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An Investigation into the Design and Analysis of the Front Frame Bumper with Dynamic Load Impact †

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Abstract: The present study is aimed at upgrading the passenger car's front inner bumper. The dynamic explicit time-stepping method IMPACT was used to conduct the impact analysis. The programme was first evaluated against experimental findings for beams subjected to impacts at low loads. The deviation between the simulated and experimental findings of the deflected beam ranged from 1.6% to 9.5%. The genuine bumper was subjected to two different kinds of impact simulations. The data were used as a standard against which to compare future bumper improvements. Internal energy absorption is much higher in all the conditions. All three designs are able to absorb more energy without changing their overall performance.

Keywords: chassis; dynamic impact; frame; front bumper; structural analysis

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1. Introduction

In order to reduce the amount of damage caused by head-on crashes, researchers have looked at the possibility of changing the front ends of light vehicles [1]. Many experiments have been undertaken to acquire a better understanding of the bumper mechanism and its reaction to force and to analyse the consequences of a collision for a vehicle bumper [2]. Marzbanrad et al. [3] tested the behaviour of a front bumper beam made of three different materials and evaluated it in terms of deflection, impact force, stress distribution, and energy absorption, etc. An impact simulator was used for this modelling. The findings suggest that the elastic strain energy of a bumper beam made of a sheet moulding compound might be increased in this redesign, while the deflection, impact force, and stress distribution were all reduced. Composites have many applications and are widely employed in many fields, including the automotive and maritime transportation industries [4]. Results from an impact study on composites may be used in the design of a new component and to acquire insight into the material's resistance to failure and damage during an impact with low velocity, such as the dropping of a tool. The circumstances with respect to material, structure, form, and loads that would be brought about for a bumper in the case of a head-on collision were evaluated, and the conclusions of the research were useful in suggesting adjustments for improvement or changes in design [5]. Sonawane et al. [6] revealed that properly aligning the front metal bumper with enough rigidity yielded the greatest results in terms of minimizing wear and tear on the car's various parts. The number of crush initiators, the bumper thickness, and the bumper shape are the most important design considerations for a crash energy management system. A bumper system is a group of components at the front and rear of a vehicle that mitigates kinetic energy without damaging it in low-speed impacts and dissipates energy in high-speed impacts while providing cosmetic and aerodynamic benefits [7]. The bumper cross section is crucial to bumper beam design. The bumper's cross section hits the impactor. Bumper materials absorb energy based on the cross section. The aim of this study is to develop a front frame bumper which would be economical and demonstrate improved impact behaviors.

2. Design, Modelling, and Meshing

The primary function of the front inner bumper is to serve as an energy absorber, hence simplifying the overall model. The energies referred to as crash energies are produced when there are rapid alterations to the starting state of a system, such as during a collision. In these instances, the fast change in relative velocity results in the conversion and concentration of energies at the specific location of impact. AutoCAD is a widely used computer-aided design (CAD) software application employed by professionals in the fields of architecture, engineering, design, and drafting [8]. It facilitates the creation of both two-dimensional and three-dimensional digital drawings and models. The use of this technology is prevalent throughout diverse sectors such as architecture, engineering, construction, manufacturing, and product design.

We start with IMPACT VCS 3.2 software testing and validation and simulations of the bumper model; after testing and validation, we matched these results with the experimental findings. The alternate inner front bumper was chosen using simulated data. Transverse impact plastic strain varies by location and enhances dynamic buckling under loads due to model surface imperfections. Crash occupant survivability depends on vehicle structural energy absorption. Impact kinetic energy absorption relies on vehicle frame material and shape. For examination, all parts of a suggested front bumper design are meticulously constructed for the anticipated dimensions, as shown in Figure 1. These elements are properly blended to provide an assembled frame for accurate findings and observations.

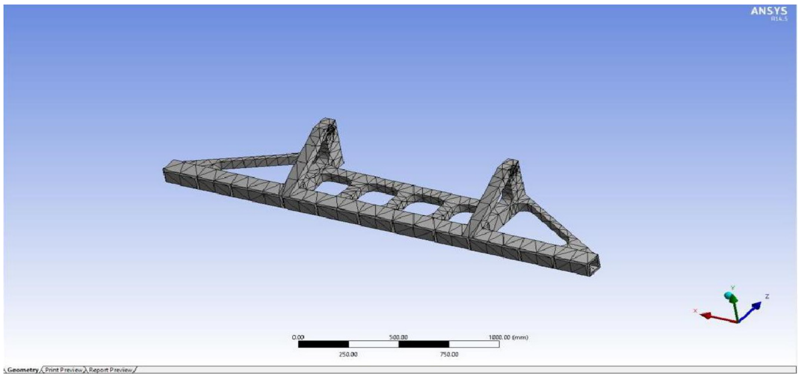

Figure 1. Meshed front bumper frame.

3. Result and Discussion

The load analysis consists of finding out the response of the proposed front bumper design during the application of three different load conditions (20 kN, 50 kN, and 130 kN). Loads were applied to the designed frame to analyse some important parameters, namely, total deformation, maximum shear elastic strain, strain energy, and maximum shear stress. The total deformation of the frame under 20 kN, 50 kN, and 130 kN is shown in Figures 2–4. The strain energy of the frame under 130 kN is shown in Figure 5.

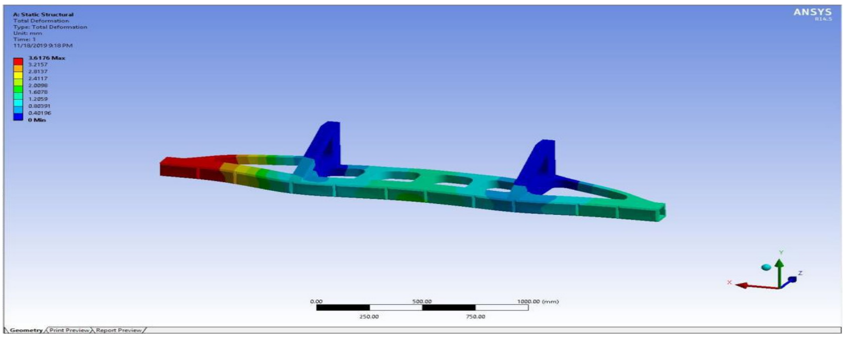

Figure 2. Total deformation of the frame under 20 kN.

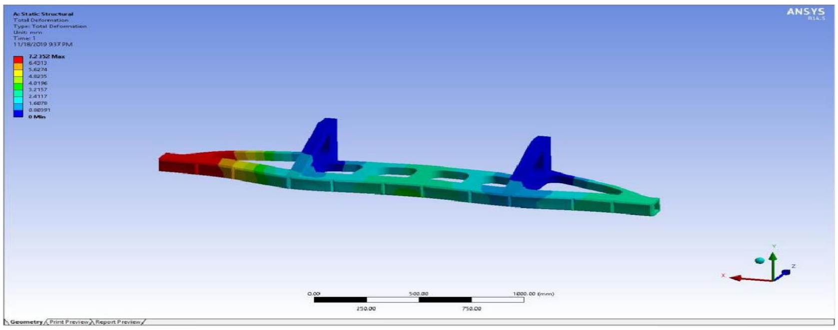

Figure 3. Total deformation of the frame under 50 kN.

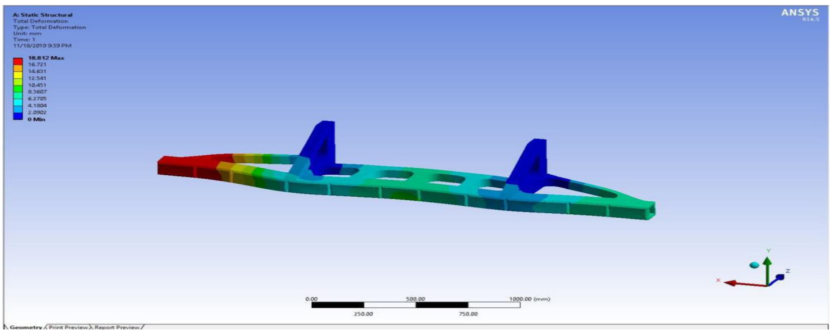

Figure 4. Total deformation of the frame under 130 kN.

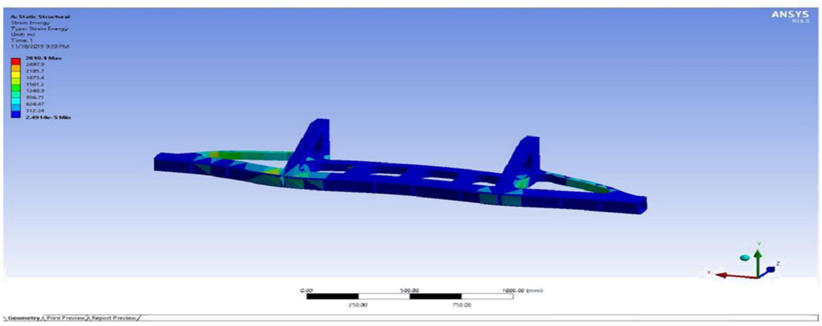

Figure 5. Strain energy of frame under 130 kN.

The results obtained for load analysis of 20 kN and 130 kN are shown in Tables 1 and 2, respectively. It can be summarised that the total deformation while applying loads was considerably less compared to other materials, and that our model demonstrated better strain energy than aluminium. Maximum elastic shear exists between stainless steel and aluminium. It was observed that the values for the compared materials are the same for equivalent stress and shear stress.

Table 1. Load analysis for 20 kN.

	Stainless Steel	Al Alloy	E-Glass
Total deformation, mm	0.07699	3.2157	0.028772
Von misses stress, N/m	4.4836	4.485	4.485
Strain energy	2.1325	92.378	3.023
Max elastic shear	8.843×10^{-5}	0.00359	3.219×10^{-5}
Max shear stress, N/m	2.3605	2.3527	2.3527

Table 2. Load analysis for 130 kN.

	Stainless Steel	Al Alloy	E-Glass
Total deformation	6.33368	16.721	0.12465
Von misses stress, N/m	21.602	23.322	21.609
Strain energy	56.774	2497.9	21.213
Max elastic shear	0.000428	0.018711	0.000155
Max shear stress, N/m	11.419	12.234	11.382

4. Conclusions

This article presents a discussion of the results of the IMPACT benchmarking test as well as a creative alternative design for the inner front bumper of an automobile that takes into consideration the effects of impact crashes. Based on the analysis, it becomes evident that the front metal bumper plays a significant role in absorbing collision energy during low-speed impacts. The design process of the metal bumper has resulted in a notable enhancement in terms of its energy absorption capability. It has been discovered that the bumpers of colliding cars align geometrically, resulting in their engagement during low-speed collisions. Furthermore, it has been observed that the quantity of individuals initiating collisions, the width of the bumper, and the form and profile of said bumper are the primary factors to consider when constructing an effective crash energy management system.

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