REVIEW OF DESIGN & ANALYSIS OF BUMPER BEAM IN LOW SPEED FRONTAL CRASHES

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Abstact:- In this seminar, the most important parameters including material, thickness, and shape and impact condition are studied for design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact. The bumper beam analysis is accomplished for composite and aluminum material to compare the weight and impact behavior. The strength in elastic mode is investigated with energy absorption and impact force in maximum deflection situation. In this seminar, a front bumper beam made of three materials: aluminum, glass mat thermoplastic (GMT) and high-strength sheet molding compound (SMC) is studied by impact modeling to determine the deflection, impact force, stress distribution and energy-absorption behavior. The mentioned characteristics are compared to each other to find best choice of material, shape and thickness. The results show that a modified SMC bumper beam can minimize the bumper beam deflection, impact force and stress distribution and also maximize the elastic strain energy. In addition, the effects of passengers in the impact behavior are examined. The time history of the calculated parameters is showed in graphs for comparison. Furthermore, beside the above-mentioned benefits, some more advantages like easy manufacturing due to simple shape without-ribs, economical aspects by utilizing low-cost composite material and reducing weight with respect to others can be achieved by SMC material

I. INTRODUCTION:-

Bumper beams are one of the key structures in passenger cars for which careful design and manufacturing should be considered in order to achieve good impact behavior. The bumper beam is the main structure for absorbing the energy of collisions. Since, suitable impact strength is the main expectation for such a structure. A commercial front bumper beam was chosen in this study for modeling and impact test. With the introduction of automobile safety legislation, crash- worthiness and safety should be considered as preconditions in light-weighting design of bumper beam .The automobile bumper weight can be reduced by the use of composite and high- strength metallic sheet of a thinner thickness material. Fig. 1 shows the schematic diagram of a low-speed impact test. According to these conditions, the car should be placed on a flat surface with released gear and brake and impacted both from front and side directions .Since the real low-velocity test stated in the agreement requires laboratory equipment, simplifications were assumed to make finite element modelling possible. The consequence of adopting this concept, however, is that when the bumper is impacted by a stiff object, such kind may happen in a parking accident or in the legislative low-speed impact pendulum test ,then the bumper fascia alone may not be sufficiently stiff to resist the impact. The simplifying assumptions were deemed not to change real conditions but to create more critical conditions, which could provide a reliable basis for the design and analysis of bumper beams. There were four main strategic parameters being studied during the test modeling in the first step for metallic material. Firstly, the material, i.e., how the type of material can affect the impact specifications and what kind of materials can be used as replacement in order to lower part weights. The effect of module of elasticity and yield strength on impact behavior of bumper beam was under investigation in this section. Secondly, the thickness, i.e., how the bumpers beam thickness can affect the impact specifications. Thirdly, the shape, i.e., how even small changes and modifications can result in easier manufacturing processes and lessening material volume without lowering the impact strength.

II. PROBLEM DEFINITION:-

Finally, the impact condition, i.e., how test conditions other than the previously mentioned parameters can affect the impact behavior. Steel and aluminum structures with a specified thickness that did not fail during the test depicted clearly that they are not suitable as bumper beam structure due to increasing weight. They increased the weight of the structure by nearly 500% and 100%, respectively, in comparison with the composite bumper. In the next step, the composite materials like GMT and SMC are used and studied to find best impact behavior. To summarize, the objective of this research was to develop and propose a replaced composite bumper, which could satisfy following requirements:

1. Easy to manufacture by simplifying the shape. This was accomplished by removing strengthening ribs of bumper.
2. being economical by utilizing low-cost composite materials.
3. Achieving reduced weight compared to the metallic bumpers.
4. Achieving improved or similar impact behavior compared to the current metallic structure.

To study the characteristics of composite materials, both GMT and SMC material properties were used to model the bumper. Due to the primary strategy of manufacturing simplification, the ribs were removed from the design in the two composite models. Since the test with the presence of passenger is the most realistic and most critical case, the test conditions were for the case of full passengers and this is the reason that all composite tests are accomplished with passenger. The GMT bumper was simulated under the same test conditions. Firstly, the GMT bumper with strengthening ribs and 4mm thickness are studied and in the next stage all ribs are removed and the thickness increased to 5mm. implementing this strategy, the material properties for a high strength SMC were assigned to the bumper beam. To satisfy the simplified manufacturing strategy, again, all ribs were removed and to reduce the weight, the thickness was decreased from 4 to 3mm. Analysis showed that the structure failed at a few locations just slightly higher than yielding point, indicating that these locations had to be strengthened. After increasing the thickness in the high-stress locations to 4mm, the structure was again tested. No yield was reported for the entire structure, and the weight remained equal to that of the GMT bumper.

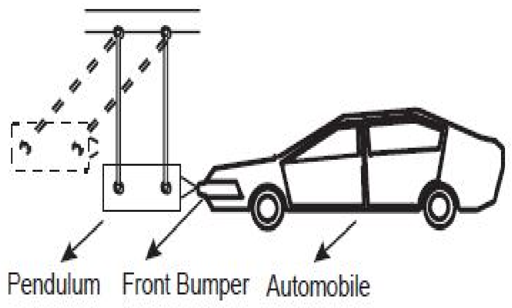


Fig. 1 Low speed impact test

III. BUMPER AND ITS PURPOSE:-

A bumper is a shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. Some bumpers use energy absorbers or brackets and others are made with a foam cushioning material.

3.1 Main parts of the conventional bumper systems:

There are several models and systems for bumpers of passenger cars. Traditional models have corrugated open section areas for installing some car elements and increasing bending strength of the bumper. Main parts of the conventional bumper systems are depicted in (Fig.3.1)

i. **Fascia:** bumper fascias must be aerodynamic, lightweight and aesthetically pleasing to the consumer. Usually fascias are made of polypropylene, polyurethane or polycarbonate.
ii. **Energy absorbers:** energy absorbers are designed to absorb a portion of the kinetic energy from vehicle collision. Its types include foam, honeycomb and mechanical ones. However mechanical absorbers have several times the weight of foam and honey comb absorber, they receive limited usage.
iii. **Reinforcing beam:** this part is a key component of the bumper and helps absorb the kinetic energy and provide protection to the rest of the vehicle.

In other words, in low-speed contacts, the kinetic energy of impactor is absorbed by changing the impact force direction by the spring system (as mechanical energy absorbers) and in high speed contacts it is absorbed by deformation of conic composite cells of the bumper (as reinforcing beam). The main elements of advanced bumper are as follows (see Fig.3.2):

i. **Front rubber tape:** that is composed of polypropylene (PEP) for damping of poor contacts.
ii. **Fascia:** it indicates the aerodynamic form of the bumper and is used as a bearing for spring system retainer.
iii. **Spring system:** it contains 26 vertical springs for converting the kinetic energy to the spring potential energy, In addition to 4 horizontal springs for connecting the fascia to base plate.
iv. **Conics and base plate:** they are main elements of the bumper for energy absorbing in high speed contacts (i.e. reinforcing beam).
v. **Connecting plastic parts:** two propylene (PEP) parts that connect the bumper base plate to the car.

3.2 Purpose of Bumper

A bumper is a shield made any of material like steel, aluminum, rubber or plastic that is mounted on the front and rear of passenger car. The function is when a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. Some bumper use energy absorbers or brackets and others made with foam cushioning material. The car bumper is design to prevent or reduce physical damage to the front car. It is also design to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collision. It is not safety feature intended to prevent or mitigate injury to occupants in the passenger cars. Bumper car rides are designed so that the cars can collide without much danger to the riders. Each car has a large rubber bumper all around it, which prolongs the impact and diffuses the force of the collision.

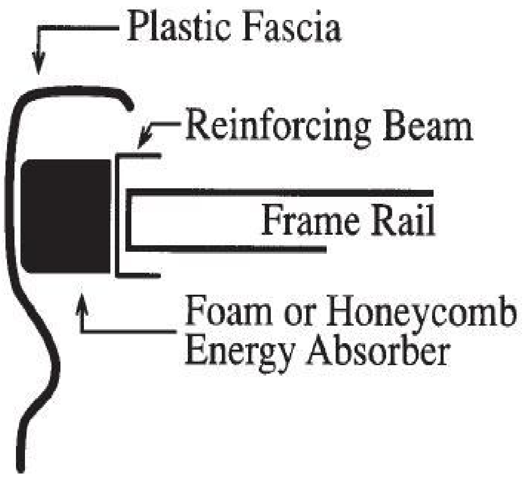


Fig 3.1 Configuration of common bumper type [2]

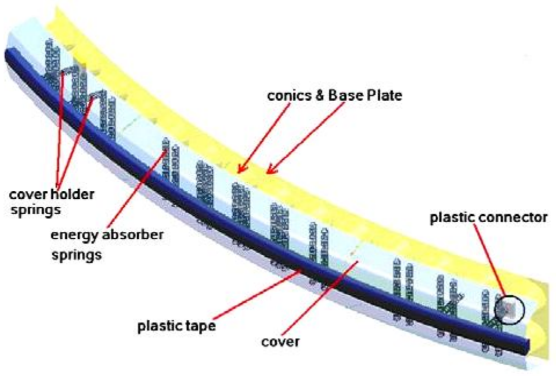


Fig 3.2 Schematic configuration of the desired bumper [2]

3.3 IMPACT MECHANICS:-

It is important in the study of impacts to distinguish between the two different types of impacts that occur, elastic and plastic impacts. In an elastic impact a negligible amount of energy is lost between the two impacting bodies, for example, the collision of two billiard balls. A plastic impact involves a significant amount of energy dissipated in the collision. An impact between two vehicles or between one vehicle and a rigid body, where the vehicles crumple on impact, is an example of an elasto-plastic impact. The impacting phenomenon between an impact or and the front bumper in a low-speed full crash could be very complicated, since transient and nonlinear analyses are involved. But, in designing the front bumper, automobile manufacturers insist that the bumper system should not have any material crash or failure. Therefore, up to that point, the total energy is conserved throughout the impact duration. Since the impactor is assumed to be rigid and the bumper beam was made of metallic and composite material and shock absorber is a relatively low stiffness material, the distribution of the impact load is irregular along the contact area and over the contact region of the bumper, the bumper beam subjected to the impact load undergoes a constant deformation dmax. A principle of energy conservation in the elastic impact is used; the kinetic energy before impact is conserved and converted to elastic energy and the kinetic energy of the impactor and the automobile at its maximum deflection,

$$\frac{1}{2}m_A v_A^2 = \frac{1}{2}K_{eq}\delta_{\max}^2 + \frac{1}{2}m_A v_0^2 + \frac{1}{2}m_B v_0^2$$

Where mA is the mass of the impactor , mB the mass of vehicle, vA the velocity of the impact or before impact and v0 the final velocity of the impactor and vehicle in maximum deflection point. Key the equivalent impact stiffness of a bumper and is obtained by the relationship of displacement and reaction forces from beam analysis. An important consideration of momentum is that it can be neither created nor destroyed. Thus, the momentum before an impact is equal to the momentum after the impact. At the moment of its maximum deflection, a principle of momentum conservation before and after impact can be ex- pressed as follows:

$$m_A v_A = (m_A + m_B) v_0$$

$$\delta_{\max}^2 = \frac{1}{K_{eq}} \frac{m_A m_B}{m_A + m_B} v_A^2$$

After separation point, energy and momentum conservation equations can be expressed as follows:

$$\frac{1}{2}m_A v_A^2 = \frac{1}{2}m_A v_{A2}^2 + \frac{1}{2}m_B v_{B2}^2$$

$$m_A v_A = m_A v_{A2} + m_B v_{B2}$$

where vA2 and vB2 are the final velocities of the impactor and vehicle, respectively in separation point. In the elasto-plastic impact, the principle of linear momentum conservation satisfies, since impact forces are equal and opposite.

$$m_A v_A + m_B v_B = m_A v_{A2} + m_B v_{B2}$$

In this case, the velocities after impact may be determined with the coefficient of restitution (e). The coefficient of restitution (COR) is the ratio of speed of separation to speed of approach in a collision.

$$e = \frac{v_{B2} - v_{A2}}{v_A - v_B}$$

An object with a COR equals to 1 collides elastically, while an object with a COR of 0 will collide inelastically, effectively sticking to the object it collides with, not bouncing at all. The coefficient of restitution is a number which indicates how much kinetic energy (energy of motion), remains after a collision of two objects. If the coefficient is high (very close to 1), it means that very little kinetic energy was lost during the collision. If the coefficient is low (close to 0), it suggests that a large fraction of the kinetic energy was converted in to the heat or was otherwise absorbed through deformation. The Eq.of

Eplastic can be used to find the energy dissipated, ED, during an impact. This is found by subtracting the kinetic energy of the two masses after impact, and the kinetic energy of the impactor before impact.

$$E_{\text{Plastic}} = \frac{1}{2}m_A v_A + \frac{1}{2}m_B v_B - \frac{1}{2}m_{A2} v_{A2} - \frac{1}{2}m_{B2} v_{B2}$$

IV. SCOPE OF STUDY:-

EFFECT OF BUMPER BEAM MATERIAL:-

To investigate the effect of bumper beam material on the impact behavior, two parameters are studied here: the modulus of elasticity and the yield strength. The effects of each parameter are presented as follows.

Modulus of elasticity

Steel, magnesium and aluminum were the three conventional metals whose specifications were assigned to the bumper in separate tests. Other characteristics of the model such as shock absorber, impactor , etc., remained constant for all the case studies. Mechanical specifications of the isotropic and metallic materials are illustrated in Table2 that are used for the analysis. 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. Fig. 3 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 [9,13], 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. 3, 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. 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. 4–6 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 was 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. 7, 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.

Material properties of the models.

Material	E (GPa)	υ	S_y (MPa)	ρ (kg/m^3)
Commercial steel bare-CS	207	0.3	190	7860
Aluminum 3105-H18	68.9	0.33	193	2720
Magnesium AZ31B	450	0.35	180	1740
PEP	1.2	0.4	27	900

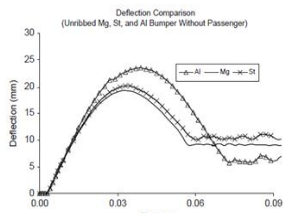


Fig. 3 Mg, steel & Al bumper deflection

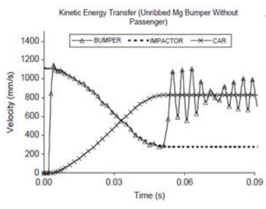


Fig.4 kinetic energy transfer in mg bumper

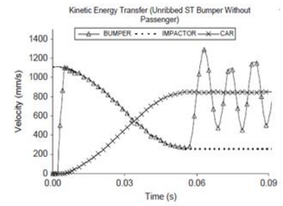


Fig. 5. Kinetic energy transfer in steel bumper

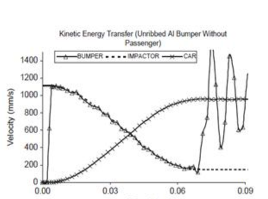


Fig. 6. Kinetic energy energy transfer in Al bumper

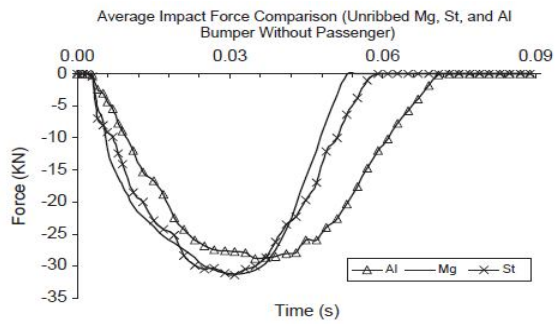


Fig. 7. Impact force in three case studies of bumpers

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 Table3. Fig. 8 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 impact or velocities after impact increases by increasing the yield strength. Figs. 9and10 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. 6,9and10. 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. So, bumper system collides in elastically with coefficient of restitution of lower than one and consequently plastic strain energy dissipate during an impact. Impactor velocity after impact may be determined by Eqs .(6) and (7). As shown, the car begins to obtain kinetic energy at the same time the impactor loses it. Since the whole of impactor kinetic energy does not transfer to the car and a portion of this energy converts to elastic and plastic strain energy as shown in Fig. 11, imp actor velocity does not become zero and also the car does not accelerates to the impact or initial velocity of 4km/h.

Material properties of the models.

Material	E (GPa)	υ	S_y (MPa)	ρ (kg/m^3)
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

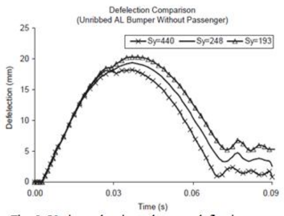


Fig. 8. Various aluminum bumper deflections

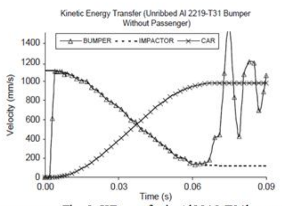


Fig. 9. KE transfer in Al2219-T31bumper.

The middle point of the bumper has the same velocity as the impactor when it is in direct contact with it. At the time of separation, the bumper becomes once again part of the car and thus begins vibrating to adjust its velocity to that of the car. The velocity reported for bumper is average amount for the nodes mentioned at its middle which are contacted to the impactor at the time of impact. In Fig. 12, the impact forces in aluminum bumper beams are shown. It is observed from this figure that the average impact force decreases by decreasing the aluminum strength.

Thus, in comparison with steel and magnesium, using of high- strength aluminum with more thickness, while has a better performance in impact, can be obtained lighter structure.

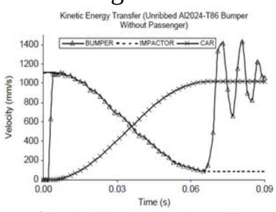


Fig. 10. KE transfer in Al 2024-T86bumper

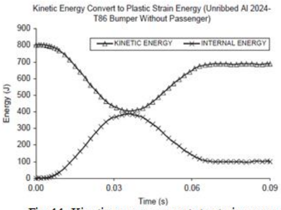


Fig. 11. Kinetic energy converts to strain energy

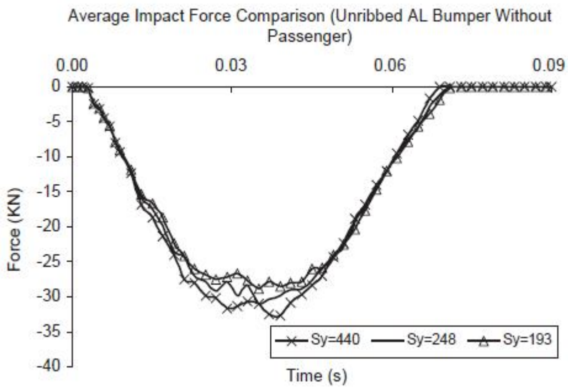


Fig. 12. Impact forces in aluminum bumpers

V. BUMPER THICKNESS:-

Different bumper beam thickness made of high-strength steel (Bare/EG-HF 80Y100T) with 584 MPa yield strength are also 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 [14]. Mechanical specifications of this steel are shown in Table3.

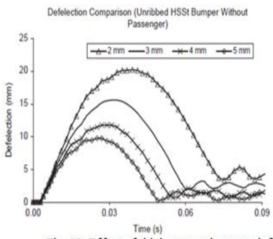


Fig. 13. Effect of thickness on bumper deflection

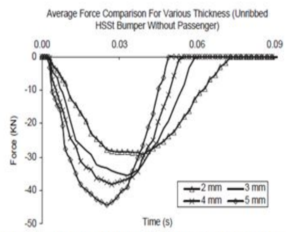


Fig. 14. Effect of thickness on impact force

Fig. 13 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. 14. 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.

VI. EFFECT OF RIBS THICKNESS:-

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. 15, 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 MP a yield strength is chosen. Fig. 16 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.

In addition, it is observed from Fig. 17 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 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.

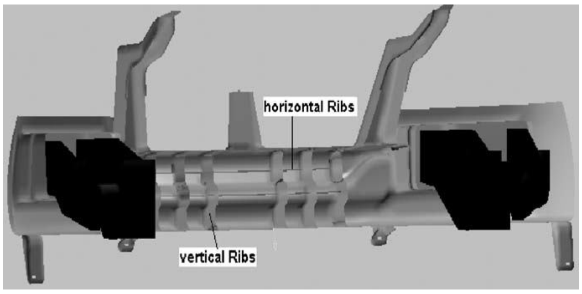


Fig. 15. Ribs on vertical and horizontal direction

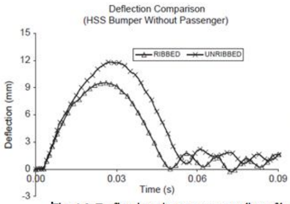


Fig. 16. Deflections in two case studies of bumpers

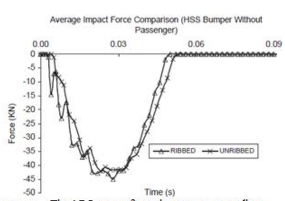


Fig.17 Impact force in two case studies

VII. PASSENGERS:-

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. 18. 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 imp actor 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. 19 during the impact. As shown in Fig. 19, 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. An observation is the difference in impact velocities between ''with passengers'' and ''without passengers'' conditions. In case of the car without passengers, the kinetic energy of impactor does not transfer completely to the car , thus its velocity does not become zero as shown in Fig. 20. Furthermore, a portion of kinetic energy converts to plastic strain energy, so the car does not accelerate to the initial velocity of 4 km/h. In case of the car with passengers, the impactor is not able to transfer the momentum completely to a structure weighing more (see weights in Table 2). So the impactor returns after impact, as seen by negative velocity direction in Fig. 21. 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.

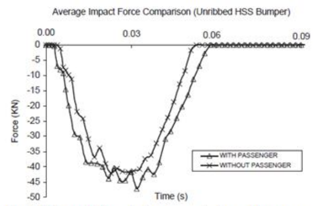


Fig. 18. Impact force in two case studies of bumpers.

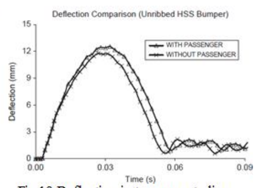
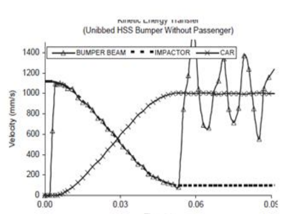
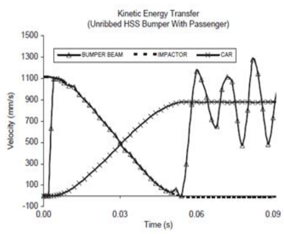


Fig.19 Deflection in two case studies





VIII. COMPOSITE BUMPER BEAM:-

The GMT bumper used in this research is a structure made from short glass fibers, 12–25 mm long randomly mixed with thermoplastic resin (mechanical specifications of the isotropic GMT composite is shown in Table4). GMT is produced in thin sheets of 1 mm thickness with various fiber mats like continuous, chopped, randomly laid, unidirectional and mixtures of these configurations that all yield specific characteristics. In the bumper studied, 3–4 randomly laid chopped fiber sheets are placed in a die and heat formed by a press. The molten resin flows in the cavities of the die and forms its shape. Ease of melting and recycling of thermoplastic resins are two main reasons for their increasing usage in industry, however loose tolerance in manufacturing limits their utilization in places where accuracy is required. The ribs are formed in the shape of concave cavities in the dies, which cause a complex die design. SMC is a short-fiber composite composed of randomly laid chopped fibers in a thermoset resin. The process of producing SMC sheets needs careful consideration due to problem of keeping sheets in the curing room [16]. This process is important, since the material will then be placed in a die press and formed to shape. Cross-linking curing occurs during the hot press operation and the structure is produced. The specifications of high-strength SMC are shown in Table 4. Presence of passengers creates a most critical condition, so car is assumed with passengers in all conditions. In this part, the current ribbed bumper beam made of GMT with 4mm thickness was studied and failed in the test model. In the subsequent stage all the ribs are removed and the structure was strengthened by increasing the thickness to 5mm for preventing yield in beam structure. After analysis it is observed that the maximum stress reached to 220.78MPa. In Fig. 22, stress distribution in maximum stress time is shown. In the next process, the specification of SMC composite were assigned to the bumper and all the ribs removed and the average thickness was reduced to 3mm. The created structure failed in the test model at some zones with slightly more than material yield strength. The structure was strengthened by increasing the thickness of these local zones up to 4mm. The reinforced zones are shown in Fig. 23. After local strengthening, there was no report of yielding at any zone and the maximum stress reached 306.04 MPa. Fig. 24 shows the maximum vonMises stress distribution in the time that stress reaches to 306.04 MPa. The weights of real GMT, modified GMT and modified SMC bumper beam are 2.89, 3.16 and 2.83 kg, respectively. The results compared together and the advantage of new material enumerated with comparing two studied GMT bumpers. Below are some advantages for using SMC instead of GMT: 1. The ribs are removed, thus the bumper structure would be more easily manufactured. 2. The weight of structure will decrease or remain the same. 3. SMC material manufacturing method is easier than that of GMT. 4. The volume of SMC structure will decrease by reducing average thickness. The deflection comparisons among SMC, un-ribbed GMT and real GMT bumpers are shown in Fig. 25. It is observed in real GMT bumper with increasing the bumper beam thickness to 5mm can remove all the ribs without any changes on impact behavior and reach to easy manufacturing.

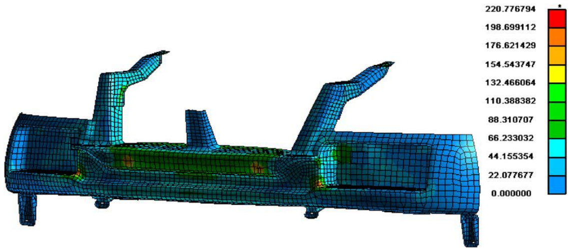


Fig. 22. Maximum vonMises stress distribution in modified GMT bumper.

IX. FINITE ELEMENT MODELING:-

There was a general approach for all the aforementioned models, i.e.with different material, shape and thickness created in LS_DYNA. The CAD data of the bumper structure was imported and the surfaces were created and meshed. Since the average thickness of bumper was much smaller than the other dimensions of the part, the best element for meshing was the shell element. Some various choices of impact elements can be considered like implicit and explicit model. Here, nonlinear explicit impact modelling elements were used for analysis. The bumper is attached to two semi-cubic plastic polypropylene (PEP) holders as shown in Fig. 2, which act as interface between the bumper and the car body. The holders react as shock absorbers and act like mechanical fuses when they are destroyed in high velocity and destructive impacts, preventing the main bumper from being damaged [8]. Each holder is screwed to four points on the bumper, where all degrees of freedom of corresponding nodes on the bumper and the holder were coupled in the models. Each holder is also attached to the carboy by screws at two points. In this modelling, one fourth of the car weight was attached to each screwed node that located behind the holders as a point-mass element. The mass of the car was assumed rigid and lumped as opposed to the bumper structure Bumper and holders meshed by shell element with Belyches- ko-Tesy element formulation. Material type 3 (mat–plastic–kinematic) is used for simulation of metallic materials. This model is suited to model isotropic and kinematic-hardening plasticity with the option of including rate effects. This material type is used for simulation of isotropic composite materials in this study. The imp actor, as a steel structure, was modelled with rigid solid impact elements according to precise dimensional drawings from the E.C.E. Standard. Material types 20 (mat-rigid) are used for simulation of impactor. Fig. 2 shows the model of bumper beam and the impactor. As shown, the imp actor collide to the bumper beam in straight direction and perpendicularly. Table 1 shows the FEM characteristics of each component in the modelling. No friction was assumed between imp actor and bumper surfaces and the car was taken to be lying on a flat and frictionless surface. The imp actor contact velocity was 4 km/h for straight impact (representing condition of longitudinal impact test as defined in

Section 2.7 of the R42 regulation) as stated in the ECE standard [9]. The period of test modeling begins from first contact and lasted until full separation and stress release.

CONCLUSION:

The study of effect of different parameters on impact behavior of metallic bumper in low-velocity impact leads to the following results:

1. Use of materials with low young module cause to low rigidity and use of high-strength materials lead to good impact behavior. Because, the maximum stress of the bumper structure will be lower than yield stress. So aluminum is the best choice between those two metals for this purpose.
2. Increasing bumper thickness causes a rise in bumper rigidity and impact force. Consequently, it results in reduction in bumper deflection and stress.
3. Addition of ribs causes an increase in rigidity of bumper beam center and consequently increases the impact force. It also decreases bumper deflection. Furthermore, the manufacture processing will be more difficult with-ribs.
4. Presence of passengers has a negative effect on impact behavior. As shown in Section 7, presence of passengers causes an increase in bumper deflection and stress. Also impact force has been increased by passengers. So in case of the car with passengers, if the bumper has a good performance, surely it will have better function in ‘‘without passenger’’.

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