Institution: Anglia Ruskin University

Unit of Assessment: UoA 15 General Engineering

Title of case study: Novel Offset Deformable Barrier leading to changes in European Standards and improved vehicular safety

1. Summary of the impact (indicative maximum 100 words)

Research into variable mechanical energy absorption, using Finite Element (FE) modelling and analysis, funded by Cellbond Ltd., led to a design specification for an Offset Deformable Barrier (ODB). Such barriers are used within the motor manufacturing industry to test vehicular safety. Based on the findings of our research, the barrier used in car crash tests has been redesigned. The design specification for the barrier has been adopted by the European New Car Assessment Programme (EuroNCAP). All newly designed cars are tested with this type of barrier before they enter production. The use of FE modelling and virtual crash testing allows barriers to be designed with particular properties and for the crash testing cycle to be shortened.

2. Underpinning research (indicative maximum 500 words)

Research using FE modeling of variable energy absorption by honeycomb materials, at Anglia Ruskin University, dates back to 1996. Such research involves modeling of the physico-chemical properties of materials and engineering products for the development and manufacture of composite structures. One application of such structures is testing of impact absorption as applied within the automotive industry. The behaviours of the crash test barriers and prototype cars can be predicted using the FE models and then tested experimentally for verification of the results. The designs of the barriers are then refined prior to entering production. In this case study, FE analysis has been applied to the design of an ODB [1] used in frontal and offset impact tests according to the specifications developed for the Federal Motor Vehicle Safety Standards (FMVSS), EuroNCAP, Australian New Car Assessment Programme (Australian NCAP), Japanese New Car Assessment Programme (JNCAP) and the Insurance Institute for Highway Safety (IIHS). Our research specifically provides the methodology to create the advanced dynamic FE model of the ODB and support its subsequent certification. The research uses LS-DYNA as the analysis tool to create the model. Static compressive tests, at different angles of impact, provide the necessary information to construct the aluminium honeycomb material cards within the barrier. The research also models the dynamic stiffening of the honeycomb during the simulation by generation of strain-rate scale factor curves. Adhesive properties are obtained using Climbing Drum, T-Peel, Tensile and Plate Shear test results. In all assessments, the barriers are mounted on a rigid wall and tested at certain impactor speeds [2-4].

Additionally, to construct realistic FE models in this research, specially adapted material cards, allowing shear forces to be considered in the models and measured in the real tests, were incorporated into the barrier along with solid elements. This allowed the simulation and testing of a compartmentalized vehicular front section. This was the first time that such compartmentalized simulation and testing was possible. This facilitated the design and manufacture of a crash test barrier with specific properties to enable, for the first time, simulation of vehicles of different types. Ultimately the design based upon FE models and experimental data has been adopted by EuroNCAP and most motor manufacturers. EuroNCAP is the recognized institution for defining and rating car safety standards, which are recognised benchmarks for all car safety tests. The crash test barrier manufactured by Cellbond is now sold globally and used by most motor manufacturers.

The work, involving identifying the material from which the ODB must be manufactured, its crush strength, foil thickness and honeycomb cell size, began in 1996, led by Professor Hassan Shirvani (Anglia Ruskin University), along with collaborators at Cellbond through a Teaching Company Scheme Programme. This was followed up in 1998 through a KTP programme (Academic – Shirvani, KTP Associate – Paul Owen). The work led to the successful submission of a patent in 2002, which was granted in 2005 and which was subsequently purchased by Cellbond in 2006. In

2006, a Cellbond-funded PhD studentship was awarded to Asadi, which was completed in 2011 and through which the design of the barrier was completed.

The barriers were modelled at Anglia Ruskin University and Cellbond in collaboration with ARUP [4-7] and Jaguar-Landrover.

Key researchers were Professor Hassan Shirvani (research group leader and Senior Lecturer September 1996 – February 2001; Professor March 2001 to date), Dr. Ayoub Shirvani (Researcher October 2001 – July, 2008; Senior lecturer August 2008 to date) and Dr. Habtom Mebrahtu (Senior Lecturer September 2000 – February 2010; Principal Lecturer February 2010 to date).

3. **References to the research** (indicative maximum of six references)

1. http://www.cellbond.com/Products/Barriers/barriers.aspx

2. M. Asadi, B. Walker (2011) "Application of Shell Elements to Create Advanced Finite Element Model for Offset Deformable Barrier", Int. J. Vehicle Structures & Systems, 3, 139 - 143. Available in REF2.

3. M. Asadi, I. Bruce, H. Shirvani (2009) "An Investigation to Compare the Application of Shell and Solid Element Honeycomb Model in ODB", 7th European LS-DYNA Conference. Available on demand from the HEI.

4. M. Asadi, B. Walker, H. Shirvani (2008) "Development of the Advanced Finite Element Model for ODB Impact Barrier", Japan LS-DYNA User Conference. Available on demand from the HEI.

5. Sh. S. Esfahlani, H. Shirvani, A. Shirvani, S. Nwaubani, H. Mebrahtu and C. Chirwa (2013) “Hexagonal honeycomb cell optimization by way of meta-model techniques” Int. J. of Crashworthiness, 18, 264 - 275. Available in REF2.

6. Sh. S. Esfahlania, H. Shirvani, A. Shirvani, H. Mebrahtu, S. Nwaubani (2013) “Design, development and numerical analysis of honeycomb core with variable crushing strength” American J. of Engineering and Applied Sciences, 6, 8 - 19. Available in REF2.

7. Sh. S. Esfahlania; H. Shirvani, A. Shirvani, S. Nwaubani, H. Mebrahtu (2013) “Comparative study of Honeycomb optimization using Kriging and Radial Basis Function” J. of Theoretical and Applied Maths Lett. 3. Available via DOI: 10.1063/2.1303102

4. Details of the impact (indicative maximum 750 words)

Road safety is now more important to policymakers and the public than ever before. In 2004, road accident deaths stood at 43,500 in the European Union (source: CARE database) and around 42,600 in the US (source: FARS database), with hundreds of thousands more road users suffering serious injuries. The crashworthiness of a vehicle is regulated by legislation such as ECE R94, R95, FMVSS 201, 208 and 214 for occupant protection. Vehicle safety ratings and new car assessment programmes have also increased public awareness of these design criteria. Through such programmes the public are informed about the occupant safety of new car designs. Manufacturers are also placed under increasing pressure to increase occupant safety. Such features are widely used as a marketing tool.

The test protocols designed by EuroNCAP of (i) offset frontal impact and (ii) side impact are designed to represent the most severe test that a car can undergo in terms of passenger protection. It is therefore essential that the tests are fit for purpose.

Before the design of the ODB, the crash test was carried out using two car bodies (shells).

However, the criticism of this type of test is that crashes between two identical cars are very rare. Additionally, the shells were not manufactured from materials with variable energy-absorbing properties representing the different compartments on the front of a car. This means that the car fronts were not truly represented. What was required was a crash test barrier that could represent a generalised car structure into which different car makes could be crashed, thus mimicking with greater accuracy "real life". Additionally, different parts of the crash test barrier would have to be designed to absorb different amounts of energy mimicking the compartmentalised structure (e.g. chassis, bonnet, wing, bumper) of the front of a motor vehicle.

The research work on the design and modelling, initiated at Anglia Ruskin, and implemented at Cellbond, allowed for the first time a crash test barrier that more closely mimics the front of a generalised motor vehicle. The properties of the barrier can be modelled and its crash test behaviour predicted allowing the honeycomb to be "tuned" to behave like the front of a car of a desired type. Additionally the modelling allows new data to be collected. In the old test only the impact perpendicular to the front of the car was considered. With the availability of the finite element modelling and the honeycomb structure, the shear forces involved (non perpendicular to the car front) can also be considered for the first time. This allows greater understanding of the behaviour of the front of the car being tested in the crash situation.

The barriers were tested and adopted by Cellbond-MIRA (Motor Industry Research Association), the Transport Research Laboratory and EuroNCAP. Following on from this, they were trialled and approved by the National Highway Traffic Safety Administration. As a consequence of this and the requirement for crash tests to be employed for all new models of motor vehicle, these new barriers have been adopted widely across the motor vehicle manufacturing industry. Cellbond supplies these barriers. The global market for these barriers represents a significant increase in commercial income and opportunity for the company.

The significance of the impact resulting from this research is therefore several fold:-

(i) For the first time the ODB can be tuned to represent the front of a car of a specific type;
(ii) The shear forces involved in a crash situation in terms of car and barrier behaviour can be understood for the first time;
(iii) This is the first time that a heterogeneous crash situation can be modelled and tested increasing the range of crashes that can be simulated and understood;
(iv) Safer and more robust cars can be designed and manufactured increasing vehicular occupant safety.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Director of Group Operations, ENCON CAM / Cellbond.

2. 17th ESV Conference 2001, EURONCAP - Views and Suggestions for Improvements http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/esv/esv17/proceed/00087.pdf

This document discusses the crash test, the technical specifications for the barrier and states that the Cellbond barriers are used for the test.

3. http://www.euroncap.com/tests/frontimpact.aspx

This document explains the Euro NCAP test method for assessing frontal impact, including reference to and description of the ODB.