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RESEARCH ARTICLE

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MATERIAL OPTIMIZATION OF CAR FRONT BUMPER

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ABSTRACT

In this study we tried to find out the best material for car front bumper to replace the existing car bumper material for superior performance and weight optimization as well. For this research study we considered the two others material with existing car bumper material for analysis purpose. We produce a mathematical approach to calculate the induced stress in different material car front bumper at the time of impact and compared them to chose the best material to replace the existing material of bumper. We also keep it mind that the car bumper material must be light in weight and cheap in cost to achieve best efficiency at economic way. We did the market survey to investigate the cost of materials and density of material to find out the cost and weight of material for comparison.

INTRODUCTION

Bumper is a one of important part of an automobile as safety point of view. It is introduce on front of an automobile so it's necessary that it should be have good strength and stiffness to absorb the impact and the time of impact. The design of bumper being not simple because it's having lots of constraints which have to be fulfilling at the time of design. Light in weight and cheap in cost with good impact strength are major factor which should be keep in mind at the time of design. Different automobile companies having different type of bumper design. However every time the main criteria being safety, cost and weight. Bumper is one amongst the necessary structures in rider cars. That we want to own careful style and producing so as to make sure smart impact behaviour. The new bumper style should be versatile enough to cut back the rider and injury and keep intact in low-speed impact besides being stiff enough to dissipate the K.E. in high speed impact. The bumper beam is that the key structure for riveting the energy of collisions. Since, this is often energy riveting structure appropriate impact strength is that the main demand for such a structure, this analysis analyses the parameters that directly affects impact characteristics and proposes simply accomplishable modifications ensuing from impact modelling on bumpers. A bumper is tested for the impact. With the introduction of automobile safety legislation, crashworthiness and safety ought to be thought-about as preconditions in light-weight style of bumper. To summarize, the target of this analysis was to develop and propose a replaced composite bumper that might satisfy following requirements:

I. Easy to manufacture by simplifying the form.
II. Being economical by utilizing cheap composite materials.
III. Achieving reduced weight compared to the existing bumper
IV. Achieving improved strength or similar impact behavior Compared to exiting bumper structure.

II. LITRETURE REVIEW

Manideep Kumar Vandanapu, RatnakarPandu[1]: The aim of this paper is to design

a bumper which is to improve crashworthiness of the bumper beam. Crashworthiness is the ability of the bumper beam to prevent occupant injuries in the event of an accident and this is achieved by minimizing the impact force during the collision. This study was investigated the difference of producing bumper beam using roll forming method compare to stamping method. Based on observations design improvements will be made in terms of shape, size and or material based on design modification objectives. The study was focused on existing design performance, advantage and limitations. Modified front bumper design will be tested using FEM software for impact loads as per international standards.

Nitin B. Yadav, SandipBudhe[2]: In present paper authores did the study about different bumpers. Bumper is a valuable part of any automobile which is directly connected to the chassis of vehicle. So when collision are happened the force that transfer to the parts of vehicle through the linkage. There is no mechanism to drop that linkage. In this paper we studied new proposed bumper by using hydraulic cylinder to minimize the impact of collision. The cylinder used here work in two stages. This bumper are applicable in all type of vehicle need to change the stiffness of spring that we use in cylinder, so proposed bumper system suggested for future research.

B.Vinod Kumar Reddy,ChagantipatiSridevi [3]: "Impact Analysis of Front Frame Car Bumper" it should be noted in this paper modeling, solving and results are analysis are done in a ANSYS software respectively. The suitable material that can be used as the bumper in terms of economical but still maintaining the toughness is Carbon Fiber composite which is not expensive compare to the best material from the analysis Aluminum alloy, Mild steel(chromium Coated).

Bharat P. Patil, Prashant N. Ulhe[4] :The aim of this work is to reduce the degree of damage to passengers, and vehicle's body caused by vehicle collisions. Crash phenomena involving road vehicle were studied for the purpose of developing an impact attenuation design that can withstand specific speed.

III. BACKGROUND OF STUDY

The automobile trade has been improved considerably since 1953 by raising the composite materials. Since it's proven that the composite materials are able to do the fascinating properties like low weight, high fatigue strength, easy forming and high strength, although its light-weight weight is that the major reason for the increasing application of the composite materials within the industry. Within the production of vehicles, the low weight of elements leads to a big reduction of the fuel consumption and consequently the reduction of the greenhouse emission and alternative emissions. Since the experimental tests, significantly at complete, square measure terribly expensive and need extremely specialized check facilities and conjointly the model being evaluated certainty and suffer great deal of damages.

IV. FUNCTIONS OF CAR BUMPER

A bumper is sometimes designed for providing a shielding and providing the security from the collision. Bumper is usually created of steel, metal rubber or plastic that is mounted on front of a vehicle. The most perform of the bumper is to soak up energy and shocks and to cut back the injury which can have an effect on the automotive. Some bumper use energy absorbers or created with foam artifact material. Bumpers also are designed to prevent or reduce the physical injury and to guard the hood, trunk, grille, fuel tank, exhaust and radiator besides the engine or front half. Bumpers are supposed to prevent injury to occupants within the cars. They are also designed so that the cars can collide without much danger to the drivers and also provide cushioning effect to pedestrians.

Fig-1 Actual function of car bumper (source: Cheon S.S, 1995)

V. STANDARDS FOR CAR BUMPER

Different standard are set for testing of car bumper according to different countries traffic norms.

(i). Velocity 48 kmph or 13.34 m/sec Federal Motor Vehicle Safety Standards

(ii). Velocity 64 kmph or 17.74 m/sec Insurance Institute of Highway Safety Standard

VI MATHEMATICAL MODELING

Kinetic energy of bumper before collision,

$$\text{Kinetic Energy} = \tfrac{1}{2} M*v^2 \quad \ldots\ldots(1)$$

Strain Energy of bumper after collision

$$\text{Strain Energy} = \tfrac{1}{2} \sigma 2V/E \quad \ldots\ldots(2)$$

Since at the time of collision the total kinetic energy of Bumper is converted into strain energy of Bumper, so according to law of conservation of energy, total Energy of the system is constant. So, balancing energies of the Bumper.

Change in Kinetic Energy = Change in Strain Energy

$$\tfrac{1}{2} M*v2 = \tfrac{1}{2} \sigma 2V/E \quad \ldots\ldots(3)$$

From equation 3, we can find stress generated in Bumper.

So, Stress generated by bumper is given by,

$$\sigma 2 = M*v2*E/V$$

$$\sigma = \sqrt{(M* v2*E/ V)} \quad \ldots\ldots(4)$$

$$\sigma = Kr* \sqrt{(M* v2*E/ V)} \quad \ldots\ldots(5)$$

Where, Kr= Ks* Ksz * Kc * Ke.

Kr= Resultant Factors corresponding to shape, size, stress concentration, and endurance limit as shown in following table.

Table1 Values of Design Stress Factors for Materials

Material	Shape Factor K_s	Size Factor K_{sz}	Stress Concentration Factor K_{sz}	Endurance Limit Factor K_c	Resultant Stress Factor K_r
ABS Plastic	1	1	2.5	1	2.5
CFRP	1	1	1.1	1	1.1
GFRP	1	1	1.8	1	1.8

Now, Applying Material conditions for Bumper,

[1] Stress for ABS Plastic

For Velocity, v = 13.34 m/s,

Density $\rho = 1020\ kg/m^3$

Volume, V = 0.002731 m3,

Mass, M = ρ*V

= 1020*0.002731

= 2.786 Kg

Modulus of Elasticity, $E = 2000*10^6\ N/m^2$,

Resultant Stress Factor, Kr = 2.5

So, from equation 5,

$$\sigma = Kr* \sqrt{(M* v2*E/ V)} \quad \ldots\ldots(6)$$

$\sigma = 2.5* \sqrt{(2.786 * 13.34^2*2000*10^6/0.002731)}$

$\sigma = 2.5*\sqrt{3.63*10^{14}}$

$\sigma = 2.5*19053331.05$

$\sigma = 47633327.62\ N/m^2$

Value of Max Stress at 13.34 m/s σ = 47.63 mpa

For Velocity, v = 17.74 m/s,

Density $\rho = 1020\ kg/m^3$

Volume, V = 0.002731 m3,

Mass, M = ρ*V

= 1020*0.002731

= 2.786 Kg

Modulus of Elasticity, $E = 2000*10^6\ N/m^2$,

Resultant Stress Factor, Kr = 2.5

So, from equation 5,

$$\sigma = Kr* \sqrt{(M* v2*E/ V)} \quad \ldots\ldots(7)$$

$\sigma = 2.5* \sqrt{(2.786 * 17.74^2*2000*10^6/0.002731)}$

$\sigma = 2.5*\sqrt{6.42*10^{14}}$

$\sigma = 2.5*25339516.23$

$\sigma = 63348790.58\ N/m^2$

Value of Max Stress at 17.74 m/s σ = 63.349 mpa

[2] Stress for CFRP Material

For Velocity, v = 13.34 m/s,

Density $\rho = 1800\ kg/m^3$

Volume, V = 0.002731 m3,

Mass, M = ρ*V

= 1800*0.002731

= 4.916 Kg

Modulus of Elasticity, $E = 35000*10^7$ N/m2,

Resultant Stress Factor, Kr = 1.1

So, from equation 5,

$$\sigma = Kr* \sqrt{(M* v2*E/ V)} \quad \ldots\ldots(8)$$

$\sigma = 1.1* \sqrt{(4.916 * 13.34^2*35*10^{10}/0.002731)}$

$\sigma = 1.1*\sqrt{1.12*10^{17}}$

$\sigma = 1.1*334838153.9$

$\sigma = 368321969.3\ N/m^2$

Value of Max Stress at 13.34 m/s σ = 368.32 mpa

For Velocity, v = 17.74 m/s,

Density $\rho = 1800\ kg/m^3$

Volume, V = 0.002731 m3,

Mass, M = ρ*V

= 1800*0.002731

= 4.916 Kg

Modulus of Elasticity, $E = 35000*10^7\ N/m^2$,

Resultant Stress Factor, Kr = 1.1

So, from equation 5,

$\sigma = Kr^* \sqrt{(M^* v2^* E/ V)}$ ..... (9)

$\sigma = 1.1^* \sqrt{(4.916 * 17.74^2 * 35 * 10^{10}/0.002731)}$

$\sigma = 1.1^* \sqrt{1.9827 * 10^{17}}$

$\sigma = 1.1 * 445279524$

$\sigma = 489807476.4\ N/m^2$

Value of Max Stress at 17.74 m/s σ = 489.80 mpa

[3] Stress for GFRP Material

For Velocity, v = 13.34 m/s,

Density $\rho = 1200\ kg/m^3$

Volume, V = 0.002731 m3,

Mass, M = ρ*V

= 1200*0.002731

= 3.277 Kg

Modulus of Elasticity, $E = 6000 * 10^7$ N/m2,

Resultant Stress Factor, Kr = 1.8

So, from equation 5,

$\sigma = Kr^* \sqrt{(M^* v2^* E/ V)}$ ..... (10)

$\sigma = 1.8^* \sqrt{(3.277 * 13.34^2 * 60 * 10^9/0.002731)}$

$\sigma = 1.8^* \sqrt{1.28 * 10^{16}}$

$\sigma = 1.8 * 113193656.5$

$\sigma = 203748576.4\ N/m^2$

Value of Max Stress at 13.34 m/s σ = 203.75 mpa

For Velocity, v = 17.74 m/s,

Density $\rho = 1200\ kg/m^3$

Volume, V = 0.002731 m3,

Mass, M = ρ*V

= 1200*0.002731

= 3.277 Kg

Modulus of Elasticity, $E = 60 * 10^9$ N/m2,

Resultant Stress Factor, Kr = 1.8

So, from equation 5,

$\sigma = Kr^* \sqrt{(M^* v2^* E/ V)}$ .....(11)

$\sigma = 1.8^* \sqrt{(3.277 * 17.74^2 * 60 * 10^9/0.002731)}$

$\sigma = 1.8^* \sqrt{2.2658 * 10^{16}}$

$\sigma = 1.8 * 150528891.6$

$\sigma = 270952004.8 N/m^2$

Value of Max Stress at 13.34 m/s σ = 270.95 mpa

Table2 Comparison of calculated impact

Velocity m/sec	Material	Impact Stress in mpa
13.34	ABS Plastic	47.63
	CFRP Material	368.32
	GFRP Material	203.75
17.74	ABS Plastic	63.349
	CFRP Material	489.8
	GFRP Material	270.95

Comparison of calculated mass for different materials bumpers --

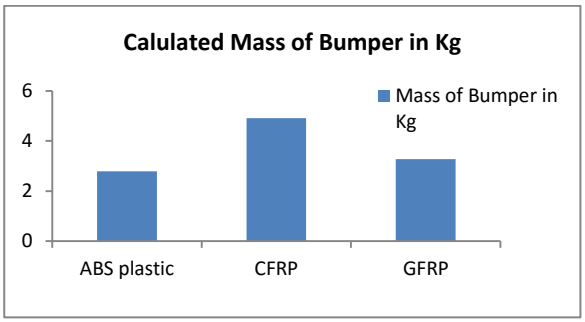

Figure 2 comparison of mass of bumper

VII. CONCLUSION

After the study we got the result that ABS Plastic material bumper shows less impact stress. which is most desirable for absorbing impact it's also very light in weight and less in cost so we can conclude that for the manufacturing of car front bumper material ABS plastic is a best choice rather than use of existing material GFRP for manufacturing of car front bumper. CFRP is another good choice and performed better in theoretical analysis but it is bulky and costlier than existing material and suggested material.

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