Impact Analysis of an Automobile Bumper

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Abstract - *Road accidents are increasing day to day and death cases are more because of the lack of proper safety systems in the vehicles. In case of automobiles, frontal impact constitutes 60% of the total crash cases. Proper design of bumpers reduces damage to vehicle and passengers during accidents .Now a days bumper is used in vehicle which directly connected to chassis of vehicle. So that when accidents are happened the force that transfer to other parts of vehicle through linkage. There are no other supports to absorb that impact forces. So there is a design need to absorb impact forces. For that reason here designed a new bumper system by Stiffeners. Stiffeners are used to minimize the impact of accidents and it will resists or absorbs impact forces.*

In this project, the new bumper system is designed using CREO and structural analysis is done in ANSYS Workbench. For structural analysis of the bumper, here modeled bumper designs are without stiffeners (existed), and with Rectangular stiffeners at 5 different speeds such as 20km/hr, 40km/hr, 60km/hr, 80km/hr, 100km/hr and also suggested the best material for replacing the existing material ABS Plastic with Polypropylene material to improve the overall performance of bumper.

***Key Words*: Bumper, Impact Forces, Stiffeners, CREO, ANSYS, Structural Analysis, ABS Plastic, Polypropylene.**

1. INTRODUCTION

Automobile bumper is a structural component or part of an automotive vehicle, which contributes to vehicle crashworthiness or occupant protection during front or rear crash cases. The bumper systems also protect the hood, trunk, fuel tank, exhaust and cooling systems as well as safety related components. A bumper acts as a shield normally made of aluminum, steel rubber, composite or plastic that is placed on the front and rear of an automobile vehicle. When a low speed collision occurs, the bumper system absorbs the shock or impact forces to prevent or reduce damage to the vehicle. In some vehicle bumpers energy absorbers are used and are made with foam cushioning material.

Automobile bumpers are not usually designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear crash cases at high speed. The bumper should be designed as safety feature since it is intended to reduce the magnitude of deceleration during impact.

Bumper systems design has been changing drastically over from last 20 to 30 years. According to government safety regulations and different styling concepts have resulted in new designs. For example, reinforcing beams covered by plastic fascias were introduced and used in the early 1970's. Styling fashion has changed appearance values from almost 100% chrome-plated face bars to predominately fascia system that are color coordinated with the body.

There are several design factors to be considered when selecting a bumper system. The most important factors is the ability of the bumper system to absorb shocks to meet the original equipment manufacturers (OEM's) internal bumper standard. Another factor is to stay intact at high-speed impacts. Weight, manufacturing process ability and cost are also the factors that have to be considered during the design phase. Both initial bumper cost and repair cost are also important.

1.1 Literature

Pradeep Kumar Uddandapu [1] In this review material used is ABS plastic and PEI. The aim of this study is to analyze and to study the structure and material. In this research analysis is done for speed according to regulations and also by changing speed in this analysis. The density of ABS plastic and PEI are less than that of steel therefore the overall weight of car bumper is reduced. In this conclusion, comparing the results of ABS plastic and PEI with steel, the stress values are less for ABS plastic compared to other two materials, therefore ABS plastic is better for utilization comparing PEI.

Sachin Manoj kumar Jain[2] discussed parameters such as shape, material, design and analysis of bumper has been studied to improve its crash performance, material selection and designing having more importance. Virtual analysis been more advantageous than impact test as it provides a great platform to carry out simulation of the model in real conditions, which reduces time, money, man power and material cost and provides more accurate results. The most important factor of material selection is done keeping in mind engineering design and its feasibility.

G.Ravikumar Reddy, M.Suneetha [3] Designed a mechanism to absorb impact forces from bumper system by springs. For structural analysis of the bumper , materials such as Glass mat thermoplastics (GMT), carbon fiber composite and aluminum B390 materials are used. The bumpers with springs and without springs are designed and analysis is done. The stresses, displacements and frequencies are calculated at different speeds 5Kmph, 35Kmph, 60Kmph and 80Kmph by static and modal analysis.

B.A. Bohra , Prof. D.B. Pawar [4] in their thesis describes impact analysis is done by varying speed according to regulations and also by changing the materials ABS plastic and PEI for same bumper design. This research aims towards improvement in the design of front bumper of passenger car and gives the economical solution for the front bumper material and design by improving the safety increasing aspects. Based on the performance analysis, here conclude that the ABS plastic is superior bumper material among comparison and modified bumper design is best as compare to existing bumper design.

1.2 Material Properties

The material properties of the ABS Plastic and Polypropylene (Copolymer) are taken for analysis of bumper.

Material	Density(kg/m^3)	Young's Modulus (MPa)	Poisson's Ratio
ABS Plastic	1020	2240	0.39
Polypropylene	940	3500	0.42

1.3 Problem Definition

Force Calculation for Bumper

For Force calculation on bumper, here considered Tata Nano Car Bumper for design i.e., bumper drawings and load purpose.
Mass of car =745kg
Mass of four passengers = 300kg ie., 75kg each
Total Mass of vehicle in motion m = Mass of car + Mass of passengers
= 745 +300; m = 1045kg
According to Newton's Second Law of Motion, The net force on a body is equal to the product of the body's mass and its acceleration.
In equation form Newton's Second Law can be written as,
F=m * a
Here , F – Net Force in N; m - Mass in Kg
a - Acceleration in m/s^2
$a = \frac{(v-u)}{t}$
v- final velocity (m/s) ; u- initial velocity (m/s) ; t- time (s)

Assumptions:
1. Initial Velocity = 0 m/s
2. Time = 1 s

- **Case 1 For V = 20kmph**

$v = 20 \times \frac{5}{18}$
v = 5.555 m/s
$a = \frac{(v-u)}{t}$; $a = \frac{(5.555-0)}{1} = 5.555$m/s
F=m×a
F=1045 x 5.555
F=5804.97 N
F ≅ **5805 N**
Therefore, during the frontal impact the car bumper experiences the force of 5805N at the speed of 20kmph.

- **Case 2 For V = 40kmph**

Similarly by calculating force using above steps, we get
F=11611N
Therefore, during the frontal impact the car bumper experiences the force of 11611 N at the speed of 40kmph.

- **Case 3 For V = 60kmph**

Similarly by calculating force using above steps, we get
F=17416 N
Therefore, during the frontal impact the car bumper experiences the force of 17416 N at the speed of 40kmph.

- **Case 4** For **V = 80kmph**

Similarly by calculating force using above steps, we get
F= 23222 N
Therefore, during the frontal impact the car bumper experiences the force of 23222 N at the speed of 80kmph.

- **Case 5** For **V = 100kmph**

Similarly by calculating force using above steps, we get
F=29027 N
Therefore, during the frontal impact the car bumper experiences the force of 29027 N at the speed of 100kmph.

2. MODELING OF BUMPER USING CREO

The bumper is designed using CREO Part Module. Here modeled bumpers for analysis are Bumper without stiffeners and with Rectangular stiffeners. For modeling purpose, Nano Twist is considered for dimensions.

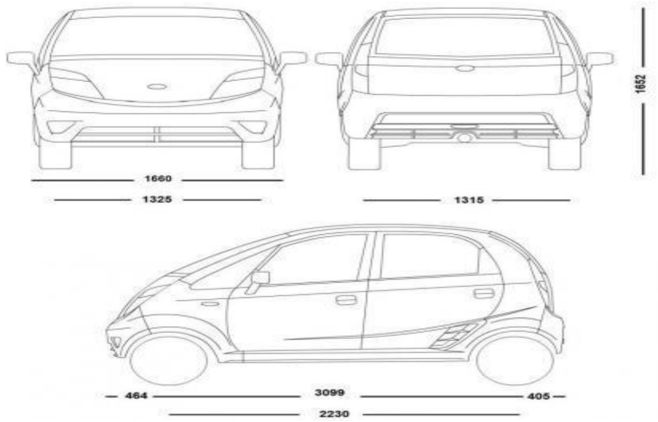

Fig 1: Tata Nano Twist Drawings

Following pictures indicates modeling procedure of bumper using CREO Part Module.

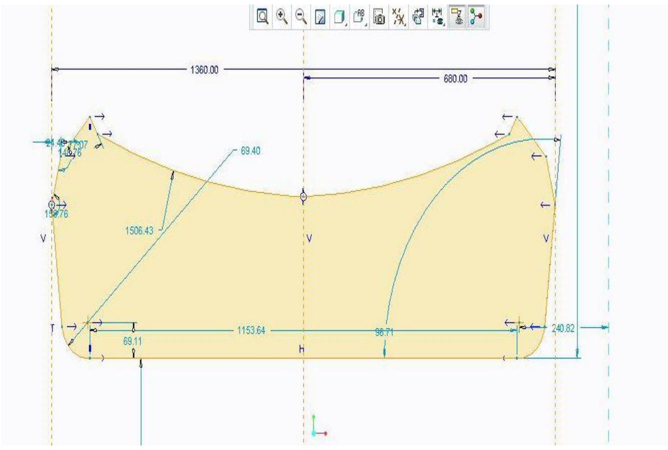

Fig 2: Front Sketch of Bumper

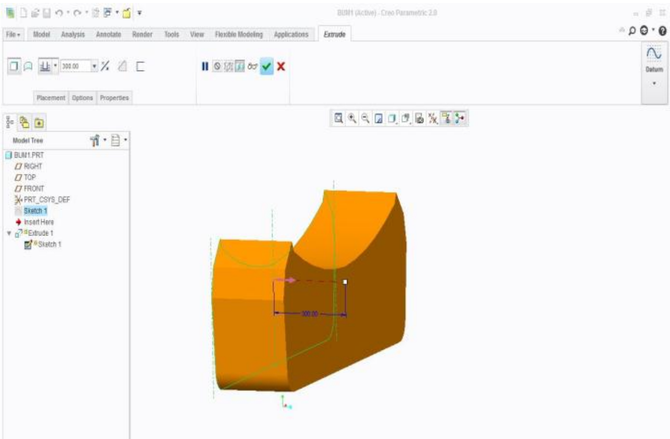

Fig 3: Extruding Bumper

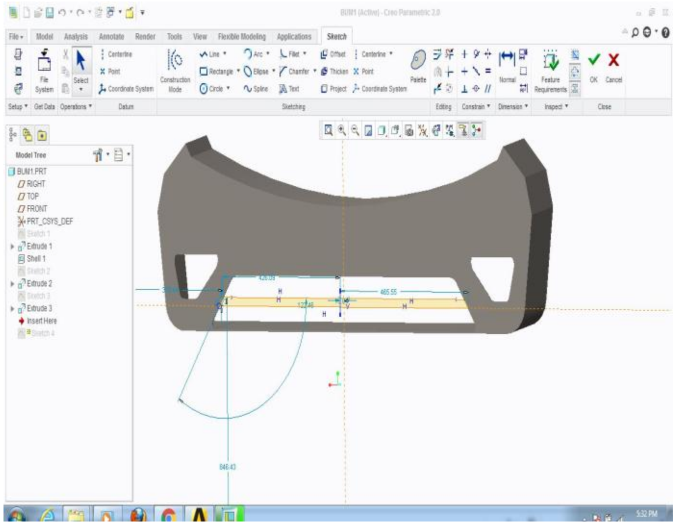

Fig 4: Modeling Bumper Grills

Modeling of Bumper (Existed):

The final model of bumper without stiffeners shown below.

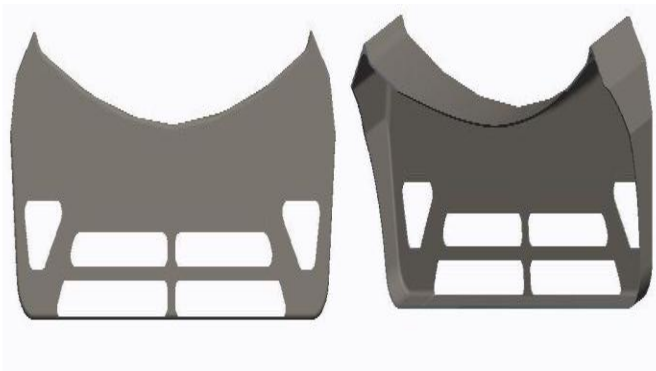

Fig 5: Standard (Existing Nano Twist) Bumper

Modeling of Bumper with Rectangular Stiffeners:

The final model of bumper with rectangular stiffeners shown below.

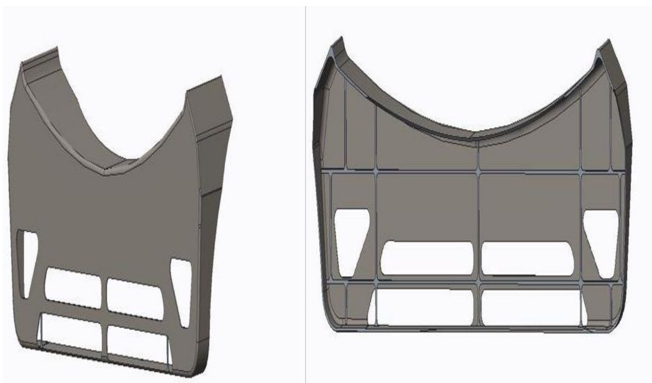

Fig 6: Bumper with Rectangular Stiffeners

3. ANALYSIS OF BUMPER USING ANSYS WORKBENCH

ANSYS 15.0 is used to run the analysis. By assigning material and the previously created IGES file is imported on ANSYS Workbench file geometry. After importing boundary conditions are applied i.e., Fixed supports at end faces, Force on front and side faces.

Geometric model: The geometric model for the bumper is as shown below.

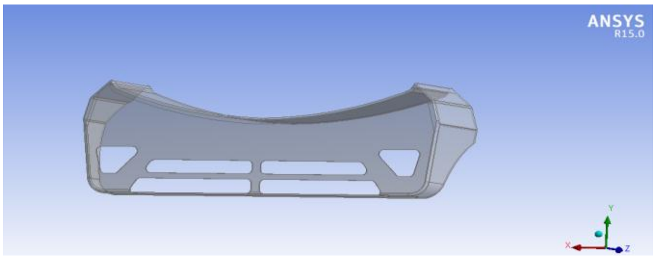

Fig 7: Geometric Model of Bumper

Meshed Model: The meshed model for the bumper is as shown below.

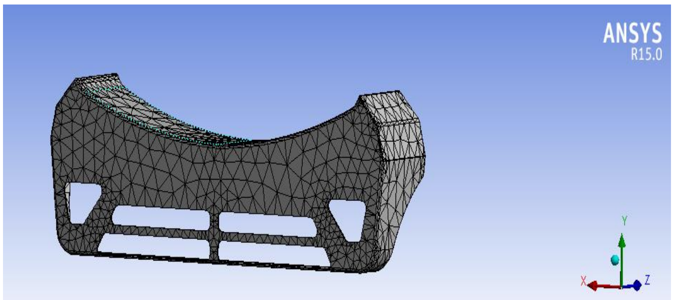

Fig 8: Meshed Model of Bumper

Boundary Conditions: The boundary conditions for the bumper are as shown below . The velocity 20km/hr and Force is 5805N.

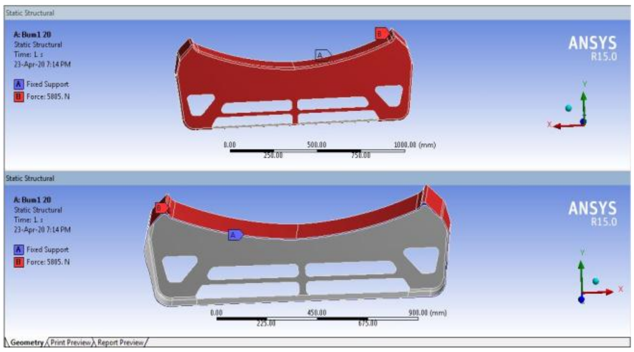

Fig 9: Boundary conditions of Bumper

Note:

For bumper analysis, in boundary conditions, fixed supports are same for both existing and rectangular stiffeners bumpers used here but force changes according to velocities.

Analysis of ABS Plastic Bumper without supports:

Total Deformation and Equivalent Stresses of Bumper without stiffeners at different forces are shown below.

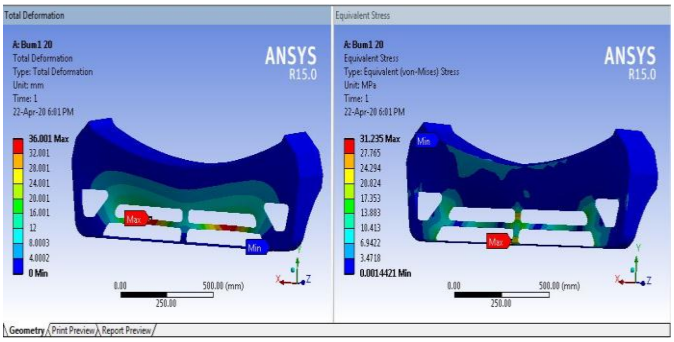

Fig 10: Total Def. and Equivalent Stresses at 20km/hr

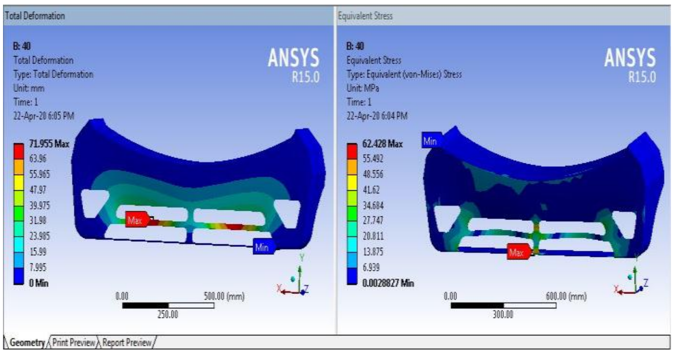

Fig 11: Total Def. and Equivalent Stresses at 40km/hr

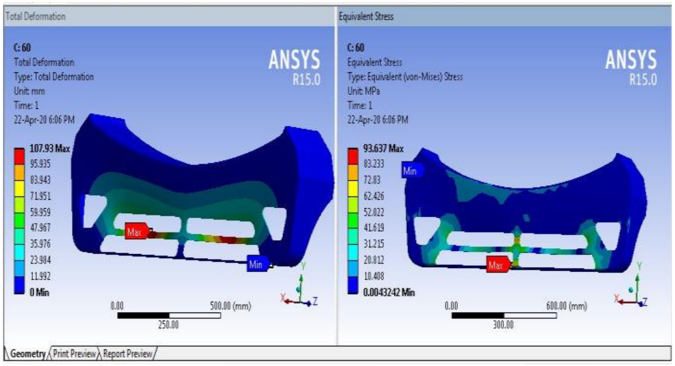

Fig 12: Total Def. and Equivalent Stresses at 60km/hr

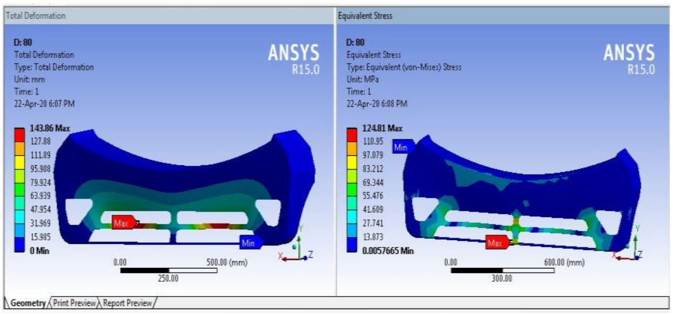

Fig 13: Total Def. and Equivalent Stresses at 80km/hr

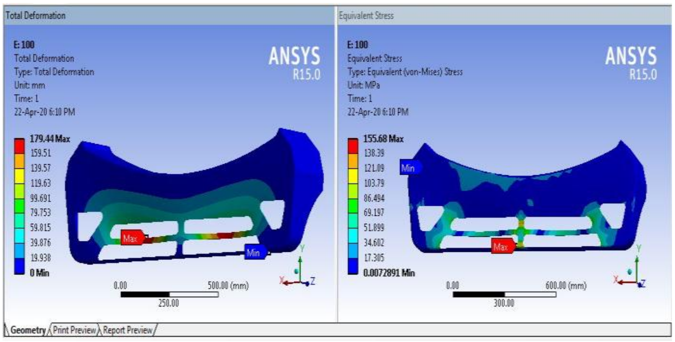

Fig 14: Total Def. and Equivalent Stresses at 100km/hr.

Analysis of ABS Plastic Bumper with Rectangular Stiffeners:

Total Deformation and Equivalent Stresses of Bumper with rectangular stiffeners at different forces are shown below.

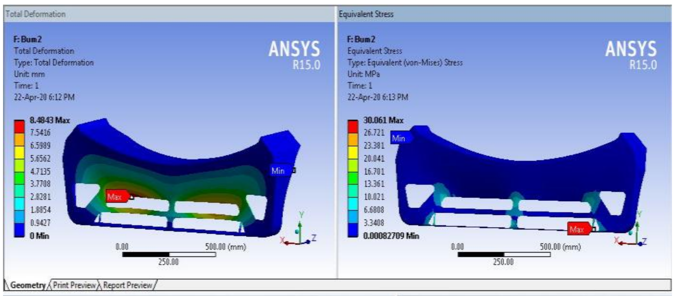

Fig 15: Total Def. and Equivalent Stresses at 20km/hr.

Fig 16: Total Def. and Equivalent Stresses at 40km/hr.

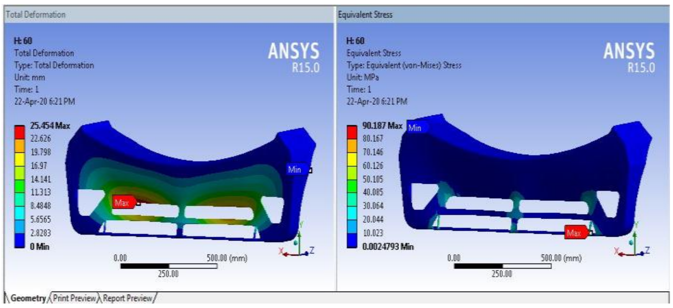

Fig 17: Total Def. and Equivalent Stresses at 60km/hr.

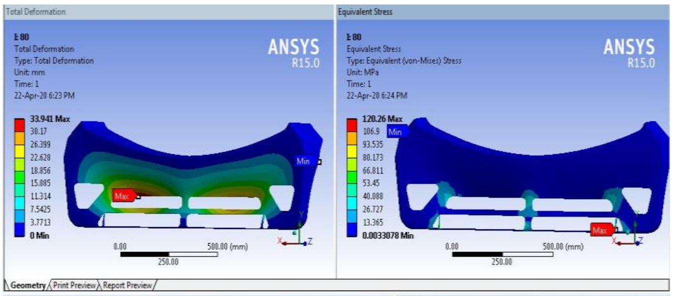

Fig 18: Total Def. and Equivalent Stresses at 80km/hr.

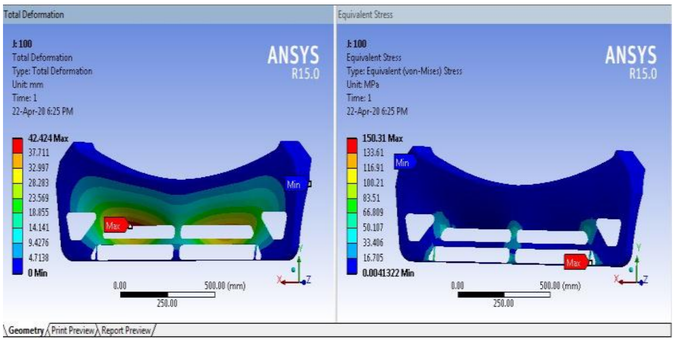

Fig 19: Total Def. and Equivalent Stresses at 100km/hr.

Analysis of Polypropylene Bumper without supports:

Total Deformation and Equivalent Stresses of Bumper without stiffeners at different forces are shown below.

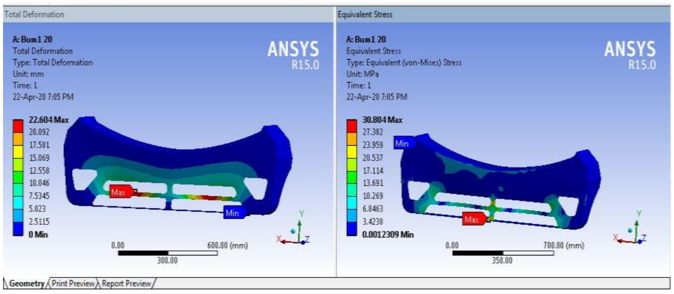

Fig 20: Total Def. and Equivalent Stresses at 20km/hr.

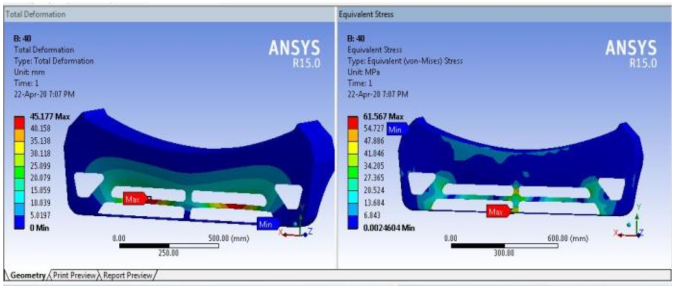

Fig 21: Total Def. and Equivalent Stresses at 40km/hr.

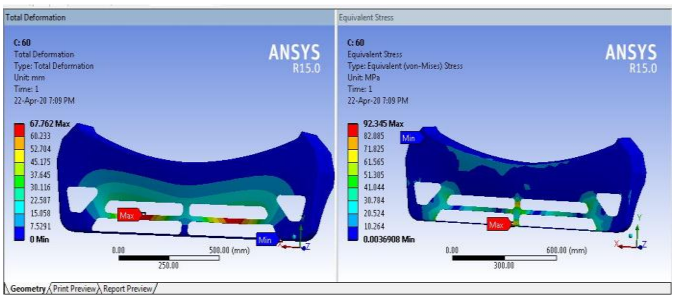

Fig 22: Total Def. and Equivalent Stresses at 60km/hr.

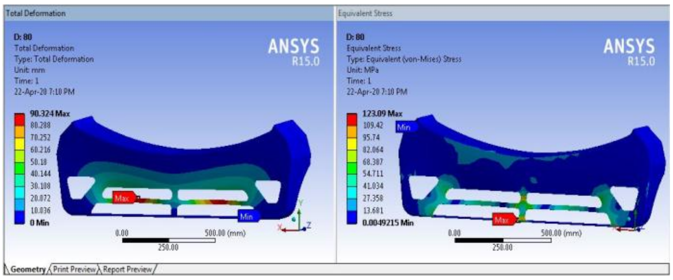

Fig 23: Total Def. and Equivalent Stresses at 80km/hr.

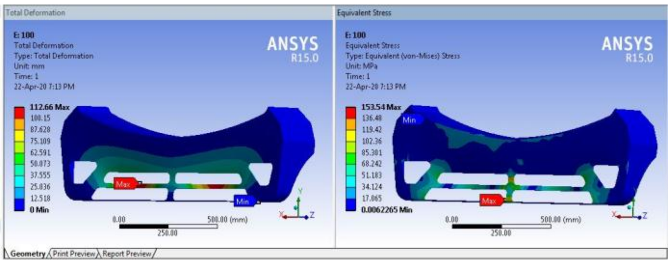

Fig 24: Total Def. and Equivalent Stresses at 100km/hr.

Analysis of Polypropylene Bumper with Rectangular Stiffeners:

Total Deformation and Equivalent Stresses of Bumper with rectangular stiffeners at different forces are shown below.

Fig 25: Total Def. and Equivalent Stresses at 20km/hr.

Fig 26: Total Def. and Equivalent Stresses at 40km/hr.

Fig 27: Total Def. and Equivalent Stresses at 60km/hr.

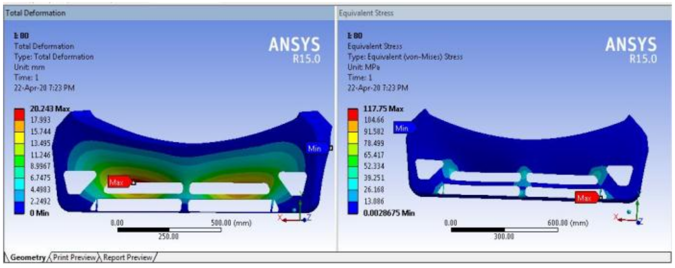

Fig 28: Total Def. and Equivalent Stresses at 80km/hr.

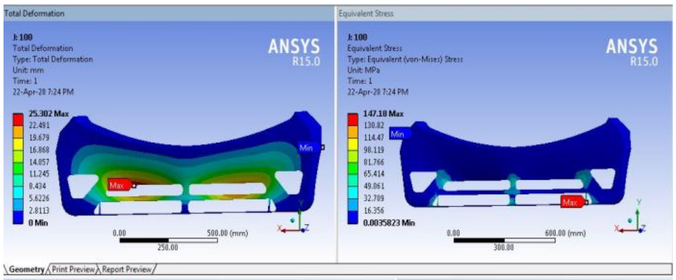

Fig 29: Total Def. and Equivalent Stresses at 100km/hr.

Results Table-1

SN o.	Material/Cross Section		Existing Bumper	Bumper with Rectangular Stiffeners
	ABS Plastic			
1	20Km/Hr	Tot.Def(mm)	36.001	8.484
		Von-Mises Stresses(MPa)	31.23	30.06
2	40Km/Hr	Tot.Def(mm)	71.95	16.965
		Von-Mises Stresses(MPa)	62.42	60.107
3	60Km/Hr	Tot.Def(mm)	107.93	25.45
		Von-Mises Stresses(MPa)	93.637	90.187
4	80Km/Hr	Tot.Def(mm)	143.86	33.941
		Von-Mises Stresses(MPa)	124.81	120.26
5	100Km/Hr	Tot.Def(mm)	179.44	42.424
		Von-Mises Stresses(MPa)	155.68	150.31

Results Table-2

SNo.	Material/Cross Section Polypropylene		Existing Bumper	Bumper with Rectangular Stiffeners
1	20Km/Hr	Tot.Def(mm)	22.604	5.06
		Von-Mises Stresses(MPa)	30.804	29.433
2	40Km/Hr	Tot.Def(mm)	45.177	10.11
		Von-Mises Stresses(MPa)	61.567	58.853
3	60Km/Hr	Tot.Def(mm)	67.762	15.181
		Von-Mises Stresses(MPa)	92.34	88.305
4	80Km/Hr	Tot.Def(mm)	90.324	20.243
		Von-Mises Stresses(MPa)	123.09	117.75
5	100Km/Hr	Tot.Def(mm)	112.66	25.30
		Von-Mises Stresses(MPa)	153.54	147.18

4. CONCLUSIONS

- By observing the Results Table-1, Bumper with Rectangular Stiffeners gives the best results for both design factors i.e., Total Deformation (mm) and Equivalent Von-Mises Stresses (MPa) compared to Standard (Existing) Bumper ABS Plastic material.

- By replacing the existing material with Polypropylene and considering Standard Bumper and Bumper with Rectangular Stiffeners for analysis, Total Deformation(mm) and Equivalent Von-Mises Stresses(MPa) are less for Bumper with Rectangular Stiffeners in Results Table-2 and also gives best result compared to ABS Plastic material in Results Table-1.

- So, by observing and optimizing the all results, Bumper with Rectangular Stiffeners is the best structure compared to Existing Bumper and existing material ABS Plastic can be replaced with Polypropylene material.

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