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Importance of Design Parameter of Bumper and a Material Study

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Abstract: Bumper is a front most part of vehicle, it keeps passengers and other parts of vehicle are safe. During impact parameters affect on bumper performance such as speed of vehicle, mass and time of impact are studied. While taking example of one of the car manufacture, design parameter such and thickness and material properties are studied. Comparative analysis of various materials is done with original steel material by FMVSS (Federal Motor Vehicle Safety Standard). Results show that mass, speed and impact time play important role, as these changes it affects on vehicle during accident. As thickness of bumper increase its deformation reduces but weight of bumper increase, present steel material possible to replace with low density PEI material. It is important that focus of selecting bumper material, if focus is safety then sometimes compromise with weight and light weightiness. If the focus is light weight bumper then compromised with safety and strength.

Keywords: Speed, Time, Velocity, Thickness, Material Properties.

I. INTRODUCTION

In automobile industry bumper play important role in terms of passenger safety, impact reducing, collision energy absorber. These things are achieve by using spring in bumper shock absorber [1-2], by using Bumper stay [3], spring damper system. These are act as impact energy absorber but it is important according to which standard bumper is to be design [4]. Some bumper models are tested by considering acceleration of vehicle, mass of vehicle and stop time of impact. Passenger cars, heavy vehicles, mini trucks all they are having different weight, so after accident impact going to change vehicle to vehicle. Mostly bumpers are design by considering Pedestrian safety [15], light weight material, bio-composite material [5]. Some bumper is design according to environment standards in order to reduce pollution, some design according to pedestrian safety purpose [6]. So every design of bumper needs good analysis of vehicle. Some of the vehicles use fabric material, sheet metals in the bumper, to design such bumper speed is keep at low. Because of less weight, thickness of bumper cannot test at higher load condition they give higher deformation. Material study play important role during collision of vehicle some materials are having good impact absorbing capacity [7-8]. Now a day's light weight materials are use like carbon fibber reinforced PEI, S2 Glass Epoxy these are light weight material produce low stress during impact [9]. The testing of bumper is done according to FMVSS (Federal Motor Vehicle Safety Standard) CMVSS (Canadian motor vehicle safety standard [10]. Now a day's ABS plastic and other light weight materials are use in order to improve fuel efficiency and reduce emissions [11], to test light weight materials such as plastic ,impact of vehicle consider as parking speed ,front collision is done at 4Km/hr and side impact is half of the front as per FMVSS. In present paper importance of Newton law during collision and its parameter like speed, mass, and stop time are studied effect of one parameter on other and finally effect on impact are studied. While taking one of the examples of car bumper thickness, weight related parameter studied, The present material of steel bumper compare with latest plastic material, results show that it is possible to replace original steel material by PEI (Poly Ether Imide).

II. METHODOLOGY

As shown in below fig.1, mat lab program show relationship between weight of the vehicle and generated force. This method applicable to all vehicles in order to find force generated after impact BY NEWTONS LAW (f=MA) this condition is applicable only when vehicle hit one at the same,

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```
m=input('\n Enter mass of Vehicle including person/payload capcaty if truck(Kg):' );
u=input ('Speed at which vehicle is moving km/hr:');
t=input ('Stop time of vehicle after hitting:');
l=input ('length of bumper(m):');
b=input ('width of bumper(m):');
U=((u*1000)/3600);
DV=((U-0)/t);
f=(m*DV);
A=(l*b);
p=(f/A);

fprintf('\n Deaccleration of vehicle(m/sec^2)=%f:',DV);
fprintf('\n force acted on bumper(in Newton)=%f',f);
fprintf('\n In terms of pressure(N/m^2)=%f',p);

 Testing of bumper at specific speed of vehicle:
 Enter mass of Vehicle including person/payload capcaty if truck(Kg):2815
Speed at which vehicle is moving km/hr:36
Stop time of vehicle after hitting:0.1
length of bumper(m):1.54
width of bumper(m):0.1

 Deaccleration of vehicle(m/sec^2)=100.000000:
 force acted on bumper(in Newton)=281500.000000
 In terms of pressure(N/m^2)=1827922.077922>>
```

Fig1. Mat lab program for generating force

Case 1) below table.1 Indicate different mass of vehicle , And force generated after impact are calculated in these case we keep impact stop time as constant for all vehicle and finding relation between mass and force, if vehicle moving at a speed of 10m/s=36km/hr,

Table.1Mass of vehicle vs. force

Sr. number	Impact stop time (s)	Maximum Mass (kg)	Acceleration (m/s^2)	Force (Kn) impact
1	0.1	1000	100	100
2	0.1	2000	100	200
3	0.1	3000	100	300
4	0.1	4000	100	400
5	0.1	5000	100	500
6	0.1	6000	100	600
7	0.1	7000	100	700
8	0.1	8000	100	800
9	0.1	9000	100	900
10	0.1	10000	100	1000

Case2) in second case impact stop time changes and mass of the vehicle remain constant force is calculated for same mass, vehicle speed is constant

Table.2 Impact stops time vs force

Sr. number	Impact stop time (s)	Maximum Mass (kg)	Acceleration (m/s^2)	Force (Kn) impact
1	0.01	1000	1000	1000
2	0.02	1000	500	500
3	0.03	1000	333.33	333.334
4	0.04	1000	250	250
5	0.05	1000	200	200
6	0.06	1000	166.667	166.667
7	0.07	1000	142.857	142.857
8	0.08	1000	125	125
9	0.09	1000	111.111	111.111
10	0.1	1000	100	100

Case 3) in this case speed of the vehicle changes, at different speed how much amount of force generated is calculated, in this case stop time of vehicle is constant, speed varies

Table.3 Speed vs force

Sr.number	Speed (m/s)	Impact stop time (s)	Maximum Mass (kg)	Acceleration (m/s^2)	Force (Kn) impact
1	2.7777	0.1	1000	27.777	27.777
2	5.5555	0.1	1000	55.555	55.555
3	8.3333	0.1	1000	83.333	83.333
4	11.1111	0.1	1000	111.111	111.111
5	13.8888	0.1	1000	138.888	138.888
6	16.6667	0.1	1000	166.667	166.667
7	19.4444	0.1	1000	194.444	194.444
8	22.2222	0.1	1000	222.222	222.222
9	25	0.1	1000	250	250
10	27.7777	0.1	1000	277.777	277.777

III. Results And Discussion

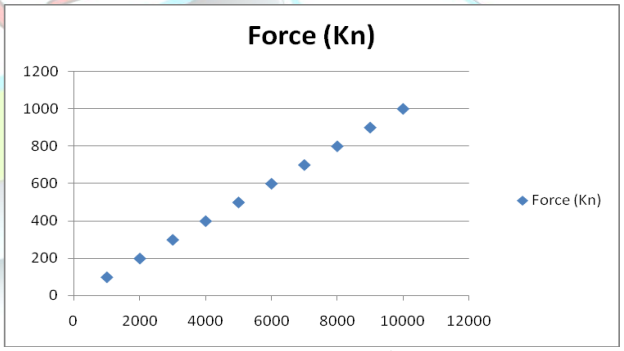

Fig.2 mass vs impact force

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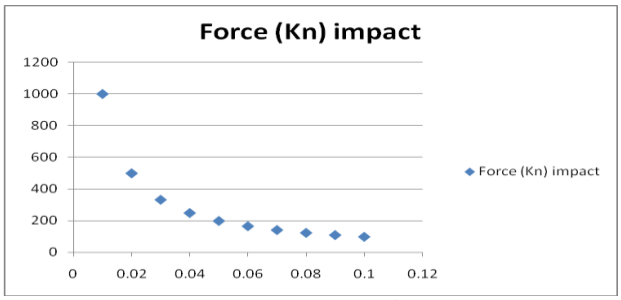

Fig.3 Impact stop time vs force

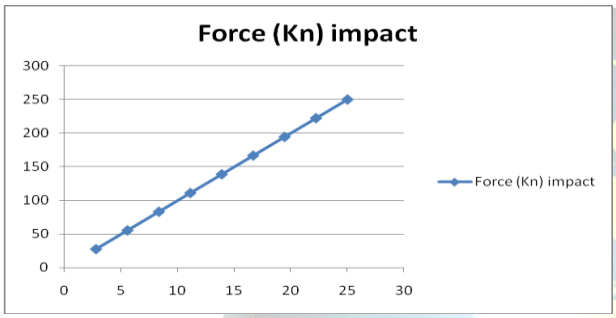

Fig.4 speed vs impact force

As shown in above fig.2 as the mass of vehicle increases impact force also goes on increases finally in that case bumper is design to take maximum amount of force. As shown in fig.4, after accident at what time the vehicle stop then amount of force is generated, as stop time of impact reaches to 0.1 sec. force goes on reducing when stop time of impact is very less then impact is generated in more amount. At this time how much amount of deformation is done in bumper is easy to find out. It means after accident K.E of vehicle comes to zero. And vehicle stop.fig.4 represent as speed of the vehicle increases impact force increase.

Design of bumper for one of the car manufacture in order to study design parameter-

Below is the design of one of the car manufacturer bumper, while design of bumper, thickness of bumper is important parameter [12].

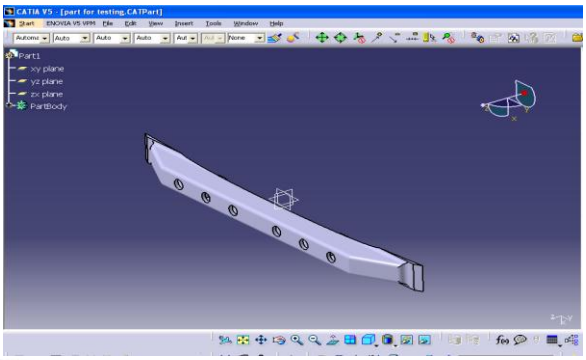

Fig.5 Car bumper

Applied force on bumper 180.560 Kn, by Appling this much amount of force what affect on bumper capacity is predicted. Initially we take bumper thickness as 3mm, then 5, 7, 9 mm. By varying thickness displacement that reduces it bumper become strong.von misses stresses are reduce it means weight of bumper increase its energy absorbing capacity increase. For this purpose we are keeping steel as a material.

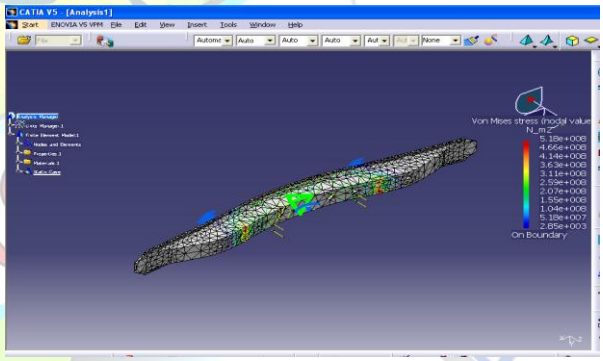

Fig.6 Von misses stress at 3mm thickness

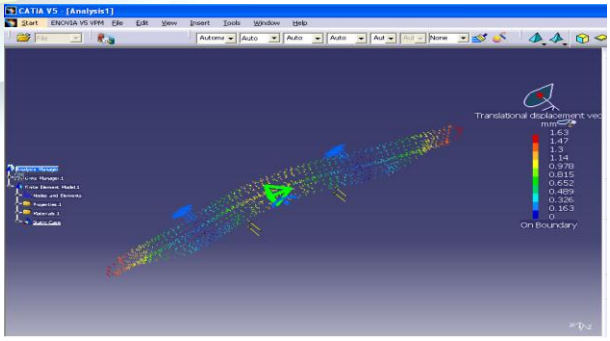

Fig.7 Displacement at 3mm thickness

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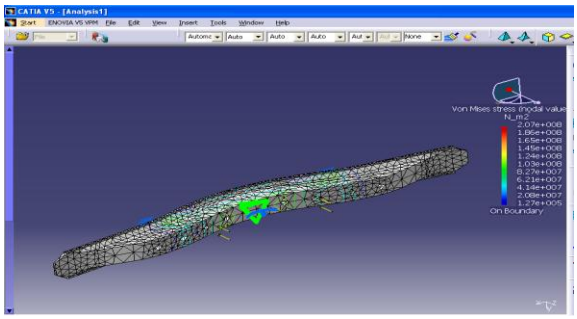

Fig.8 Von misses stress at 9 mm thickness

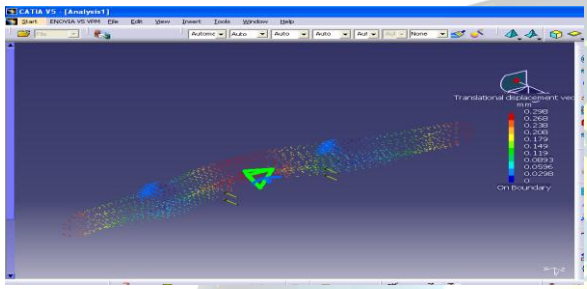

Fig.9 Displacement at 9 mm thickness

Below table.4 indicate result of design parameter such as thickness,

Table.4 results at various parameters

Thickness (mm)	Weight of bumper (Kg)	Von misses stress (N/mm^2)	Displacement (mm) in terms of deformation
3	5.096	5.18e+008	1.63
5	7.487	3.51e+008	1.4
7	9.551	4.08e+008	1.14
9	11.868	2.07e+008	0.298

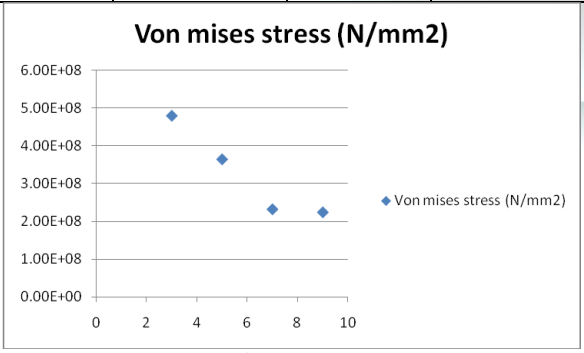

Fig.10 Thickness of bumper vs von misses stress

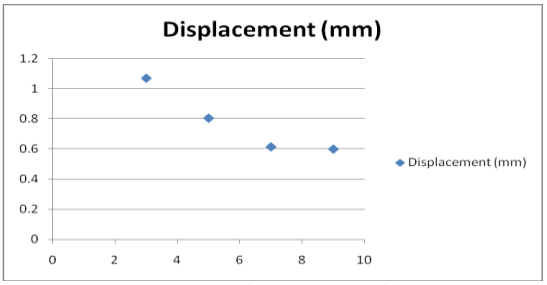

Fig.11 Thickness of bumper vs deformation

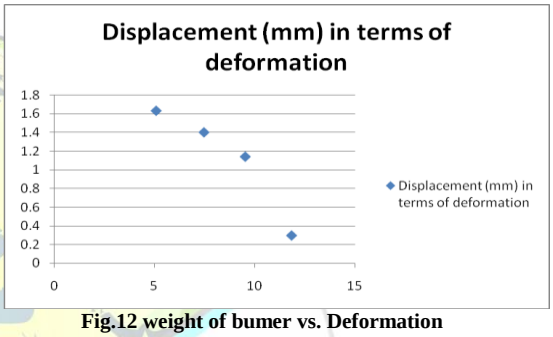

Fig.12 weight of bumer vs. Deformation

Results show that as we increase the thickness of bumper, its shock absorbing capacity increases von misses stress and displacement goes on decreasing, which is better. but the weight of bumper is increases so the solution for this problem is light weight composite material or plastic material. From fig.16 it concludes that as we increase the weight of bumper displacement of bumper goes on reducing.

Comparative analysis with different materials-

To select right material, conceptual selection [16] of properties of bumper is very important [13-14]; material properties are used during the analysis. now a day if we have seen mostly plastic bumpers are use because of light weight. the present bumper made of steel compare with light weight plastic materials, in this case another materials are taken for comparative analysis purpose such as ABS Plastic, S2 glass epoxy, PEI, PP-TD10, GMT and SMC [12]. Because these are showing good mechanical property, good impact strength with low density. Material properties for ABS Plastic and S2 Glass epoxy taken from the reference [10], as the material having good modulus elasticity show more stiffness and strength.

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Table.5 materials for comparative study

Material property	Steel (Present Material)	ABS Plastic	S2 Glass epoxy	PEI	10% talc filled polypropylene	GMT	SMC
Elastic modulus (Mpa)	2e+11 (N/mm^2)	2000	86900	31000	705.5	12gpa	20gpa
Poisson ratio	.266	0.394	0.23	0.3	0.48	0.41	0.33
Tensile strength(Mpa)	-	30	-	-	17.11		
Density (kg)	7860	1020	2460	1480	1075	1280	1830
Yield strength	2.5e+008 (N/m^2)	-	4890	230 mpa	-	230 mpa	309 mpa

Material for bumper-

During analysis original steel, ABS Plastic, S2 Glass, GMT, SMC and PP-TD10 consider.. Each and every material has different characteristic their energy absorption rate is also different, weight is different. Below cal caution show input condition and force apply to bumper which is same for all materials.

As we know that (Federal motor vehicle safety standard) FMVSS generally use to check front bumper at a speed of 4 Km/hr (1.1111m/sec), and side corners are at 2Km/hr, we use here nektons law in order to find out amount of force impact on bumper when same weight of material is at opposite direction and impact on it

F=m*a;
F=5*((1.1111-0)/0.001),
F=555.6N,

We are considering maximum impact is done at 0.001 sec.
At this input condition we find out material behaviour of bumper by using different materials by keeping same impact force.

1) Material –steel,

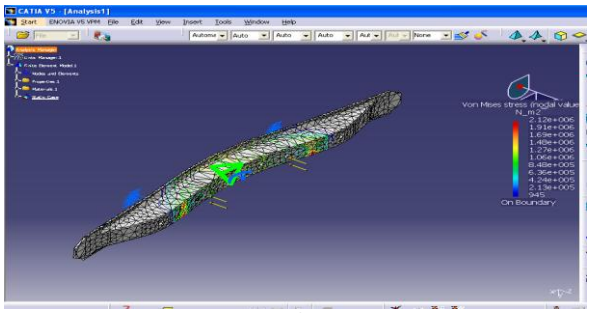

Fig.13 Von misses stress for steel material

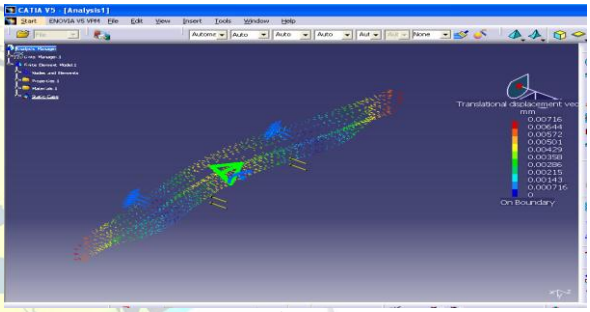

Fig.14 displacement for steel material

2) Material-SMC (Sheet moulding compound)

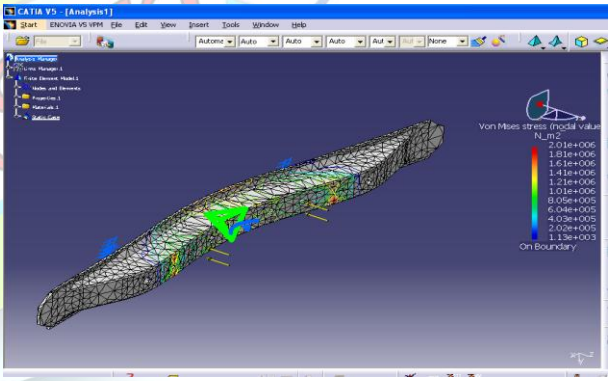

Fig.15 Von misses stress for SMC material

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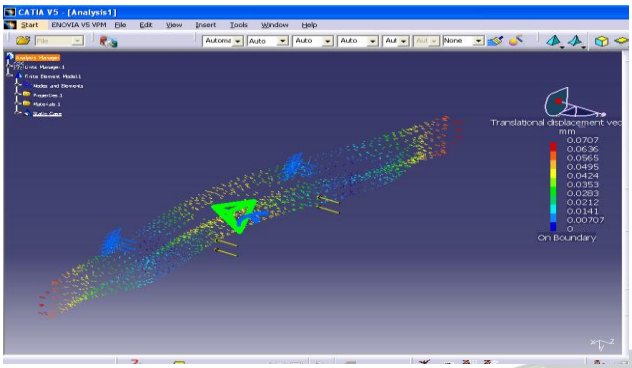

Fig.16 Displacement for SMC material

Below table.5 indicate results of comparative analysis with latest plastic materials

Table.5 Results on material basis

Material	Von-misses stress (n/m^2)	Displacement(mm)
Steel	2.12e+006	0.00716
ABS Plastic	1.86e+006	0.678
S2 Glass epoxy	2.17e+006	0.0165
PEI	2.06e+006	0.046
PP-TD10	1.36e+006	1.48
GMT	1.81e+006	0.111
SMC	2.01e+006	0.0707

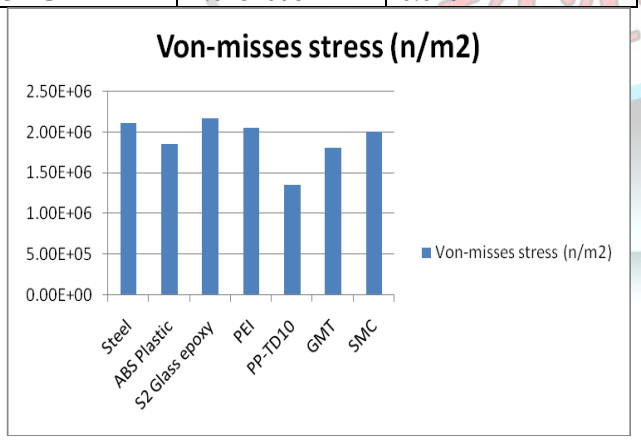

Fig.17 different Material s vs von misses stress

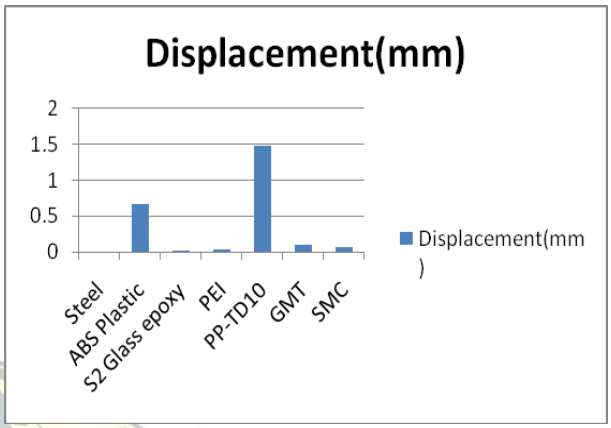

Fig.18 different Material s vs displacment

From above charts we conclude that von misses and displacement property is base on stiffness of material that is elastic modulus, as change in elastic modulus it affects mostly on displacement. We know than stiffness is the resistance to the deformation. From above fig.33 displacement of ABS Plastic and PP TD-10 is extremely more than all materials, so first we remove these two materials. After that from density Vs. Material graph density of steel AND s2 glass epoxy is high compare remaining three materials, so high weight that affect on weight of vehicle and amount of fuel consumption and finally environmental pollution. Finally three materials are remaining such as PEI, GMT and SMC.

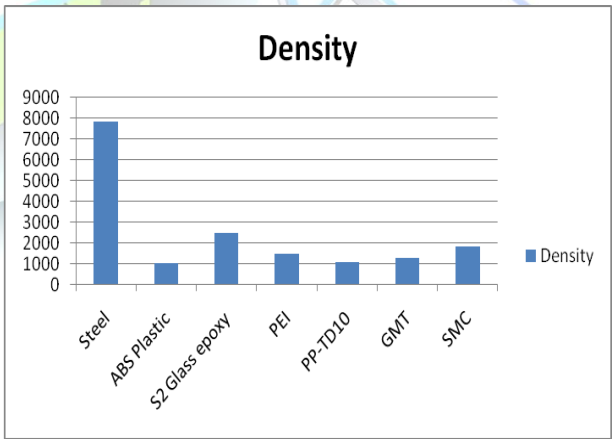

Fig.19 Density of all materials

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Out of three PEI and SMC show low deformation hence parts of vehicle after impact are safe compare to GMT. From last two we select PEI (Poly ether imides) which shows less deformation and weight of material is also less compare to all. In selection safety and light weightiness of bumper take in to consideration both should be balance

IV. CONCLUSION

Mass, speed and impact time of vehicle are dependent terms, while changing one of the parameter it effect on impact force, it increase or decreases. As we increase the thickness of bumper it is more capable to take impact force. As thickness increase von misses stress and deformation reduces, which is better but weight of bumper increases. And solution for this problem is composite or plastic as light weight material. We studied relations between different materials by taking example of one of the car manufacturer. Different material has different characteristic, from above result we conclude Fibber PEI is best satiable material for this application which is light weight material as compare to other materials it show less deformation and less von misses stress. If light weight of bumper is focus than it is necessary to compromised with strength, safety of vehicle and passenger.

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