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Design Optimization of Sports Utility Vehicle Chassis

Dileep Krishnadas K¹, Dr.S.Sankar², Tedy Thomas³, Deepak.V.K⁴

PG Student, Dept. of Mechanical Engineering, Nehru College Of Engineering and Research Centre, Thrissur,
Kerala,India¹

HOD, Dept. of Mechanical Engineering, Nehru college of engineering and Research Centre, Thrissur, Kerala, India²
Assistant Professor, Dept. of Mechanical Engineering, Nehru college of engineering and Research Centre, Thrissur,
Kerala, India³

Assistant Professor, Dept. of Mechanical Engineering, Nehru college of engineering and Research Centre, Thrissur,
Kerala, India⁴

ABSTRACT: The vehicle chassis frame is an important part of an automobile. The chassis frame is the main structure of any vehicle. In this project work chassis for a SUV was designed using SolidWorks 2016 edition and analysed using Ansys R15.0. Chassis with side members having three different cross sections such as rectangular, square and circular were analysed by applying the working load and the results were compared to select the chassis with least total deformation. Then the selected chassis was modified and was subjected to a shear force and was analysed. Then the results were compared with analysis results of the initially designed chassis. Then the chassis with least value of total deformation was selected and was applied with three different materials and the results were compared to select the most suitable material. Then the chassis model with the least value of total deformation applied with the most suitable material was analysed and results were evaluated. Then modal analysis of the optimized chassis applied with the most suitable material was performed. The analysis data was used to perform the harmonic response analysis of the chassis and different properties of the chassis were analysed. From the results it can be concluded that chassis with rectangular cross section applied with ASTM A302 alloy steel is the best choice for sports utility vehicle.

KEYWORDS: Chassis, Crossmembers, ASTM A70 steel, Carbon steel AISI 4130, ASTM A302 alloy steel.

I. INTRODUCTION

A vehicle frame is the main supporting structure of a motor vehicle to which all other components are attached, comparable to the skeleton of an organism. Chassis frame is the basic frame work of an automobile. All the automobile systems like transmission, steering, suspension, braking system etc. are attached to and supported by the chassis frame. The frames provide strength as well as flexibility to the automobile. When the vehicle travels along the road, the chassis is subjected to excitations from the engine and transmission system as well as due to the road profile. Due to these excitations, the chassis begins to vibrate. Natural frequency of vibration coincides with the frequency of external excitation, resonance occurs, which leads to excessive deflections and failure. The ladder frame is one of the simplest and oldest of all designs. This was the first type of chassis to be designed. Almost all car manufacturers used it until the early 60's. Nowadays some SUV's still use it. As the name connotes, ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by several lateral members and cross braces. It uses few, large diameter tubes. Axles play an important role in sustaining weight. It consists of two symmetrical beams, rails, or channels running the length of the vehicle, and several transverse cross-members connecting them. Originally seen on almost all vehicles, the ladder frame was gradually phased out on cars in favour of perimeter frames and unitized body construction. This design offers good beam resistance because of its continuous rails from front to rear, but poor resistance to torsion or

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warping when simple, perpendicular cross members are used. The main advantages are that they are cheap to hand build and can cope with heavy loads. The major drawback is that it has low torsional rigidity, because it is a two dimensional chassis.

II. DESIGN PROCEDURE

This section deals with the process of modeling. Model is a representation of an object, a system, or an idea in some form other than that of the entity itself. Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software. Softwares commonly used for modelling are SolidWorks, Creo, Catia, Unigraphics etc. In this project SolidWorks 2016 edition is used for the modelling process.

Design of vehicle chassis

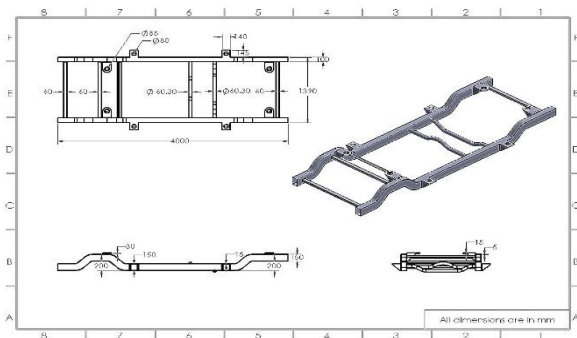


Fig.1 Chassis frame

Table 1 Dimensions of vehicle chassis

S.no	Description	Dimensions(mm)
1	Length	4000
2	Width	1390
3	Front overhang	741.35
4	Rear overhang	630.54
5	Wheel base	2628.11

Table 2 Dimensions of cross members in chassis

Sl.No.	Members used	Length x Width x Thickness(mm) or Outer radius x Thickness(mm)
Side members		
1	Rectangular cross section	150 x 100 x 5
2	Square cross section	120 x 120 x 6.3
3	Circular cross section	76.2 x 5
Cross members		
4	Rectangular cross section	60 x 40 x 3.2
5	Circular cross section	30.15 x 5

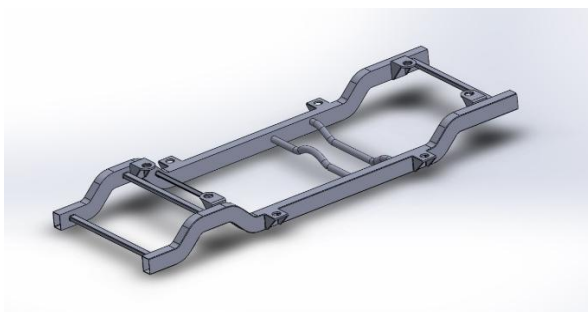


Fig.2 Chassis model designed using SolidWorks 2016

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Vol. 8, Issue 5, May 2019

III. ANSYS PROCEDURE

This section deals with the analysis of the designed model. The model that is in STEP format is analysed. Static structural analysis of both stabilizer bar link and suspension system is performed by applying the working load and number of supports used is two. The model is imported to Ansys and meshing is performed. The mesh size used is 4.4 mm. From the results obtained optimal design is selected. Suitable materials are applied to three different models of stabilizer bar link and modal analysis is performed. Different softwares such as Comsol, Radioss solver, Abaqus, Hypermesh, Ansys etc. are used for analysis. In this project Ansys R15.0 is used for design analysis.

Design Analysis

The figure shown below represents the meshed image and force application in vehicle chassis.

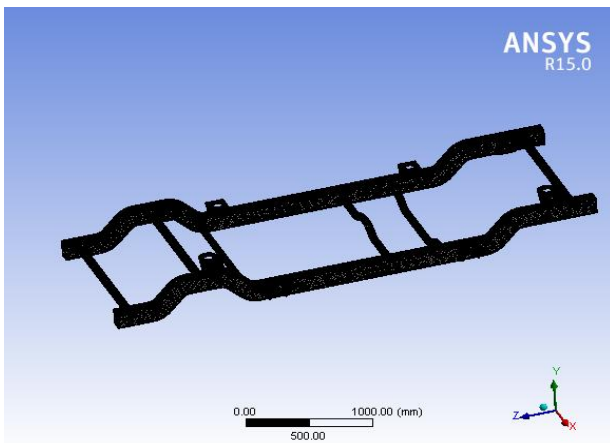


Fig.3 Meshed image of vehicle chassis

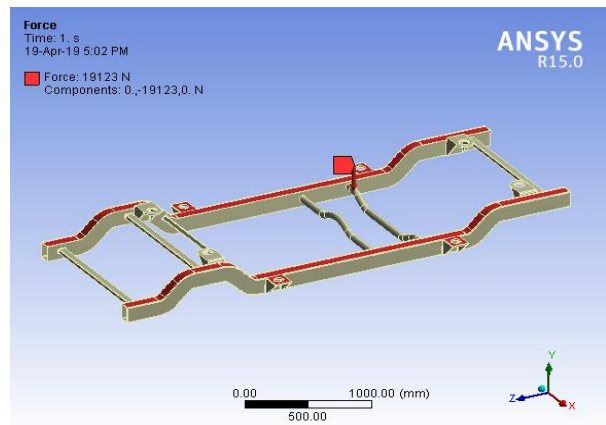


Fig.4 Force application in vehicle chassis

The figure shown below represents the total deformation of vehicle chassis with rectangular cross section side members

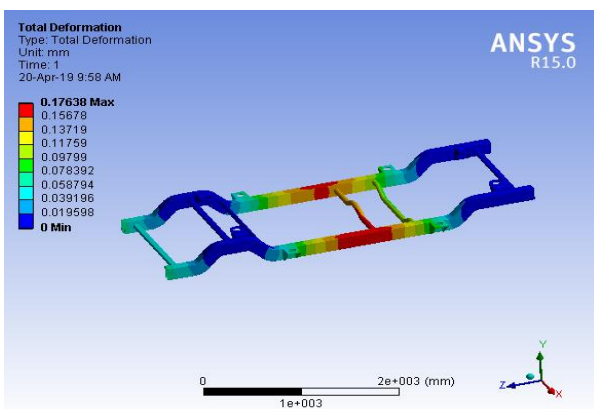


Fig.5.Total deformation of chassis with rectangular cross section side members

Table 3 Overview of analysis results

Sl.No	Side member cross section	Maximum total deformation (mm)
1	Rectangular	0.17638
2	Square	0.18879
3	Circular	0.21855

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Vol. 8, Issue 5, May 2019

From the analysis results it can be concluded that the chassis with rectangular cross section members have the least value of maximum total deformation. Hence chassis with rectangular cross section members is selected for further analyses.

The figure shown below represents the total deformation of modified design of chassis with rectangular cross section members

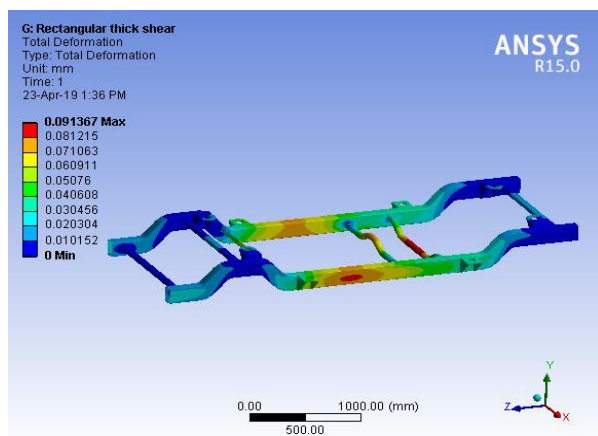


Table 4 Overview of analysis results

Sl.No	Chassis subjected to analysis	Maximum total deformation (mm)
1	Initially designed chassis	0.12358
2	Modified chassis	0.091367

Fig.6 Total deformation of modified design of chassis with rectangular cross section members

From the analysis results it can be concluded that the modified design of chassis with rectangular cross section members have the least value of maximum total deformation. Hence the modified design of chassis with rectangular cross section members is selected as the best suitable system.

IV. MATERIAL OPTIMISATION

The above shown table represents analysis results of the chassis using three different materials. Three different materials are applied to the vehicle chassis and the analysis results are compared to select the most suitable material. The three different materials used for analyses are ASTM A710 steel, Carbon steel AISI 4130 and ASTM A302 alloy steel.

Table 5 Overview of analysis results of the chassis using three different materials

Design parameter		ASTM A710 steel	Carbon steel AISI 4130	ASTM A302 alloy steel
Total deformation(mm)	Max	0.13447	0.14264	0.13132
	Min	0	0	0
Directional deformation(mm)	Max	0.0085705	0.0090842	0.0083719
	Min	-0.1344	-0.1426	-0.13129
Equivalent stress (MPa)	Max	34.79	35.639	32.964
	Min	2.7998e ⁻⁵	4.0825e ⁻⁵	1.6629e ⁻⁵
Equivalent elastic strain	Max	0.00022381	0.00024272	0.00020829
	Min	4.5064e ⁻¹⁰	1.2769e ⁻⁹	4.1432e ⁻¹⁰

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Vol. 8, Issue 5, May 2019

V. MODAL ANALYSIS AND HARMONIC RESPONSE ANALYSIS

Modal analysis

Table 6 Total deformation of chassis at different natural frequencies

Mode	Frequency(Hz)	Total deformation (mm)	
		Max	Min
1	62.292	3.2032	0
2	75.713	9.2614	0
3	82.771	9.0721	0
4	84.686	6.7197	0
5	86.338	9.469	0
6	92.174	8.7454	0

Harmonic response analysis

Table 7 Overview of harmonic response analysis results

Sl.No.	Design parameter	Max	Min
1	Total deformation (mm)	831.43	0
2	Directional deformation (mm)	21.078	-25.711
3	Equivalent elastic strain	0.29812	7.545e ⁻¹⁴
4	Equivalent stress (MPa)	62116	1.1851e ⁻⁹
5	Elastic strain intensity	0.45303	8.5948e ⁻¹⁵
6	Normal stress (MPa)	45658	-41803
7	Normal elastic strain	0.12962	-0.12855

From Table 6 it can be concluded that the natural frequency at which the total deformation value is minimum is the first modal frequency. The first modal frequency value is 62.292 Hz and the total deformation value at this particular frequency value is 3.2032 mm. The results obtained from modal analysis are used to perform the harmonic response analysis of the chassis.

VI RESULTS AND DISCUSSION

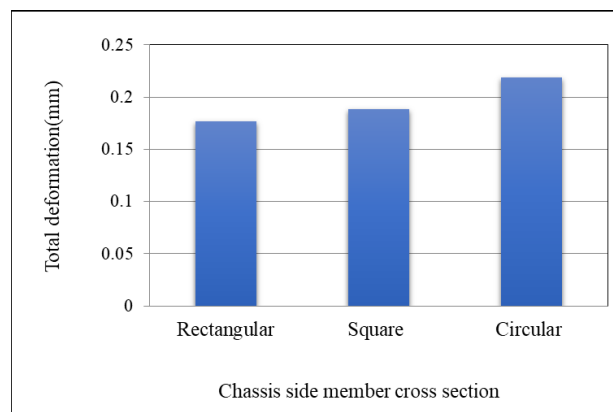


Fig. 7 Total deformation of chassis vs chassis side member cross section

Chassis with side members having rectangular cross section was modified by increasing thickness of the cross section from 5 mm to 6.3 mm. Then both the initially designed and modified chassis was subjected to analysis by applying a

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Vol. 8, Issue 5, May 2019

shear force of value 10000 N in opposite directions on both side members. It was found out that the total deformation of the modified chassis has reduced by 26.06%. The design modification of the chassis has increased the weight of the chassis from 357.47kg to 393.92 kg. Hence the weight of the modified chassis is increased by 36.45 kg

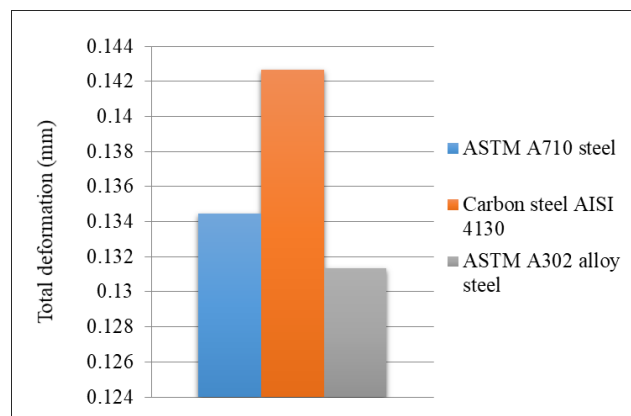


Fig 8 Comparison of total deformations of chassis applied with three different materials

The three different materials such as ASTM A710 steel, Carbon steel AISI 4130 and ASTM A302 alloy steel were applied to the chassis and it was found out that the chassis applied with ASTM A302 alloy steel exhibits the minimum total deformation.

VII.CONCLUSION

In this project a chassis for a SUV was designed using SolidWorks 2016 edition and the designed model was analysed using ANSYS R15.0. Initially three chassis with different side member cross sections were designed. Then a force equivalent to the load acting on the chassis of value 19122.97 N was applied. From the analysis results it was found out that chassis with side members having rectangular cross section has minimum total deformation. Then the chassis was modified by increasing the thickness of side member cross section from 5 mm to 6.3 mm. The weight of chassis was then increased by 36.45 kg. Total deformation of the modified and initially designed chassis were analysed by applying a shear force of 10000 N in opposite directions acting along X axis and it was found out from the analysis results that modified chassis has better resistance to shear forces by 26.06% as compared to the initially designed chassis. Then three different materials such as ASTM A710 steel, Carbon steel AISI 4130 and ASTM A302 alloy steel were applied and the total deformation values under a load of value 19122.97 N were calculated and it was found out that chassis applied with ASTM A302 alloy steel has the minimum total deformation. Thus ASTM A302 alloy steel was selected as the chassis material and the modal analysis of the chassis was carried out. The first six natural frequencies of the chassis was found out. Also the total deformation values at these six natural frequencies were found out. The analysis data obtained from modal analysis was used to perform harmonic response analysis and different design parameters such as total deformation, directional deformation, equivalent elastic strain, equivalent stress, normal stress and normal elastic strain were evaluated and the results were tabulated.

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Vol. 8, Issue 5, May 2019

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