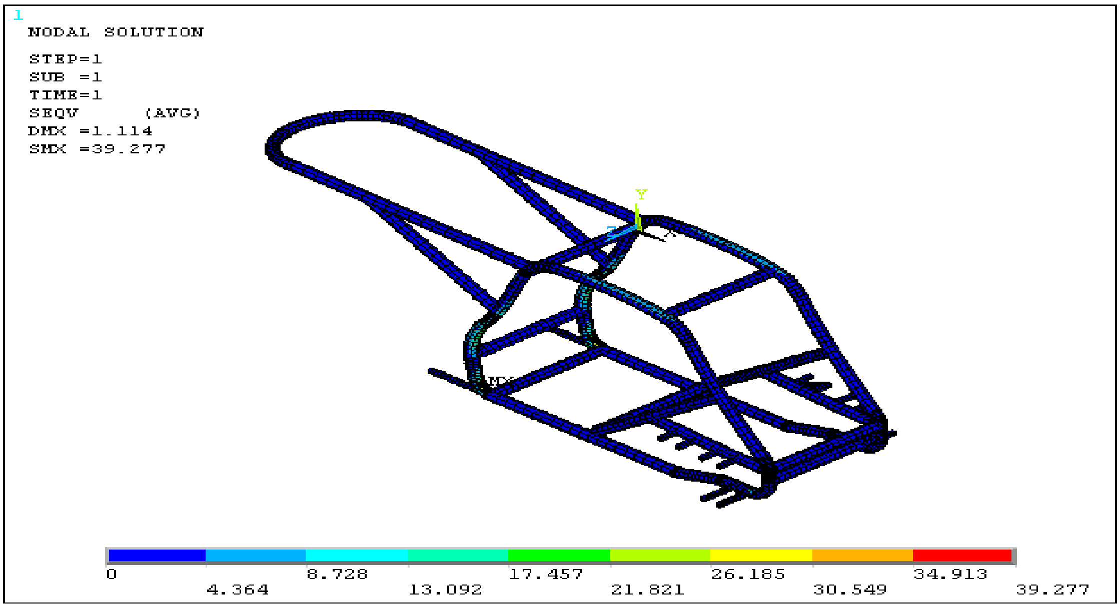


Fig.9 Modal analysis natural frequency is at 56.3Hz

III. RESULTS AND COMPARISION

The theoretical results and the computational results are almost same. The software analysis is done taking into consideration the whole chassis for the applied load, but in the theoretical calculations we consider only the critical clamp to check the stresses induced, hence the theoretical values might differ slightly from the Ansys results. Below is a table comparing the theoretical results and the computational results

Table 4: Obtained Values Comparison

Various stresses	Theoritical Results	Ansys results for 1018 steel
Maximum Normal stress	40.04Mpa	42.96Mpa
Minimum Normal stress	15.34Mpa	13.04Mpa
Maximum shear stress	33.55Mpa	26.34Mpa

From modal Analysis the first natural frequency has occurred at 23 Hz which is safe for land vehicles. By using 4130 Chrome Moly Steel the displacement is observed as 0,011 mm which is much less than as using Steel AISI 1018. The Von mises stress obtained by using 4130 Chrome Moly Steel is 39.27 which is also less than using Steel AISI 1018 i.e 48.19 MPa, The Natural frequency as observed by using 4130 Chrome Moly Steel is 56.3 which is more than using Steel AISI 1018 i.e 23 Hz.

IV. CONCLUSION

From the theoretical Calculations and Software Analysis results it is seen that the stresses obtained are within the material properties of Steel AISI 1018, and also a comparison is made when 4130 Chrome Moly Steel is used. The stresses, displacement and natural frequency obtained by using 4130 Chrome Moly Steel are still better . Hence it can be concluded that 4130 Chrome Moly Steel can be used as the material for the All Terrain Vehicle.

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