Advanced Finite Element Model for AE-MDB Side Impact Barrier

Authors:

M. Asadi[1], P. Tattersall[1], B. Walker[2], H. Shirvani[3]

1. Cellbond Composites Ltd.
2. ARUP Campus (UK)
3. Anglia Ruskin University (UK)

Correspondence

Mehrdad Asadi
FEA Engineer
Tel +44 1480 435302,
Fax +44 1480 450181
Email m.asadi@cellbond.com

Abstract

This paper represents a new Finite Element simulation model for AE-MDB v3.9 side impact barrier and proposes a method on creating suitable assumptions and material data. Cellbond AE-MDB barrier investigation was carried out to produce an advanced FE model. Experimental Flat Wall and Offset Pole test results were used to validate the accuracy of the developed models. The explicit LS Dyna 3D code was used to model the geometries, and the Material Card data was obtained from several static compressive tests at different angles to characterize the yielding function of the aluminum honeycomb parts. The dynamic models were also validated by a Flat Wall test which represents the crash performance of AE-MDB barrier. For dynamic tests the barrier was mounted on a mobile trolley and it was tested at speed of 35 km/h. In Offset Pole test, the AE-MDB barrier was subjected to an asymmetric crush with a rigid vertical pole in which test speed was 20 km/h. The final comparison of the overall results demonstrates a good correlation between test data and CAE results for both the Flat Wall and Offset Pole tests.

Keywords

Side impact, Crash Barriers, AE-MDB, LsDyna, Finite Elements

1- INTRODUCTION

The development of a new EU side impact barrier was started by EEVC WG13 during 2001 in support of European Governmental contributions to IHRA [1, 2]. The new barrier was named the Advanced European Mobile Deformable Barrier (AE-MDB) to distinguish it from the Regulation 95 MDB. The EEVC WG13 design resulted in a specification of the AE-MDB V2 which initially APROSYS planned to evaluate. Some modifications on part stiffness were carried out later to make the barrier more representatives with respect to proposed applications and demands [3]. The new AE-MDB barrier was named V3.9 (Figure 1) and had reduced stiffness in the lower row resulting in a subsequent reduction globally.

Figure 1. AE-MBD V3.9 parts and a comparison of V2 and V3.9 barrier strength corridors
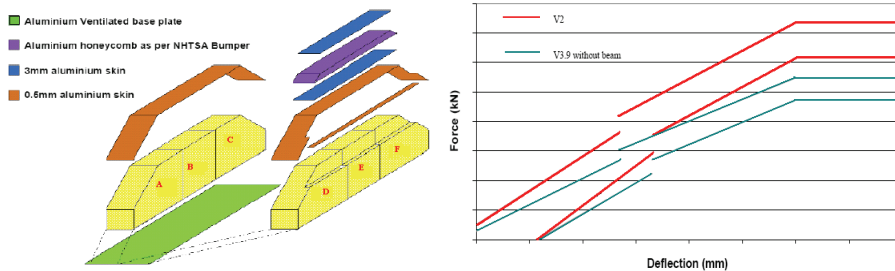
Blocks D & F and E of V3.9 are equal to 55% of the same blocks in the V2 barrier, and block E in the V3.9 barrier equaled 60% of the stiffness of blocks D & F of the V2 barrier. The global barrier stiffness corridors for V2 and V3.9 (without adding a beam element) are shown in Figure 1.

This paper represents a new Finite Element simulation model for the AE-MDB v3.9 side impact barrier and proposes a method on creating suitable assumptions and material data. Cellbond AE-MDB barrier was investigated to produce an advanced FE model while experimental Flat Wall and Offset Pole test results are used to evaluate and validate the accuracy of the developed model.

The AE-MDB barrier is comprised of six individual honeycomb blocks A to F (see figure 2) with cladding skin and rigid honeycomb bumper. This side impact barrier has been developed represent a car to car side collision experiment and represents the bullet car during the test.

Figure 2. Comparison AE MDB/vehicle front and Typical design corridor
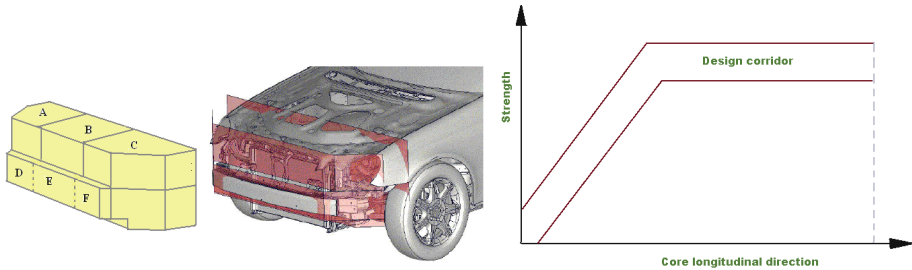
Unlike IIHS barrier, The AE-MDB contains six separate honeycomb blocks (excluding front bumper). Each block has individual stiffness characteristics, all of which increase in stiffness vs. deformation. The barrier is symmetric about an imaginary axis crossing any middle point of the barrier and is perpendicular to the top surface. Each block should meet the strength criteria throughout the whole section (Figure 3). The main blocks are covered with a 0.5mm aluminum skin and the bumper honeycomb piece is significantly stiffer than body parts, is located in front of main cores. The bumper includes two 3mm aluminum plates at both sides and edge angles follow the general shape of main body.

3- FINITE ELEMENT MODEL AND MATERIAL DATA

Despite having some reliable modeling methods to simulate honeycomb crush behaviour [4, 5], it becomes time-consuming to create and solve complex geometries with various boundary conditions. Recruiting the Modified-Honeycomb-Material (Mat 126) card and modeling the honeycomb parts with solid elements creates an efficient way to solve the models. However, accurate material data in different formats are needed. The yielding function technique has given well-mannered results in investigations of ODB [6] and MDB [7] crash barriers. In this method the yield stress of honeycomb is a function of different parameters [8] as described in equation 1.

$$\sigma^y(\varphi, \varepsilon^{vol}) = \sigma^b(\varphi) + (\cos\varphi)^2 \sigma^s(\varepsilon^{vol}) + (\sin\varphi)^2 \sigma^w(\varepsilon^{vol}) \qquad \text{(Eq.1)}$$

in which

φ = Section angle with the strong axis

$\sigma^b(\varphi)$ = Yield stress as a tabulated function of section angle

$\sigma^{s/w}(\varepsilon^{vol})$ = Stiffness as a tabulated function of volumetric strain

A total of 90 static angular compressive tests were carried out to verify the assumptions and establish the material card data. Figure 3, illustrates the test arrangements for different angled section of the honeycomb blocks. The composite material used in the static tests was Cellbond's 1.8 ¾ 3003 aluminum honeycomb and the block dimensions were 200 mm x 180 mm x 50 mm which was tested at speed of 10 mm/min. Plot (1a), shows the typical value of yield stress versus section angle in different etched layers of AE-MDB honeycomb blocks. In all tests the highest compressive stress was measured in zero degree (strong axis) and as the angle increases, the compressive stress decreases. All strengths in different samples drop down to similar magnitude after 60 degrees and the 35 degrees cut section represents almost half of normal core strength.
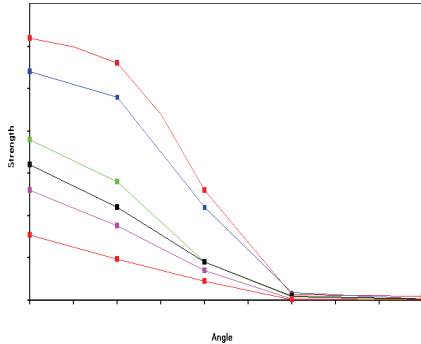
Figure 3. Static angled compressive test procedure
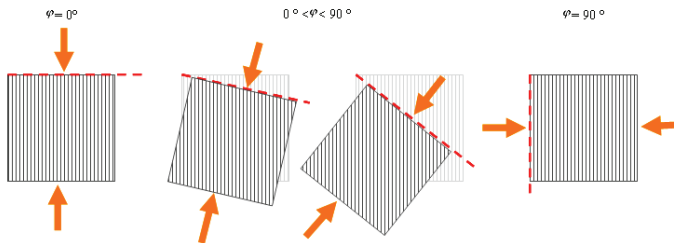
In the FE model, each block (A-F) was split into several segments with reasonable depth along the strong axis and average strength referencing the beginning and end of each segment in honeycomb part. A strain-rate scale factor curve was also defined to convert static test results into suitable data in honeycomb material card during the analysis procedure. The Arup-Adhesive (Mat 169) material card was developed to simulate the connection between parts in which the results from Climbing Drum, T-Peel, Tensile and Plate Shear tests were used to get proper card data. Graph 1b, shows the results from Solid-Solid tensile test schematic results.

Plot 1

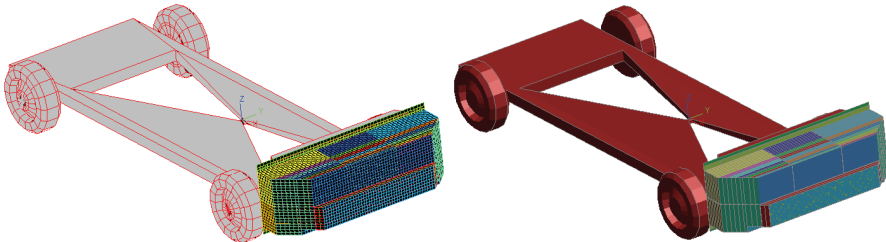a) Compressive stress vs. cut section angle   b) Solid-Solid tensile test results
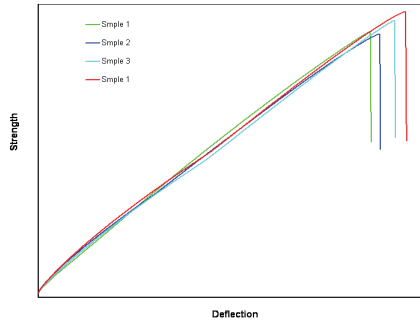
Null material shell elements with reasonable thicknesses were supplied through solid layers in main cores and bumper part to enhance contact control criteria during crash. FE perspective and shaded views of AE-MDB model are shown in figure 4.

Figure 4. AE-MDB FE model

4- EXPERIMENTAL TESTS AND RESULTS

To evaluate and assess the accuracy of the created model, the dynamic analysis was based on two experimental test setups. Flat Wall test represents the crush performance of AE-MDB barrier in a collision with load-cell wall. The barrier was mounted on a moving trolley and tested at 35 Km/h. In the Offset Pole test, AE-MDB barrier was subjected to an asymmetric crush with a rigid vertical pole in which test speed was 20 Km/h. The overall mass of barrier and trolley was 1500 kg in tests and data was read

from both load-cells and accelerometers. Figure 5, gives the offset pole test specification.
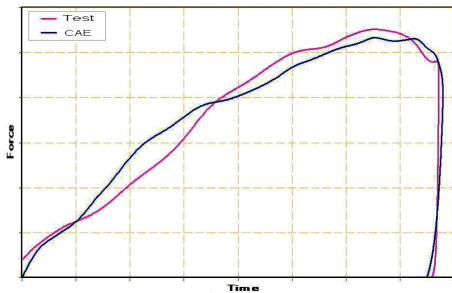
Figure 5. Offset Pole test setup
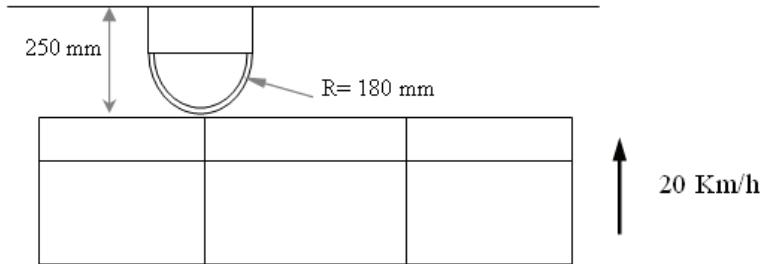
In the Flat Wall (Load Cell) test; results were obtained from separate load cells mounted beyond the rigid wall and assessment was based on integrated magnitude of individual row data. Plot 2(a), illustrates a comparison of experimental test data and FE analysis that is based on Rigid-Wall normal force records, while figure 6, shows deformed barrier after collision.

Plot 2

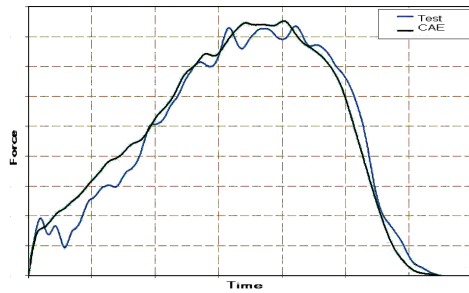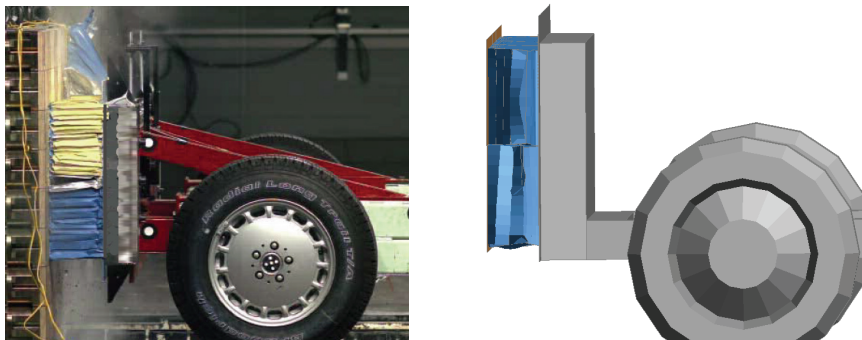a) AE-MDB Flat wall test and CAE   b) AE-MDB Offset Pole test and CAE

Figure 6. AE-MDB Load-Cell test and FE model

In the Offset Pole test, comparison is based on the accelerometer readings. The accelerometer was mounted on the trolley's rigid body to record data within specified time steps. The data from accelerometer at the centre of gravity of test trolley are taken as the evaluation criteria for the FE model. Plot 2(b), shows the comparison of CAE results with those obtained from experiment; while the local motion side acceleration component vector was considered as the assessment tool. Figure 7, represents a general view of crashed barrier.

Figure 7. AE-MDB Offset Pole test and FE model
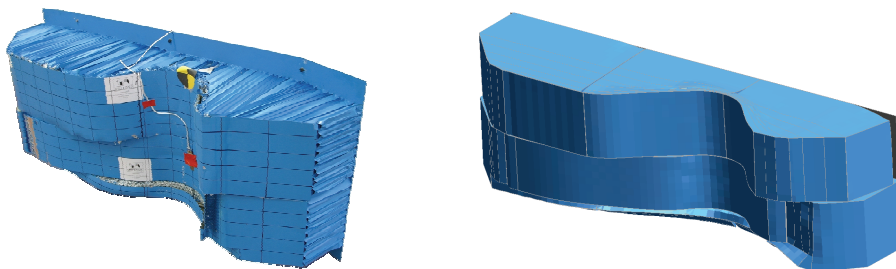
5- DISCUSSION

The results obtained from the FE models not only show appropriate correlation visually; also the numerical output data are within the accepted limits. Plot 2(a) and 2(b) show the front part of the supplied model has slightly lower energy absorption rate than the

actual barrier. However, this is negligible and would fall well within a barrier design corridor. Another important observation in this investigation is that, the collision time and thus the crash distance is the same for FE analysis and experimental tests despite structural complicacy. The proposed model represented an acceptable performance with accurate numerical output and moreover, a reasonable convergence time on the computer. Another notable outcome of the analysis is the existence of the similar deformation pattern and crush mode in both tests. In the Flat Wall test; stroked pattern and trolley travel distance appear the same within the FE model and the backend of all honeycomb cores remain uncrushed as it was noticed in the experimental result. The analysis also produced a satisfactory crash pattern in the Offset Pole test and simulates an acceptable shear performance between bumper, main body and Pole. During the test, some minor separation was seen between the barrier and the ventilation-support frame of the barrier, while this was resulted in a slight detachment between the main core and back plate in the FE model. Using Null elements between solid layers helped to control internal contact and improved the structural behaviour under local shear applications.

6- CONCLUTION

Analysis of the data for new AE-MDB v3.9 shows a good numerical and visual correlation between FE model and experimental investigation for both the Flat Wall and Offset Pole tests. The yielding function technique to define the MAT 126 properties, in association with the multilayer segment configuration encompassing approximate strength on each layer and strain rate gives acceptable results. Also, the stiffening curves contributed a suitable performance and gave satisfactory output compared to the experimental test data. Recruiting Null shell elements with a reasonable thickness within solid layers gave the ability to model the element penetration and thus negative volume errors during shear performances. The developed technique is a superior technique to regular non-linear analysis since the convergence time is reduced a great deal.

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