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Research paper

Impact Analysis and Modification of Front Inner Bumper

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Abstract

This paper presents the modification of an existing front inner bumper of a passenger car. The manufactured bumper was captured by using three-dimensional scanner ATOS-GOM in order to obtain the CAD cloud geometrical data. Impact analysis was the conducted by employing dynamic explicit time stepping algorithm software IMPACT. The software was firstly benchmarked with known experimental results of beam under low velocity impact. The simulation and experimental results of the deflected beam were relatively comparable with variation from 1.6 to 9.5%. Two impact simulations were then performed on the real bumper; 40 percent offset collision and full frontal collision. The collisions were tried in different velocity of 48 km/h, 64 km/h and 110 km/h. The results were utilized as the benchmarking platform to enhance the bumper performance. Two alternative design modification were tried. Both design A and B exhibit significant increase of internal energy adsorbed. Even with the increase of energy being adsorbed by both the designs, still design B exhibits superiority in every way possible.

Keywords: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.*

1. Introduction

The research for the deformation of front inner bumper based on a single impact velocity and point of impact was conducted by [1, 2]. However, for this research multiple scenario were included to generate a wider comprehension toward the behavior of front inner bumper during collision. The scenario would adhere to the standards of Federal Motor Vehicle Safety Standards and Regulations [3].
The research will primarily focus on the front section of a normal four wheel sedan, specifically the front inner bumper as most exterior bumper serves no crash-worthiness attribute. Figure 1 shows as an illustration of the front inner bumper. To conduct the simulation, a few parameters are most important including material, thickness, shape and impact condition are studied for design and analysis of an automotive front bumper beam to improve the crash-worthiness design [1]. However, the research will focus on a three stage velocity to simulate impact at low velocity, intermediate velocity and high velocity.

Fig. 1: Front inner bumper

To simplify the model of a front inner bumper, the front inner bumper acts as a energy absorber. These energies or so called crash energies are generated in an event of sudden changes to its initial conditions for example during a collision the relative velocity changes abruptly causing the energies to convert and focus at the point of impact.
To understand the location during the impact where the loading is concentrated, there are numerous tests to determine the impulses and the severity of the crash. The impact tests that covers in this research is frontal offset models and full barrier test of a family sedan. In addition relative low speed of impact is ignored of its inertia [4], whereas different materials reacts different during im pact and may differ greatly from each other depending on the speed of impact and the location of impact [5, 6].
During a transverse impact, the plastic-strain varies depending on the location of impact [7] and the severity of dynamic buckling during loading will increase due to imperfections on the surface of the model [8]. The vehicle occupant survivability during a collision is deter-

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mined by the vehicle's structure ability to absorb the energy generated [9]. By using simulation, the bio mechanics of the human body during crash can be assessed [10]. However, the full extend of possible injuries of occupants would not be sustained should the occupant's head did not travel in acceleration exceeding 57.6 G [11]. The vehicle frame material and geometry shape also influence the amount of kinetic energy absorb during crash [12, 13].

1.1. Frontal offset impact

In the event of a dynamically or statically impact that occurs in a scenario where two vehicles are involved, in general a vehicle with vehicle or another impact scenario where only a vehicle is involved and the vehicle is impacting against a fixed rigid barrier or fixed deformable barrier. Having that in mind, a frontal offset impact caused by a smaller contact area [10], therefore reducing the effective stiffness of the vehicle's front end structure instead of the full effective stiffness during a full frontal impact.

1.2. Full barrier impact

Huang [14] had performed experimental investigation of impact on front bumper. The bumper was impacted to the full barrier as well as offset barrier. Huang [14] recorded full barrier impact and comparing with offset impact. The dynamic crush was displaced up to 812.8 mm, which occurs on the time stamp of 92 ms in full barrier and the total absorbed energy is 100% of the initial kinetic energy. Whereas for the offset test, the corresponding time stamp is 59 ms. The offset vehicle was still moving with a velocity of 23 mph or 37.015 km/h which is the remaining 65% of the initial impact velocity. Therefore, it is assumed that the percentage of initial kinetic energy in crushing during the second part of the offset crush is 203 mm which is 43% (square result of 65%).
This research measured the existing front inner bumper on various impact occurrence then compared with the two modified models to find an alternative design of the bumper with better performance on impact.

2. Methodology

This research conducted two stages. The first was test and validation of the software IMPACT. Once the test and validation showed satisfactory results, comparable with the experimental ones, the simulation of the real bumper model was the conducted. The results of the simulation analysis was set as the initial benchmark to select the alternative design of the inner front bumper. The CAD data of the bumper was obtained from digitizing of the existing one.

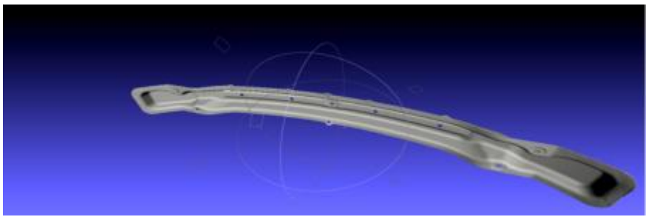
2.1. Computational model of front inner bumper

Three dimensional scanner as shown in Fig. 2a was employed to capture CAD data from the physical bumper of Proton Saga 1.3 model. The scanner camera acquires 3 axis of X,Y,Z coordinates on the surface of a physical object. Each discrete X, Y, Z coordinate is referred to as a point. The conglomeration of all these points is known as a *point cloud*. Typical format's for point cloud data are either an ASCII text file containing the X,Y,Z values for each point or a polygonal mesh representation of the point cloud known as an STL file format.

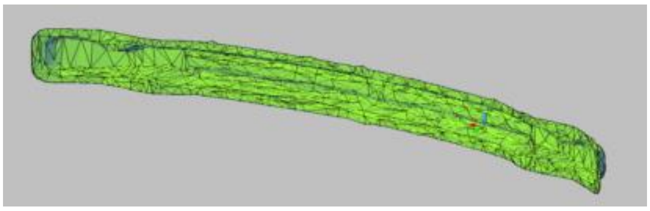
(a) (b) (c)

Fig. 2: (a) Three-Dimensional scanner and projector camera (b) Recoloring and reference nodes (c) Scanning process

The preparation for scanning was initiated by color alteration on the bumper surface. Non-glossy reflective specimen surfaces is one of the working requirements of the three dimensional scanner. As the scan progresses to different points, a series of black ring stickers was used to define a reference node on the working specimen (see Fig. 2b). After scanning process (Fig 2c) was completed, all coordinate data was then saved in .STL file format.
The alignment of CAD data to follow the universal coordinate system to be able to define the center of the model was required. The alignment was conducted in Meshlab finite element pre-processor software. The view of the computational model of the bumpers in Meshlab dan Autocad were shown in Fig. 3a and Fig. 3b, respectively.



(a)



(b)

Fig. 3: (a) Meshlab surface view (b) Autocad element view

2.2. Software test and validation

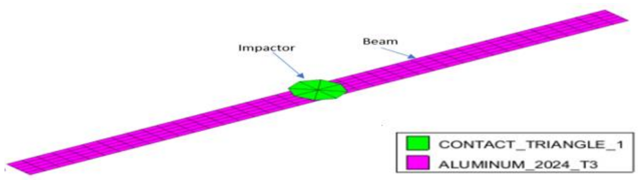
In order to ensure the validity of the numerical results obtain from proposed simulation tests, a reference results taken from Mannan et al. [15] was used as the possible experimental results. The experimental results [15] are shown in Fig.4. According to the provided dimensions and parameters set for the experiment, a simulated transversely impact test was conducted using computational models IMPACT dynamic explicit time stepping algorithm solver. The simulated result was applied and made comparative case study with the reference results to determine the percentage of error between theoretical and actual experimental results.

Fig. 4: Tested Beam of 1.55 mm Thickness Arranged in Increasing Order of Impact Velocity from Bottom to Top (17.4 m/s , 24.0 m/s , 27.8 m/s)

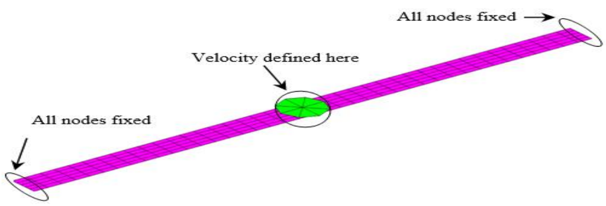
The simulation was conducted following the conditions done in experiment including the material properties, boundary conditions and the measurement parameter.

The dimension of the aluminum beam with the properties specified in [15] was 165 mm length and a width of 8.07 mm. The thickness of the aluminum beam was 1.55 mm. This beam was subjected to impact at the center of the beam with different velocity, 17.4 m/s, 19.0 m/s, 24.0 m/s and 27.8 m/s. These test objects were then identified as C38, C35, C34 and C39 for different velocity 17.4 m/s, 19.0 m/s, 24.0 m/s and 27.8 m/s, respectively.

The setup of the impactor and the boundary conditions are shown in Fig.5. The impactor was modelled as 8 contact elements whereas the beam consisted of 208 quadrilateral shell elements.



(a)



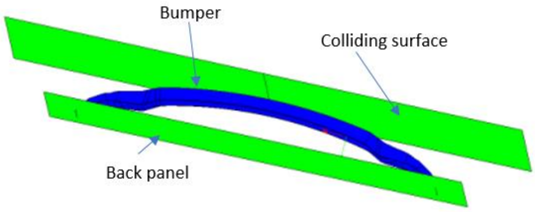
(b)

Fig. 5: (a) Impactor and beam (b) Boundary conditions

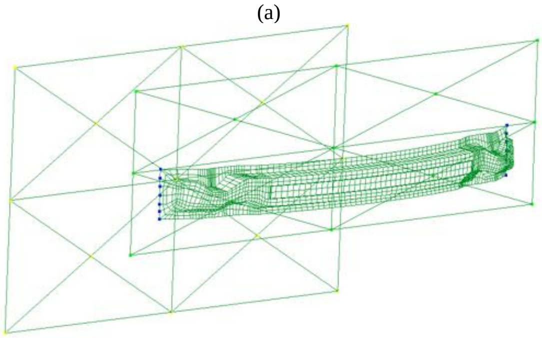
The comparison of experimental and simulation results were compared on the ratio of maximum deflection to the thickness of the beam.

2.3. Modification of bumper

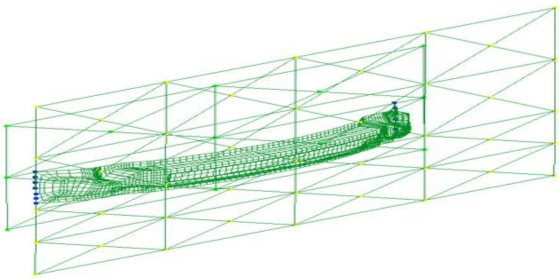
Prior to simulation analysis of the alternative models, the existing bumper model was tested to several impact simulations. The bumper was attached in its back panel while colliding surface was impacted to the bumper. The illustration of the impact collision setup is shown in Fig. 6.



(a)



(b)



(c)

Fig. 6: (a) Impact collision setup (b) 40% collision surface (c) Frontal collision

Test parameters

The standard used in this research is Federal Motor Vehicle Safety Standards or FMVSS under its categorized Standard Number 208 of Occupant Crash Protection. Under the National Highway Traffic Safety Administration (NHTSA) amendment for bumper standards [16]. All of the enlisted tests will be place with a back panel contact surface that act as a rigid non-deformable body.

1. First test, to simulate a 40 percent offset frontal impact between the bumper beam collided by a rigid contact surface traveling at 48 km/h.
2. Second test,to simulate a 40 percent offset frontal impact between the bumper beam collided by a rigid contact surface traveling at 64 km/h.
3. Third test, to simulate a 40 percent offset frontal impact between the bumper beam collided by a rigid contact surface traveling at 110 km/h.
4. Forth test, to simulate the impact between the bumper beam collided by a rigid contact surface traveling at 48 km/h.
5. Fifth test, to simulate the impact between the bumper beam collided by a rigid contact surface traveling at 64 km/h.
6. Sixth test, to simulate the impact between the bumper beam collided by a rigid contact surface traveling at 110 km h.
7. Seventh test, two different alterations made to the original bumper beam is used to simulate a full frontal impact with the assumed back panel between the altered designs collided by a rigid contact surface traveling at 110 km/h.

Point of data retrieval

The locations of the data were retrieved on two nodes as seen in Fig. 7. The benefit of conducting an explicit dynamic solver is that the point of data retrieval can be defined on any point of the specimen, as for the simulation of front inner bumper beam colliding with a full frontal or 40 percent offset collision.

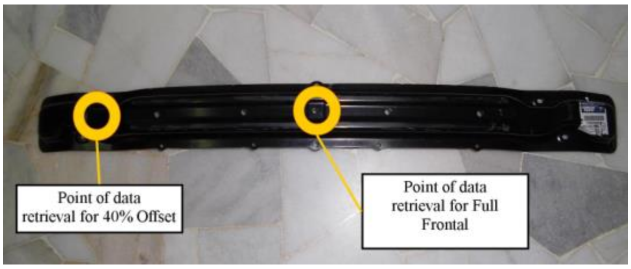


Fig. 7: Location of data collected

3. Results and discussion

3.1. Software validation

For the IMPACT software validation, the deformed aluminum beam at impact velocity of 17.4 m/s, 24.0 m/s and 27.8 m/s can be seen in comparison with the original results on Fig. 8. The ratio maximum deflection is the value of maximum deflection to the thickness of the plate.

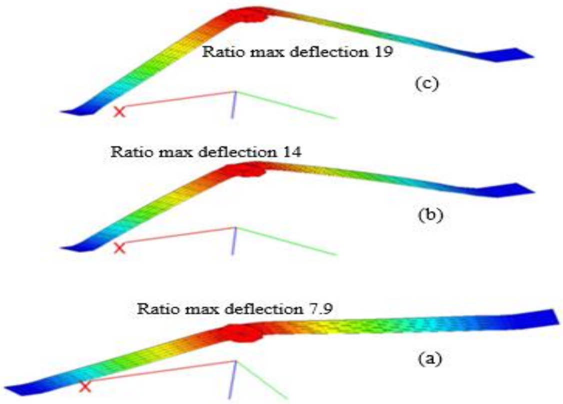


Fig. 8: Impact displacement (a) at 17.4 m/s (b) at 24.0 m/s (c) at 27.8 m/s

Similar to the original physical experiment deformation, plastic hinges formed on both ends of the constraint, transverse deformation is plastic. The offset differences are recorded in Table 1.

Table 1: Comparison between Experimental and Simulation

ID	Ratio of Maximum Deflection		Offset difference (%)
	Experiment	Simulation	
C38	7.7	7.9	2.6
C35	8.4	9.2	9.5
C34	13.6	14.0	2.9
C39	18.7	19.0	1.6

3.2. Front inner bumper simulation results

3.2.1. Forty percent offset collision

Looking at the comparison results shown in Fig.9, it seems that the time taken for the bumper to deform decreased with time for each increment of velocity. For a collision to occur under 48 km/h the time take for full deformation takes about 13.8 ms.The time taken for collision of velocity 64 km/h takes 10.0 ms for the bumper to fully deform while the fastest deformation time is 6.0 ms with a collision velocity of 110 km/h.

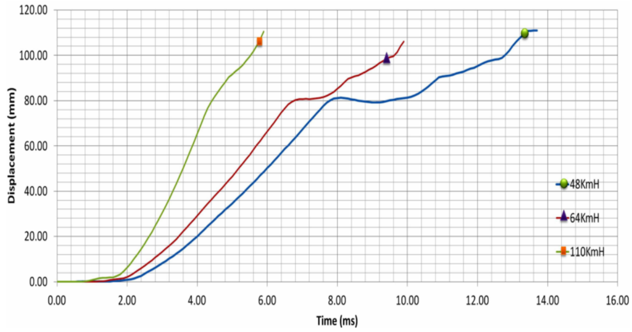


Fig. 9: Displacement Comparison at 40 percent offset

3.2.2. Full frontal collision

With a simple glance, it seems that the deformation curves shown in Fig. 10 are almost linear with increasing gradient for each increment of velocity. Still, the time taken to fully deform the bumper beam lies within the velocity of 48 km/h with a time taken of 13.8 ms whereas the fastest recorded time taken is 6.0 ms for the velocity of 110 km/h.

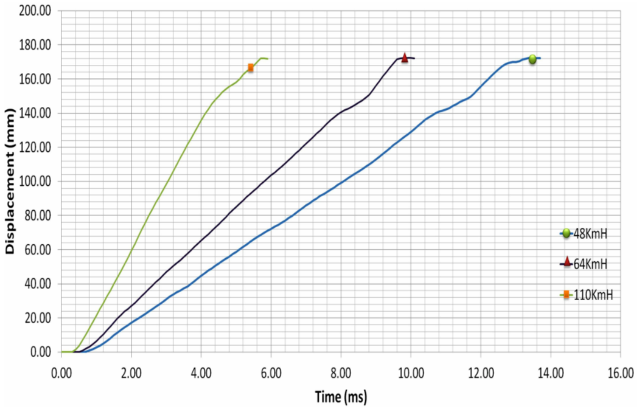
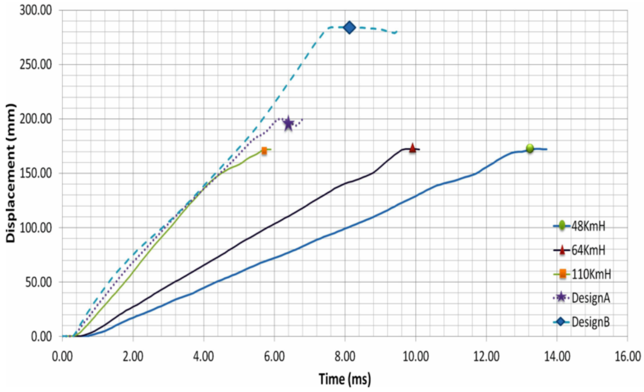


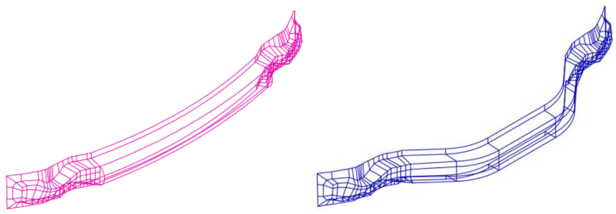
Fig. 10: Displacement Comparison at full frontal collision

3.2.3. Modification design comparison

Two alternative designs were tried. Alternative model A is similar with the original shape. The junction of middle bumper with the restrain section was modified to reduced the concentrated stress for sharp curves. In alternative model B, the middle section of the bumper was translated to the front. This shape added the total length of the car.

The time taken for full deformation increases for bumper design B with elongated width (Fig. 11). However, bumper design A also shows promising results at the time taken for deformation actually increases by a figure of 0.8 ms compared to the original front inner bumper beam. Nonetheless, the deformation time for bumper design B is relatively almost the same with the time taken for full deformation of original front inner bumper beam under a lower velocity of 64 km/h. As a reminder, the bumper design both A and B is collided with a full frontal collision traveling well within the maximum set velocity of 110 km/h.





Alternative Design A Alternative Design B

Fig. 11: Displacement Comparison at full frontal collision with alternative model A and B.

4. Conclusion

This papers presents the IMPACT benchmarking test with experimental results and new alternative design of car inner front bumper considering impact collision.

By considering the time for deform of each simulated scenarios and categories, modifications were made to increase the time of impact. With the increase of impact time from the modified bumper beam design A and B, the time for yield stress was also increased significantly. Model B however shows better performance.

Based on the simulated results, it shows that there are keen aspects of the front inner bumper beam that requires dire reform. Physically, the actual bumper beam possess the possibility to point that it was manufactured by means of a cold pressed method or metal sheet stamped on a die.

Acknowledgement

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