IMPROVEMENT IMPACT RESISTANCE FOR FRONT AUTOMOTIVE BUMPER

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Abstract

Bumpers play an important role in preventing the impact energy from being transferred to the automobile and passengers. Saving the impact energy in the bumper to be released in the environment reduces the damages of the automobile and passengers. Therefore researchers have sought to make bumpers lighter without sacrificing strength, ability to absorb impact, or passenger safety. This study investigates the possibility of adding filling material between the bumper and front car body. The experimental tests were conducted and applied on front bumper of Fiat- Sahin vehicle.

The results showed the improvement in bumper impact resistance about 260% when using one layer of honey comb cardboard cell and cardboard sheets as filling materials.

Keywords: Cardboard, bumper, impact resistance, filling material

Introduction

Automotive bumper systems are designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles in low speed collisions. To protect the hood, trunk, grill, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions. By limiting physical damage to expensive components, bumper systems reduce insurance expenses for OEMs (Original Equipment Manufacturer).

On April 9, 1971, the agency issued its first passenger car bumper standard -- Federal Motor Vehicle Safety Standard (FMVSS) 215, "Exterior Protection," which became effective on September 1, 1972. This standard called for passenger cars, beginning with model year May 1973, to withstand 5 mph front and 2 mph rear impacts against a perpendicular barrier without damage to certain safety-related components such as headlamps and fuel systems.

In October 1972, Congress enacted the Motor Vehicle Information and Cost Saving Act (MVICS Act) which mandated that the agency issue a bumper standard that yields the maximum feasible reduction of costs to the public, taking into account the cost and benefits of implementation, the standard's effect on insurance costs and legal fees, savings in consumer time and inconvenience, and health and safety considerations.

The new requirements under the MVICS Act were then consolidated with existing requirements in FMVSS 215 and promulgated in March 1976 as a new bumper standard, which was added to NHTSA's regulations at 49 CFR Part 581. The new standard which applied to passenger cars beginning with MY 1979 was referred to as the Phase I Standard. At the same time, a "no damage" requirement was placed on bumper systems for model year 1980 and subsequent years. The most recent revisions to the bumper standard took place in May 14, 1982, effective for MY 1983 and subsequent model year passenger cars. This amendment reduced test impact speeds from 5 mph to 2.5 mph for longitudinal front and rear barrier and pendulum impacts and from 3 mph to 1.5 mph for corner pendulum impacts. In addition, Phase I damage resistance criteria were substituted for Phase II criteria and a bumper height requirements of 16 to 20 inches was established for passenger cars.

Many countries have different performance standards bumper systems. Bumper systems on vehicles sold in North America are required to meet 4 km/hr FMVSS (Federal Motor Vehicle Safety Standard) pendulum and barrier impact resistance and 8 km/hr CMVSS (Canadian Motor Vehicle Safety Standard) pendulum and barrier impact requirements [2005]. In addition, most bumper systems are also designed to meet 8 km/hr IIHS (the Insurance Institute for Highway Safety) 30° corner and flat barrier impact. Bumper systems on vehicles sold in Europe and Japan are typically designed to withstand 4 km/hr ECE42 pendulum impact and 15 km/hr offset Allianz barrier impact. Future front bumper systems sold into European markets will need to meet pedestrian safety requirements in addition to ECE42 and Allianz barrier requirements. Besides many global vehicle platforms will be sold unchanged in European, Japanese and North American markets. This will require a focus on vehicle structure and styling that is flexible enough to meet all of the global legislative impact requirements.

Many energy absorbing bumper systems have been proposed to meet the challenges faced by the bumper designer. An energy absorbing bumper system made of a foam type resin of polypropylene, polyurethane or the like is one concept [Koji Enomoto, 1988]. Another foam type energy absorbing bumper is a semi-rigid resilient fascia spaced forwardly of the bumper structure and the volume defined there between filled with an integral skin urethane foam that is resiliently deformable and integrally bonded to both members [Loren E. Lura, Sandusk, 1979].

However, a non-foam type injection-molded thermoplastic energy absorber made of PC/PBT [D. Evans, S. Shuler, S. Santhanam, 1999; D.

Evans and T. Morgan 2002] has been demonstrated as having the highest efficiency of energy absorption and more consistent impact performance over a range of temperature.

M.M.Davoodi et al, [2010] focused on a hybrid of kenaf/glass fiber to enhance the desired mechanical properties for car bumper beams as automotive structural components with modified sheet molding compound (SMC). A specimen without any modifier is tested and compared with a typical bumper beam material called glass mat thermoplastic (GMT). The results indicate that some mechanical properties such as tensile strength, Young's modulus, flexural strength and flexural modulus are similar to GMT. On the other hand impact strength is still low, and shows the potential for utilization of hybrid natural fiber in some car structural components such as bumper beams. There are two main methods, flexibilisation and toughening, for modifying the resin in order to improve the impact properties of epoxy composite. They form single phase or two-phase morphology to make modifier as epoxy or from separate phase to keep the thermo-mechanical properties.

Liquid rubber, thermoplastic, core shell particle and rigid particle are different methods of toughening improvements [M.M.Davood, Sapuan, Aidy Ali, A Khalina, 2010]. In this research, thermoplastic toughening has been used to improve impact properties in hybrid natural fiber epoxy composite for automotive bumper beam and has achieved reasonable impact improvements. Two general approaches to reducing the severity of pedestrian lower limb impacts were identified: a- Provide cushioning and support of the lower limb with a bumper and a new lower stiffener, or b- Use the bumper as a platform for impact sensors and exterior airbags [Peter J. Schuster, 2006].

The selection of the best design for the automotive front bumper beam for passenger cars depends on the variety of factors which include: energy absorption (EA), cost (CT), manufacturing process (MP), weight consideration (WE), maintenance (MTN) and strength (ST) [Hambali1, Sapuan, Ismail, Nukman**,** 2009].

The overall aim of this study is to investigate the effect of adding filling material between the bumper and front car body on bumper impact resistance, and compare it with that of conventional bumpers.

Process Methodology

This work is presented in three main parts. The first part includes the description of the bumper. The second part shows different types of filling material and its preparation. The third part comprises the different tests conducted on bumper to evaluate the impact resistance of the bumper. The detail of each group is given below.

Tested Bumper Description

The bumper used was a front bumper of Fiat- Sahin car. The impact test is measured at three locations as indicated in Fig. 1. Fig. 2 shows cross-section shapes of specimens (impact location) A, B and C.

a. location (A)

b. locations (C& B)
Fig. 1 Test bumper locations

a. cross-section shape at location (A)

b. cross-section shape at location {B)

c. cross-section shape at location (C)

Fig. 2 Cross-section shape at impact test locations (A, B &C)

Filling Material and preparations

Different materials were used such as foam with different density and cardboard (slices and honey comb). Figs. 3 to 7 show specimens with different filling materials.

Fig. 3 Specimen with sponge 30 in intensity

Fig. 4 Specimen with sponge

Fig. 5 Specimen with sheets of cardboard

a. honey comb cell of cardboard.

b. specimen with honey comb cell of cardboard

c. honey comb cell & cardboard sheet

d. specimen with honey comb cardboard and cardboard sheets

Fig. 6 Steps of preparation the specimen with honey comb cardboard and cardboards sheets

Fig. 7 Double layers of honey comb cardboard cells and cardboard sheets

Figures 6 and 7 show preparation steps of double layers cardboard cells and sheets. First step is the preparation of honey comb cardboard cells to cave area under bumper. Second step is assembling cells with carton sheets bumper. Last step is filling cardboard layers and cells cave area under bumper as shown in Fig. 7.

Impact testing

Impact testing is a method to evaluate object's ability to resist high-rate loading through the determination of energy absorbed in fracturing a test piece at high velocity. Most of us think of it as one object striking another object at a relatively high speed.

The goal of the project was to build a facility capable of having a suitable bumper vehicle achieve impact energy, the potential and kinetic energy can be equated.

$$\text{Kinetic energy} = (1/2)\, mv^2 \qquad (1)$$

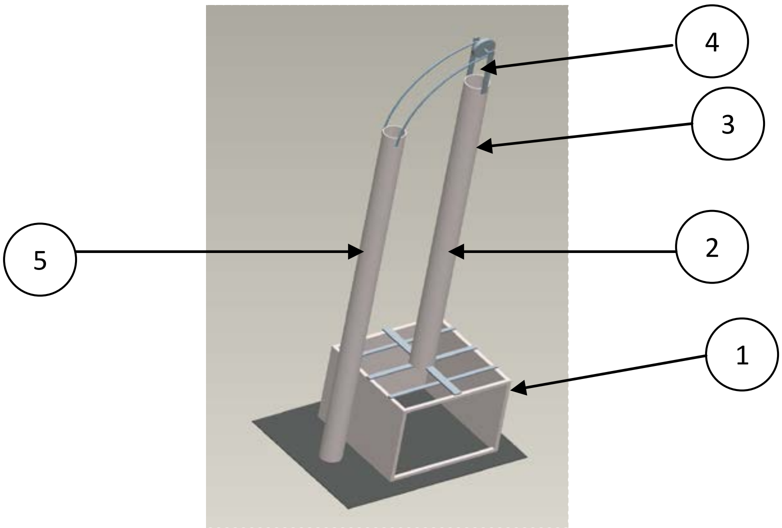
$$= mgh \qquad (2)$$

Where m is the drop mass (kg), g is the acceleration due to gravity (9.81 m/s) and h is the height of the drop mass (m).

Floating weight impact device is used to apply dynamic load on the specimens of the bumper as shown in Fig. 8.

The impact test device consists of base box 1, used to hold the specimen test, hollow shaft 2 , drop weight with wire 3, pulley 4, and fixed arm 5.

The drop weight impact test was considered (Canadian Motor Vehicle Safety Standard) [2005] as a comparison factor between the bumper with any filling material and that with different types of materials. For simplicity the height of drop weight was one meter and the change will be in drop weight values. Each test run was repeated 3 times at least under the same conditions.



1- base box 2- hollow shaft 3-drop weight with wire 4- pulley 5-fixed arm

Fig. 8 Impact test device

Figures from 9 to 11 show the shape of the tested specimen broken at the end of impact test under different drop weights. Case I when the bumper (specimen) without filling material. Case II when the bumper (specimen) is charged with different filling materials.

Fig. 9 Broken specimen (tested without material)

Fig. 10 Broken specimen (tested with filling filling material -sponge 30 in intensity)

Fig. 11 Broken specimens (tested with filling material double layer of carton as a honey comb**)**

Results and Discussion

This section presents experimental results obtained for different broken impact drop weights at different positions A, B and C, in case I when the bumper (specimen) without filling material and case II when the bumper (specimen) with different filling materials. Each test indicated substantial improvements when the specimen (bumper) charged with different filling materials, due to higher impact resistance.

Figures 12 and 13 show comparative results of impact drop weights at different positions for both cases I & II using four different filling materials.

The two Figures indicate clearly the benefit of using filling materials between the bumper and front car body. The increasing in impact resistance referring to the evaluation of impact resistance that bumper without filling materials is as conventionally used. The increase in impact resistance is found to be from 5% (for spongy 30) to 18% (for spongy 70) to 20% for cardboard sheets and to 260% (for one honey comb cell and cardboard sheets).

Figure 14 shows average improvement of impact resistance at the above mentioned cases.

The detailed analysis of the results revealed that the impact resistance of bumper is greatly affected by the type of filling material, especially when using one honey comb cell and cardboard sheets.

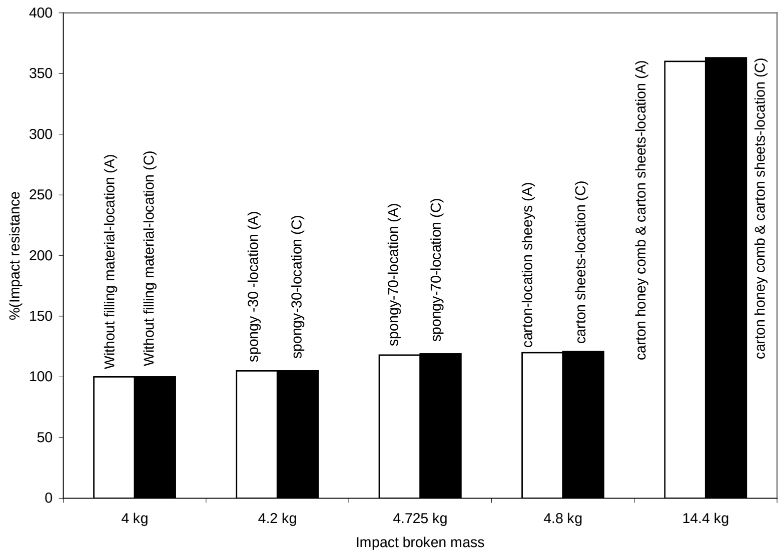


Fig. 12 Impact broken resistance (locations-A & C)

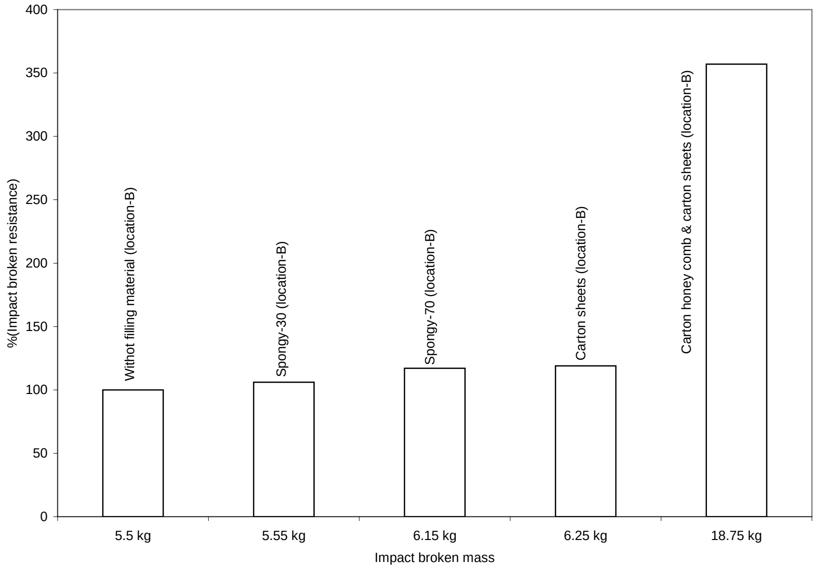


Fig. 13 Impact broken resistance (locations-B)

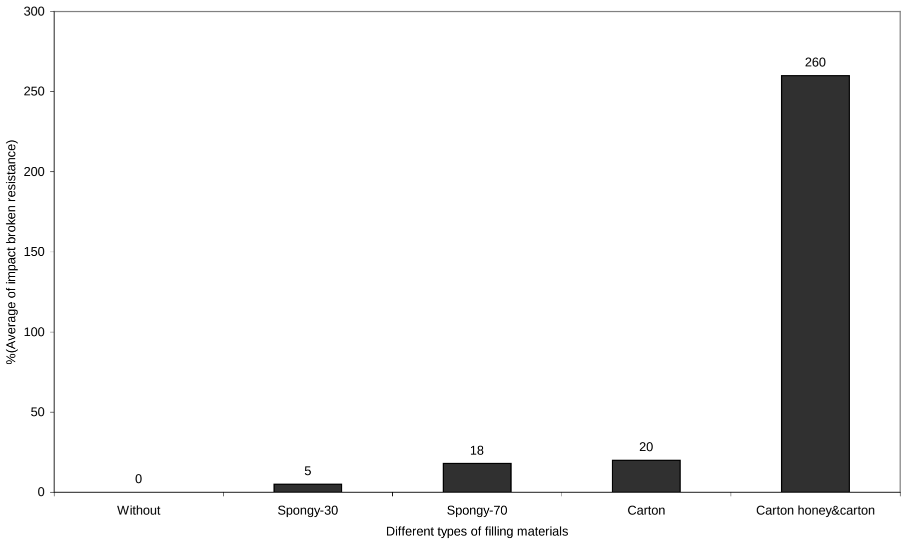


Fig. 14 Average impact broken resistance of bumper

Conclusion

1-The analysis of the laboratory results indicated that the impact resistance of bumper is affected by the types of filling materials.

2-The results showed the improvement about 260% in bumper impact resistance when using one layer of honey comb cardboard cell and cardboard sheets.

3-The filling materials selected to lower weight and cost.

References:

More information regarding bumper test procedure can be found at the NHTSA web site at: http//www.nhtsa.dot.gov/cars/testing/ procedure/TP-581-01.pdf, 2005.

Koji Enomoto, "Synthetic resin bumper assembly", U.S. patent no 4,762,352, 1988

Loren E. Lura, Sandusky, Ohio, "Energy absorbing mounting for vehicle bumper", U.S. patent no 4,178,028, December, 1979.

D. Evans and T. Morgan. "Engineering Thermoplastic Energy Absorbers for Bumpers," SAE paper 1999-01-1011, March, 1999.

D. Evans, S. Shuler, S. Santhanam, "Predicting the Bumper System Response of Engineering Thermoplastic Energy Absorbers with Steel Beam," SAE paper 2002-01-1228, March, 2002.

M.M.Davoodi et al, "Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam", Materials & Design. Volume 31, Issue 10, PP. 4927-4932, December 2010.

M.M.Davood, Sapuan, Aidy Ali, A Khalina "Thermoplastic impact property improvement in hybrid natural fibre epoxy composite bumper beam," Materials Science and Engineering, 11 012013, 2010.

Peter J. Schuster, "Current Trends in Bumper Design for Pedestrian Impact", SAE. Paper No. 2006-01-464. April, 2006.

Hambali1, Sapuan, Ismail, Nukman, "Application of analytical hierarchy process in the design concept selection of automotive composite bumper beam during the conceptual design stage", Scientific Research and Essay Vol. 4 (4), pp. 198-211, April, 2009.