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Automobile bumper by Varying Materials to control energy Absorption for improve passenger car safety performance

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Abstract - Modern bumpers are made with a combination of materials. The first element is an impact absorbing spring device, usually gas-filled cartridges which mount the front bumper to the chassis. This allows the bumper system to absorb minor impacts without any damage.

Different impact attenuation systems in the vehicle were studied with emphasis on the bumper modeling, material consideration shield made of steel, aluminum 2014, rubber, ABS, PVC, composite materials or smart material can achieve the desirable properties such as low weight, high fatigue strength.

The combination of all above investigation gives better results output, high strength, cost and weight reduction passenger safety, easily method to fabricated and manufacturing, experiment setup for crash analysis, better tools for design and analysis, high strength with less weight material fended out that achieve 3 times speed higher than the speed for which current conventional bumpers are designed to attenuate (i.e. 4 km/h).

***Keywords*-- Investigation; Bumper; Design; Material condition; Analysis; Testing**

I. INTRODUCTION

In automobiles a bumper is the front-most or rear-most part, ostensibly designed to allow the car to sustain an impact without damage to the vehicle's safety systems. They are not capable of reducing injury to vehicle occupants in high-speed impacts, but are increasingly being designed to mitigate injury to pedestrians struck by cars. Often materials are subject to forces (loads) when they are used. Mechanical engineers calculate those forces and material scientists how materials deform (elongate, compress, twist) or break as a function of applied load, time, temperature, and other conditions. Materials scientists learn about these mechanical properties by testing materials. Results from the tests depend on the size and shape of material to be tested (specimen), how it is held, and the way of performing the test. That is why we use common procedures, or *standards*, which are published by the ASTM.

Nomenclature

E Modulus of Elasticity

ν Poisson's ratio

Sy Yield Strength

ρ Density

II. EFFECT OF MATERIALS AND THEIR PROPERTIES ON BUMPER BEAM

2.1 Modulus of Elasticity

Steel, magnesium and aluminum are the three conventional metals whose specifications are assigned to the bumper. Mechanical specifications of the isotropic and metallic materials are illustrated in Table 2.1.1 to study the effect of elastic modulus on bumper impact behavior, three mentioned alloys metals with different modulus of elasticity are selected where they have equal yield strength. The impactor collides to the bumper perpendicularly with 4 km/h velocity.

Table 2.1.1 Material properties of the models-

Material	E(Gpa)	ν	Sy (Mpa)	ρ (kg/m3)
Commercial steel bare-CS	207	0.3	190	7860
Aluminum 3105-H18	68.9	.33	193	2720
Magnesium AZ31B	450	.35	180	1740
PEP	1.2	0.4	27	900

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Fig.2.1.1 shows the comparison of the average longitudinal deflection among three bumpers made of different metals. The deflection was measured at the nodes located in the middle of the bumper horizontally. Point of center of impact was assumed 445 mm above ground in this simulation according to the low-velocity impact standard for passenger cars, which gives a fixed value where most collisions occur. The separation point takes place at 0.072, 0.058 and 0.054 s, for aluminum, steel and magnesium, respectively. This may be seen in the deflection vs. time diagram in Fig. 2.1.1, where the deflections become constant. In all cases, the deflections after impact do not become zero, because the plastic deformation occurs in bumper system (beam and shock absorber). The maximum deflection point also occurs at 0.037, 0.034 and 0.033 s; with the deflections 20.25, 16.47 and 15.51 mm, for aluminum, steel and magnesium, respectively. Both phenomena are attributed to the material stiffness. In the other words, the magnesium stiffness is higher than the steel and the steel stiffness is higher than the aluminum. Linear momentum is conserved and since the impact phenomena almost always are with losing energy, kinetic energy is not conserved. With subtraction kinetic energy, after and before impact this energy dissipated in the collision can be calculated. This portion of kinetic energy of system converts to strain energy due to elastic and plastic deformations that occur in bumper system.

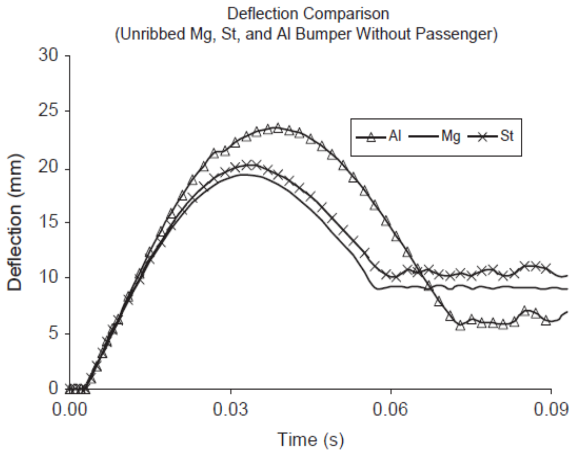

Fig. 2.1.1 Magnesium, steel and aluminum bumper deflections.

In aluminum bumper due to the low stiffness, the impact area of beam is wide. It means a wider area of bumper is involved. So plastic deformation and consequently, dissipated energy is small since coefficient of restitution is bigger than other metal. Another observation is the difference in impact velocities. With comparison among Figs. 2.1.2 - 2.1.4 clearly shows that there is a difference in impact velocities among magnesium, steel and aluminum bum-per. In aluminum bumper difference between impactor velocity and vehicle velocity after impact is higher than steel and magnesium bumper. In other words, in aluminum bumper more kinetic energy from impactor transfers to the vehicle. It means that in steel and magnesium bumpers, reduction of impactor velocity and increasing of vehicle velocity are lower than aluminum bumper. It can be proved by above-mentioned impact laws. Another parameter to study is impact force. To compare the differences among impact forces, the impactor inertia force in three states was defined as a common criterion i.e. how the impactor decelerates due to the combined effects of the bumper and car. According to Fig. 2.1.5, the impact force in aluminum bumper is the lowest; meanwhile it applies in a longer time interval. This phenomenon is due to lower rigidity of aluminum.

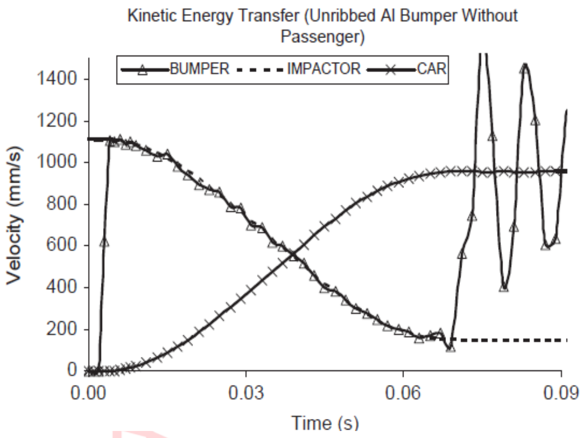

Fig. 2.1.2 Kinetic energy transfer in magnesium bumper.

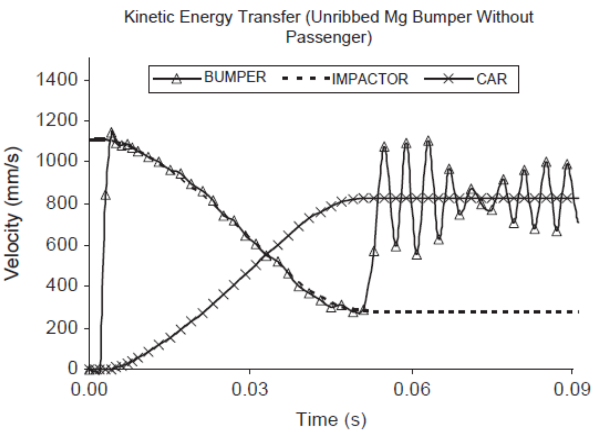

Fig. 2.1.3 Kinetic energy transfer in Steel bumper

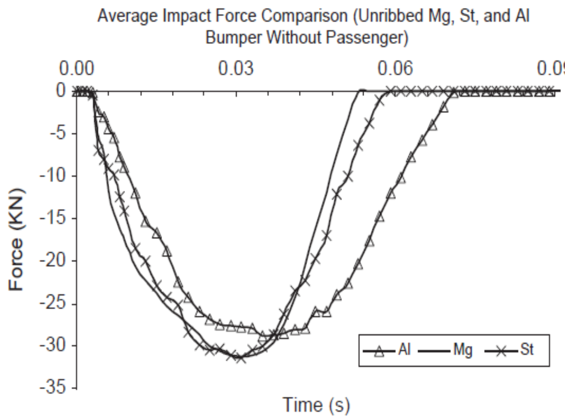

Fig. 2.1.4 Kinetic energy transfer in Aluminium bumper

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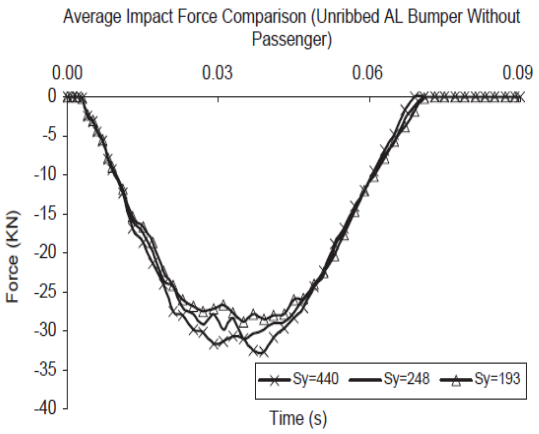

Fig. 2.1.5 Impact force in three case studies of bumpers.

2.2 Yield Strength

The effect of yield strength on impact behavior is studied with three different specifications on aluminum alloys. Properties of these aluminum alloys are shown in Table 2.2.1 Fig. 2.2.1 demonstrates comparison of bumpers deflection for different aluminum bumpers. The maximum deflection and remained plastic deflection after impact decrease with increasing the aluminum strength. Also, maximum deflection time and separation point in high-strength aluminum occur early. All phenomena are attributed to the yield strength of aluminum. For different aluminum bumpers, difference between vehicle and impactor velocities after impact increases by increasing the yield strength. Figs. 2.2.2 and 2.2.3 show these velocities. Accordingly, more kinetic energy transfers to the vehicle and as a result lesser energy dissipates. This can be clearly shown in Figs. 2.2.4, 2.2.2, 2.2.3 According to these figures, the velocity of impactor is not reduced to zero. The major reason is plastic deformation that occurs in the bumper and holders.

Table 2.2.1 Material properties for Aluminium and Steel material

Material	*E* (Gpa)	ν	*Sy* (Mpa)	ρ (kg/m3)
Aluminum 3105-H18	68.9	0.33	193	2720
Aluminum 2219-T31	73.1	0.33	248	2840
Aluminum 2024-t86	72.4	0.33	440	2780
Steel bare/EG-HF 80Y100T	207	0.3	584	7860

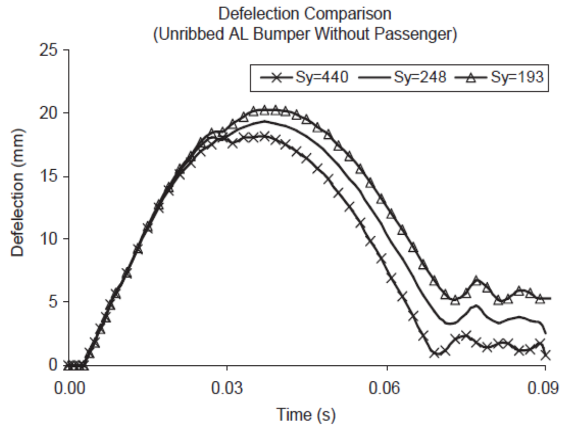

Fig. 2.2.1 Various aluminum bumper deflections.

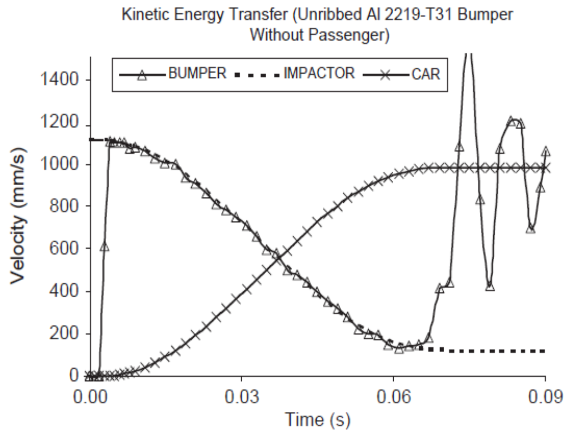

Fig. 2.2.2 Kinetic energy transfer in aluminum 2219-T31 bumper.

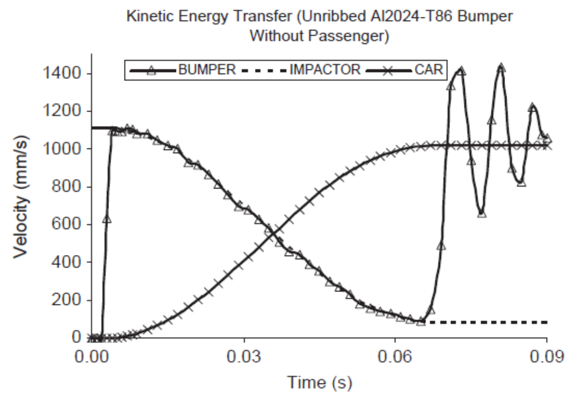

Fig. 2.2.3 Kinetic energy transfer in aluminum 2024-T86 bumper.

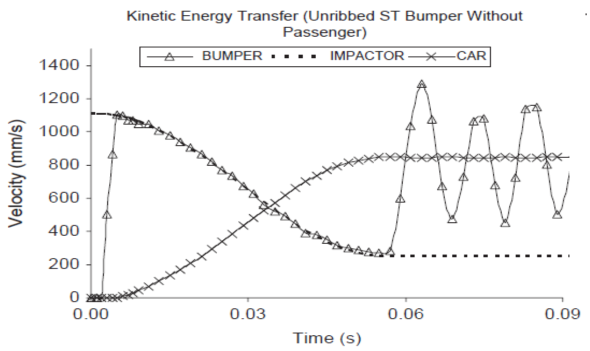

Fig. 2.2.4 Impact forces in aluminum bumpers.

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III. EFFECT OF THICKNESS PARAMETER ON BUMPER

Different bumper beam thickness made of high-strength steel (Bare/EG-HF 80Y100T) with 584 MPa yield strength were chosen to determine the effect of impact behavior. This grade of steel can be used for roll forming and stamping of door-intrusion beams, bumper-reinforcement beams, and various seating components, such as tracks, pillars, risers and towers Mechanical specifications of this steel are shown in Table 2.1.1

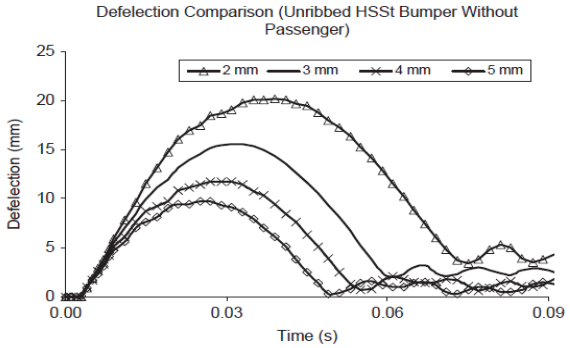

Fig. 3.1 Effect of thickness on bumper deflection.

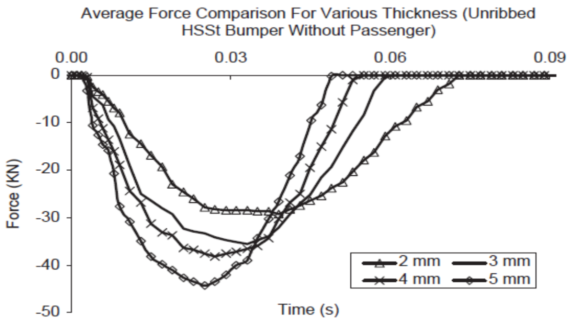

Fig. 3.2 Effect of thickness on impact force.

Fig. 3.1 shows the bumper deflection in which one can observe that the maximum deflection increases, since the bumper rigidity reduces and it is the result of decreasing the bumper beam thickness. Furthermore, the separation point and the maximum deflection point take place with a delay in thicker bumper. The study of impact forces on bumper with various thicknesses shows that the impact force enhances following increasing the bumper thickness as illustrated in Fig. 5.2. So, the acceleration rate of the car increases very fast, since this force applies in short-time interval. By investigation of kinetic-energy diagram, it is observed that more kinetic-energy transfer from impactor to vehicle and less plastic strain energy dissipates with increasing the bumper thickness.

IV. EFFECT OF RIBS ON BUMPER

The ribs are strengthening plates of average thickness 4 mm, mainly placed along the vertical and horizontal direction of bumper beam as shown in Fig.6.1, for preventing deflection of lateral surfaces and thus creating a rigid structure. To study the effect of ribs on impact behavior, high-strength steel (Bare/EG-HF 80Y100T) with 584 MPa yield strength is chosen. Fig.6.2 clearly shows how ribs can reduce deflections: 19% comparing conditions of bumper with-ribs and without-ribs. As shown in this figure, this decrease is also noticeable in separation time of the without-ribbed bumper after a time of 0.054 s, due to lower rigidity of the structure.

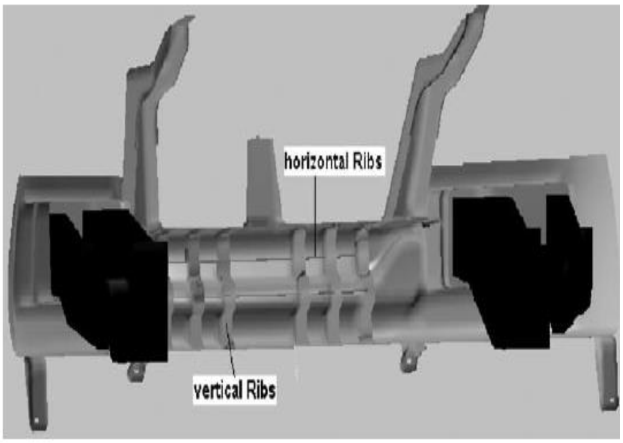

Fig. 4.1 Ribs in vertical and horizontal direction.

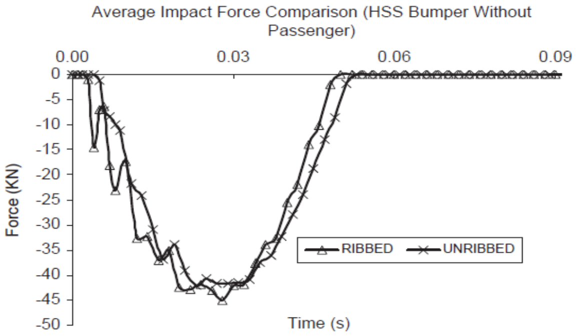

Fig. 4.2 Deflections in two case studies of bumpers

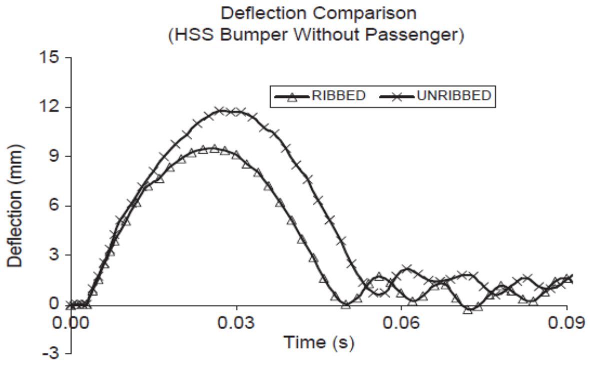

Fig. 4.3. Impact force in two case studies of bumpers.

In addition, it is observed from Fig. 4.3 that ribbed bumper has a stronger impact force than un-ribbed one. Augmentation of maximum impact force is 7%. This phenomenon increases the rigidity of the bumper structure and grows impact force. Careful attention of the impact velocities represents that the ribs do not have an influence on vehicle and impactor velocities. Here, it is

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comprehended that finding an un-ribbed structure with the same speed decelerating behavior as the ribbed bumper is a very reasonable replacement solution and should be precisely focused due to the advantage of ease of manufacturing, however; the ribs have an effect on impact behavior.

V. PASSENGER EFFECT

The presence of passengers on impact behavior with mentioned steel is investigated by considering the passenger's weight in the mass point elements. For simplification, the effect of distribution of passengers was ignored here. In fact, the presence and absent of passengers investigated in this study as in the standards also recommend three passengers added to driver. The impact force with and without passengers is calculated and shown in Fig. 7.1. It shows that the impact force is increased up to 12% by existing passengers. This phenomenon is easily explainable, since impact force is defined exactly on the basis of deceleration of the impactor or its inertia force and it is obvious that it loses speed considerably when impacting a structure of higher mass. The deflection of bumper beam is illustrated in Fig. 7.2 during the impact. As shown in Fig. 7.2, the presence of passengers has a tiny effect on bumper deflection. The percent of maximum deflection increasing of bumper beam with passenger is 6.5. Also heavier weight of vehicle cause the stress and plastic strain in bumper beam that increases and consequently plastic strain energy increases. So car's kinetic energy decreases comparing with the case of without passenger.

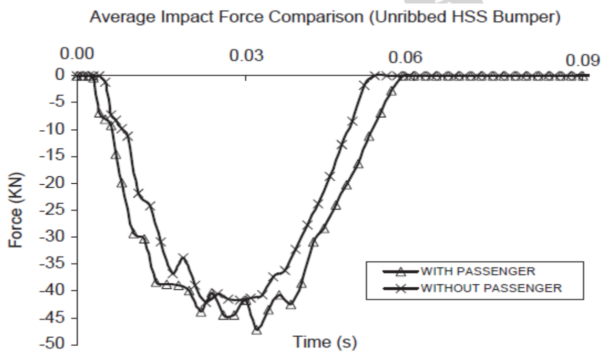

Fig.5.1 Impact force in two case studies of bumpers for passenger effect.

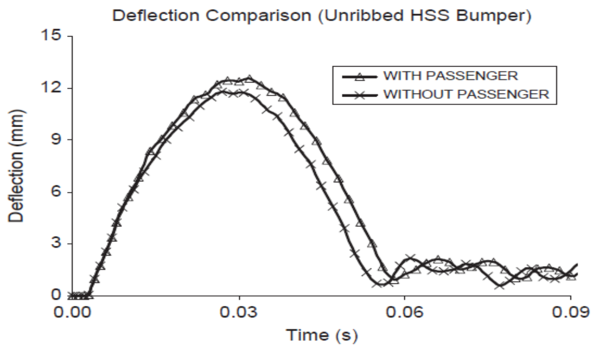

Fig.5.2 Deflections in two case studies of bumper

VI. CONCLUSION

Conducting the analysis on selection criteria of material it is absorbed steel and aluminum used springs or hydraulic units to provide both protection and cushioning allowing the bumper to absorb impact and remain relatively undamaged.

In terms of styling and practicality, here to manufacture we used rubber to absorb the impact and protect the chrome metal bumper, I may preferred this to the modern plastic covered Styrofoam and aluminum. The new ones scuff, crack and clip from something as slight as a car hitting it while parking.

From above study we concluded that Selection an appropriate Car/ SUV/ MUV or heavy duty vehicle can get desirable output on crashworthiness of bumper such as material identification modeling & analysis different component can achieve high strength, reduction in weight which can with stand impact absorbed by energy at the load acting on crashworthiness

The permissible strain values can be achieved by changing the thickness& material of bumper components. Changing the thickness& material is very cost effective way to get the assembly in safety zone as compared to others such as change in geometry or addition of ribs.

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