Modal and Static Analysis of Rear Crash Guard Employed in SUV

Pavan Kumar S.
Post Graduate Scholar
Machine Design, EWIT
Bangalore, Karnataka, India

Dr Maruthi B H
Head of the department
Mechanical Engineering Dept, EWIT
Bangalore, Karnataka, India

Aravind K.U.
Asst. Professor
Mechanical Engineering Dept, EWIT
Bangalore, Karnataka, India

Bharatish.A
Assistant Professor
Mechanical Engineering Dept, RVCE
Bangalore, Karnataka, India

Abstract*— Crash guards used in Sports Utility Vehicle (SUV) serves as a platform for avoiding frontal collisions and ensures occupant safety. This paper focuses on analyzing the dynamic and static behavior of the rear crash guards in order to predict the natural frequencies and Von mises stresses in the component. Geometric modelling of a rear crash guard for SUV (Sports Utility Vehicle) was carried out using CATIA V5 package. Further geometric model was imported into ANSYS Workbench to carry out modal analysis to understand the system behavior. The simulation predicted that the seventh mode is the safe mode which corresponds to 4.56Hz and safe stress of 61.79MPa which is less than yield stress of the material (220 MPa). Thus the results can be effectively utilized in modeling the rear crash guard behavior for crash loads and successfully identify the safe performance.

Keywords— **Rear crash guards, natural frequency, frontal collisions, SUV**

I. INTRODUCTION

Safety is one of the most important parameters of modern vehicles. Road accidents such as passenger cars collide with trucks or sandstone vehicles are one of the most common types of car accidents. The injury risk of accidents involving heavy vehicles appears to be far greater for occupants of opponent vehicles, especially for cars. And this risk increases in the case of car to truck frontal collisions. While protection against excessive deformation generally favours a stiff structure, excessive stiffness also reduces crashworthiness due to the increased risk of occupant injury during severe impacts. As such, a crashworthy structure should be stiff in some portions to prevent intrusions into sensitive areas such as the passenger cabin and fuel system, but soft in other portions to absorb the impact energy before reaching to the stiff regions. An automobile frontal/rear crash lasts about 100 milliseconds. In this short time the passenger is subjected to high inertial forces, which are caused by stiff vehicle structures, which may end up in injuries and fatalities. So in the design of vehicle structures for crashworthiness there is a need for structural subcomponent that guarantee an undeformable survival cell for the passengers and deformable subsystems able to efficiently dissipate the Kinetic energy. Some of the researchers have focused on investigating crash analysis of side/rear guard, bumper and rail. Alok Kumar khore et al. investigated the influence of thickness, material behavior, geometry, and other parameters on the compatibility of the car bumper and rear under run protection device [1]. Tejasagar Ambati et al. investigated that forces which are experienced during the crash can be reduced by altering some of the materials of the components and also stated that usage of computer software's for the simulation of vehicle crashes has become an indispensible tool for reduction of automobile development time and lowering costs [2]. S.W. Kirkpatrick et al. investigated the full size car for crashworthiness analysis and validate it with a high fidelity finite element model and develop a set of detailed finite element models for various vehicles that represent the range of vehicle types currently on the road [3]. De-Shin Liu et al. investigated under ride protective structures can reduce serious injuries when passenger cars collides with the rear end or side of the heavy vehicle [4]. Gary R. C et al. Investigated new low profile portable concrete barrier system for use in roadside work zone environments by making use of non-linear dynamic finite element impact simulation rather than full scale crash testing [5]. R. Mirzaamiri et al investigated the behavior of truck subjected to a complex crash test which consisted of three tests Front impact test, Roof strength test, Rear wall strength test [6]. Seong S C et al developed a new composite bumper that has two pads at the ends. The two pads were designed to hit the front two tires of the car when the bumper brackets collapsed during collision [7]. Z.Q. Cheng et al developed a finite element model of a four door Honda accord sedan. Their objective was to refine the model, to improve the computational performance of the model, and validate crash responses of the model with results obtained from crash test data of actual vehicles [8]. A. Deb et al designed an Aluminum based small car platform for frontal impact safety. Experiments were conducted for arriving at front end design during impact against a rigid barrier at 30 mph (FMVSS 208 condition) [9]. Kusekar Sambhaji Kashinath et al studied for design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact which includes parameters such as material, thickness and shape [10].

This paper focuses on analyzing the Rear Crash Guard (RCG) for dynamic and static behavior subjected to impact loads. Geometric modelling of a rear crash guard for SUV (Sports

Utility Vehicle) was carried out using CATIA V5 package. Further geometric model was imported into ANSYS Workbench to carry out modal analysis to understand the system behavior and calculate natural frequencies for different modes. Non linear static analysis was carried out to find the stress distribution pattern and stiffness check.

ii. Geometric modeling of RCG

The Geometric model of the Rear guard of SUV consisting of links and foot rest is carried out using commercially available software code CATIA V5 R20 which is as shown in the Figure II.

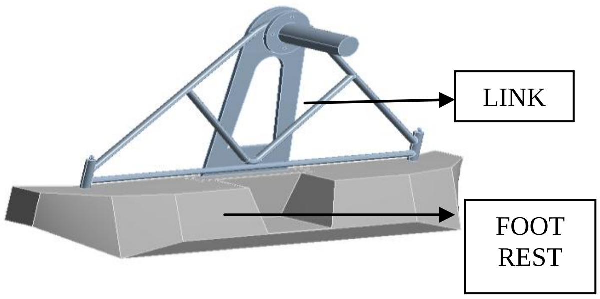


Fig II: Geometric modelling of RCG

III. MESHING OF RCG

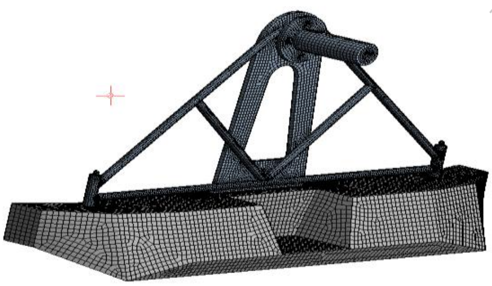


Fig III: Meshing of the RCG

Figure III shows the meshed model of a rear crash guard. In the ANSYS tool meshing is carried out for a crash guard with hex dominant method. The meshed model contains 26487 nodes and 26579 elements with SHELL181 as the element type. SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four-node element with six degrees of freedom at each node. SHELL181 is well-suited for linear, large rotation, and/or large strain nonlinear applications. Material selected for Rear guard for SUV is Aluminum alloy and Structural Steel. Table 3.1 shows the material properties of Aluminum alloy and structural steel material.

	Aluminum Alloy	Structural Steel
Young's modulus	7.1×10^{10} N/mm²	2×10^{11} N/mm²
Density	2770 kg/m^3	7850 kg/m³
Poisson's Ratio	0.33	0.3

III: Table shows material properties for Aluminum Alloy and Structural Steel

IV. LOADS AND BOUNDARY CONDITIONS

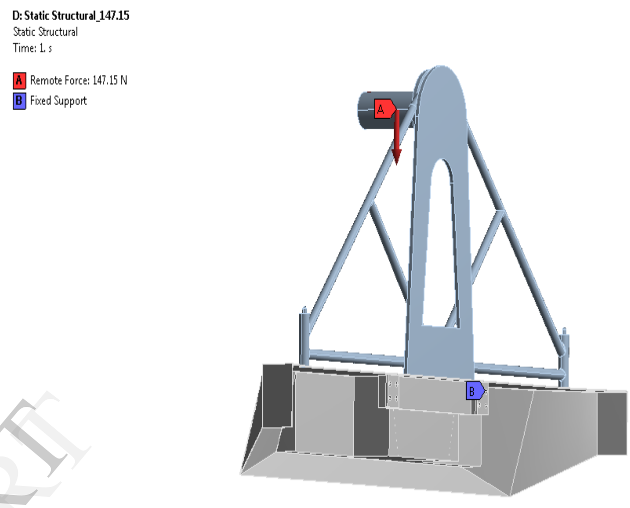


Fig IV: Loads and boundary conditions

Figure IV shows the load and Fixed position in the rear guard. Load of 147.15N is applied at the cylindrical bar in the downward direction, which represents the load of the Tier and the rear guard which has to fix to the chassis is fixed. The contact elements used are CONTACT174 and TARGET170.

CONTA174 is used to represent contact and element is located on the surfaces of 3-D solid or shell elements with midsize nodes. Sliding between 3-D target surfaces (TARGE170) and a deformable surface, defined by this element.

V. RESULTS AND DISCUSSION

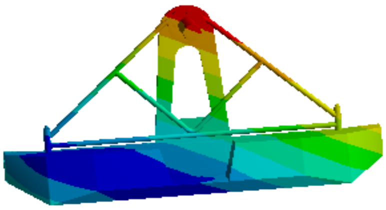
V.I Modal Analysis

Modal analysis is required in order to determine the natural frequency of the component which does not match with the natural frequency of the entire system in order to avoid resonance. In modal analysis, the connectivity of different components is achieved by calculating the natural frequency of components with basic behavior of the model. Twelve modes of the components are extracted in which first six modes are nearly zero and seventh mode is positive value which is the actual natural frequency of the component shown in the Table V.I.I

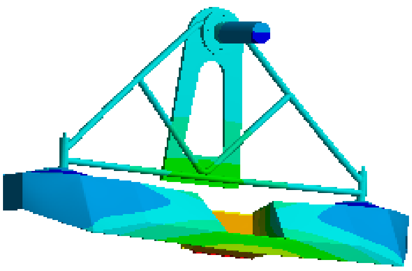
Mode	Frequency [Hz]
1	0
2	0
3	0
4	0
5	0
6	0
7	4.5624
8	38.156
9	47.045
10	55.941
11	73.821
12	74.043

V.I.I Table shows Different frequency modes corresponding to the natural frequency of the component

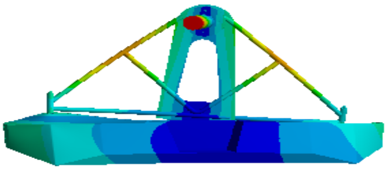
Mode shapes



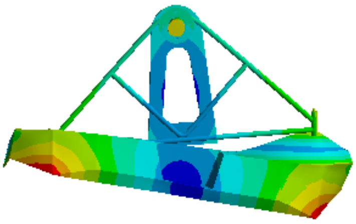
7th Mode



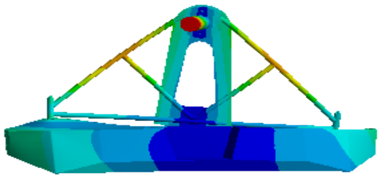
8th Mode



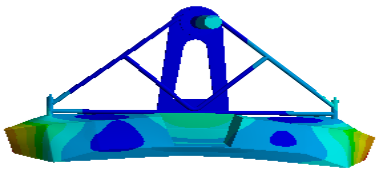
9th Mode



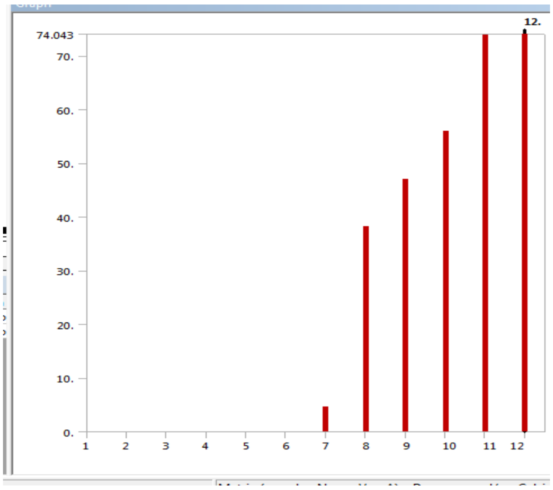
10th Mode



11th Mode



12th Mode



V.I.II: Variation of natural frequencies with modes

VI. Static Structural Analysis

Tier load of 147.15 N was applied in downward direction on the bar and the stress of 61.679 MPa and deflection of 6.7793 mm was observed as shown in the Figure V.I. Crash guard was made of aluminum alloy and yield strength of aluminum alloy was 250Mpa. Since the stress value obtained 61.67 MPa is within the yield strength of aluminum, design is safe and the crash guard ensures the occupants safety and provides a efficient platform for impact safety.

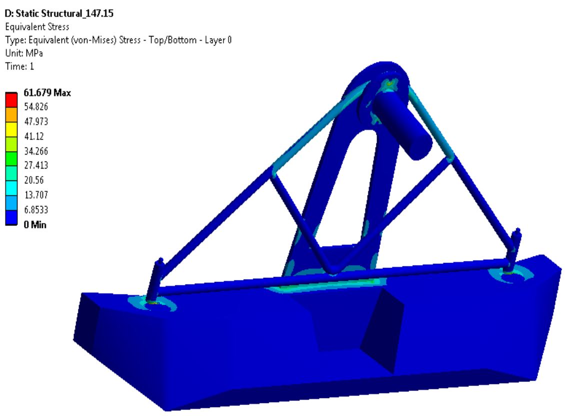


Fig V.I: Von Mises Stress distribution for a crash guard

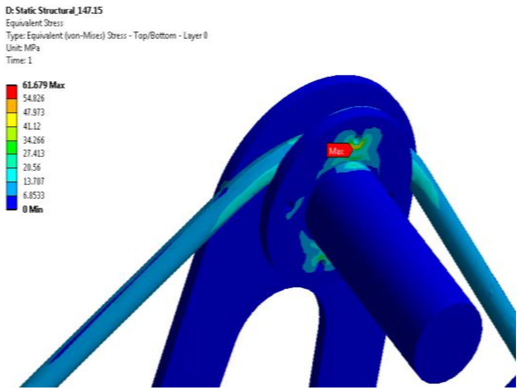


Fig V.II: Maximum Stress observed in the hole region.

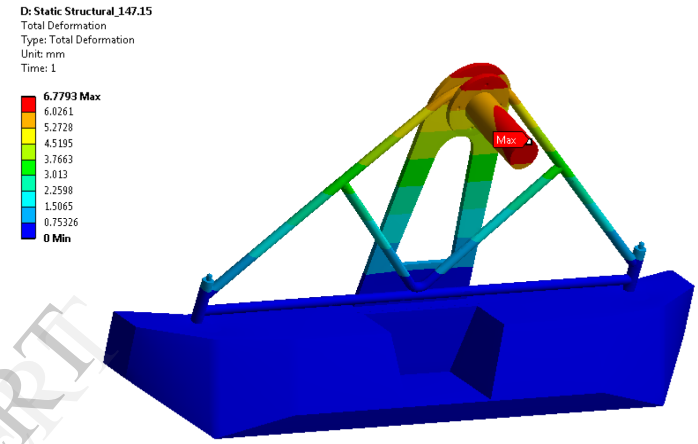


Fig V.III: Total deformation of a crash guard which is found to be 6.77mm and maximum deformation on the point of the crash guard is displayed.

VII. CONCLUSIONS

The dynamic and static behavior of the crash guard leads to the following conclusions.

1. The modal analysis of crash guard predicted the seventh mode as safe mode which corresponded to the natural frequency of 4.5624 Hz and this does not match with the natural frequency of the entire system which is equal to 85 Hz and hence the resonance condition is avoided.

2. The Von-Mises stress obtained from static structural analysis (61.679 MPa) is within the yield strength of the material (250MPa) and hence design is safe and ensures occupants safety.

3. Since the first six modes of natural frequency are zero, the contact between the components are rigid.

VIII. REFERENCES

1. AlokKumarKhore, TapanJain, Dr.Kartikeya Tripathi, **"**Impact Crashworthiness Of Rear Under Run Protection Device In Heavy Vehicle Using Finite Element Analysis", International journal of innovative research and development, Vol 2 Issue 13, page no. 332-338, 2013.

2. Tejasagar Ambati, K.V.N.S.Srikanth & P.Veeraraju, "Simulation Of Vehicular Frontal Crash-Test", International Journal of Applied Research in Mechanical Engineering (IJARME) ISSN: 2231 –5950, Volume-2, Issue-1, page no. 37-42, 2012.

3. S.W.Kirkpatrick, J.W.Simons, and T. H.Antoun," Development And Validation Of High Fidelity Vehicle Crash Simulation Models**",** Proceedings of International Crashworthiness Conference, page no. 603-611.

4. De-Shin-Liu, Nan-Chun-Lin, Chao-Chin-Huang, Yin-Lee-Meng,"Structural Design Optimization Of Side/ Rear Impact Guards Using A Coupled Genetic Algorithm Finite Element Method", Proceedings of ASME International mechanical engineering congress and exposition, page no.1-6, 2004.

5. Gary R.Consolazio, Jae H.Chung, Kurtis R.Gurley, "Impact Simulation And Full Scale Crash Testing Of A Low Profile Concrete Work Zone Barrier",page no. 1359-1374, 2002.

6. R.Mirzaamiri , M.Esfahanian , S. Ziaei-Rad, "Crash Test Simulation And Structure Improvement Of Ikco 2624 Truck According To Ece-R29 Regulation**",** International journal of automotive engineering,Vol. 2, Number 3, July 2012, page no.180-192.

7. Hollowell , S.W. Reagan , E.M. Sieveka," Seong Sik Cheon, Jin Ho Choib & Dai Gil Lee," Development Of The Composite Bumper Beam For Passenger Cars", Elsevier Science Limited, 1995, page no:491-499.

8. Z.Q. Cheng , J.G. Thacker , W.D. Pilkey , W.T. Experiences In Reverse-Engineering Of A Nite Element Automobile Crash Model" , Elsevier Science Limited, Finite Elements in Analysis and Design,2001,page no.843–860.

9. A. Deb, M.S. Mahendrakumar , C. Chavan , J. Karveb, D. Blankenburg , S. Storen," Design Of An Aluminium-Based Vehicle Platform For Front Impact Safety", International Journal of Impact Engineering 30, 2004, page no 1055-1079.

10. Kusekar Sambhaji Kashinath, Chunge Abhijit Balasaheb, "Review Of Design & Analysis Of Bumper Beam In Low Speed Frontal Crashes**",** International Journal of Industrial Electronics and Electrical Engineering, ISSN: 2347-6982, Volume- 2, Issue- 2, Feb.-2014, page no 27-34.