Smarter, safer, cleaner vehicle technology to benefit Australia

By Dr Matthew Cuthbertson Chief Executive Officer, AutoCRC

Welcome to the first dedicated AutoCRC section in Autoengineer. We are pleased to announce that AutoCRC will be a regular contributor to this excellent publication and we look forward to sharing the outcomes of our research activities with you.

The Cooperative Research Centre for Advanced Automotive Technology (AutoCRC) was created in December 2005 as part of a national strategy to secure Australia's position in the global automotive industry.

Since then, AutoCRC has delivered outcomes that directly enhance the viability and sustainability of the Australian automotive industry, its capability to export, and its productivity.

Over the last 5 years AutoCRC has used much of its $100 million research funding to provide the automotive industry opportunities to work with research providers in design, engineering and manufacturing to enhance Australia's global competitiveness, particularly in the following areas:

- Reduced concept-to-product cycle times.
- Improved manufacturing flexibility and efficiency.
- New material systems to meet the challenges of weight reduction, increased safety and enhanced functionality.
- Improved air quality and reduced consumption of fossil fuels.
- Safer, crashworthy vehicles and intelligent products and systems for increased comfort and performance with minimum driver distraction.

Project briefs and the contact details for our research project leaders can be found on our website > www.autocrc.com.

Strategic alliances

AutoCRC has also played a significant part in strategic research to enhance the global performance of the Australian Automotive sector:

Automotive Supplier Excellence Australia (ASEA) is a national program to assist the Australian automotive supply base to achieve world class levels of competitiveness and sustainability. It is supported by three local vehicle manufacturers, the South Australian and Victorian Governments and the Federation of Automotive Products Manufacturers. ASEA is currently funded through the Federal Government's New Car Plan for a Greener Future.

In the last year, we also developed the Automotive Australia 2020 Technology Roadmap. The Roadmap required the collaboration of over 160 Australian automotive industry stakeholders and positions Australia to implement a research and development plan that will ensure our industry maintains its global relevance in the coming years.

Senior industry executives were engaged in the development of the Automotive Australia 2020 Technology Roadmap facilitated by the AutoCRC.

AutoCRC has a strong education focus with over seventy postgraduate students conducting research into intelligent transport systems, lightweight materials, sensor processing technology, process and product optimisation and human factors. A summary of all postgraduate research can be found on our website > www.autocrc.com.

For information about how your organisation could benefit from collaborating with the AutoCRC, please contact Research Manager and Project Review Committee Chair Dr Gary White > E. gary.white@autocrc.com.

AutoCRC Student Research Award 2010

The annual AutoCRC Student Research Award was announced recently with the $1500 first prize presented to Paul Gangemi for his research into Fuel Composition Sensing. His entry was selected from six finalists who presented their research to an audience of academic and automotive industry participants.

The research pursued by Paul Gangemi looked at the design of control systems to cope with gaseous fuels that have varying stoichiometric ratios. His literature review showed that the stoichiometric ratio for Compressed Natural Gas globally varies quite considerably, and that Liquid Petroleum Gas's stoichiometric ratio is fairly consistent globally.

At the 2010 AutoCRC Student Research Award presentation Paul Gangemi (left) received the prize from AutoCRC Research Manager Dr Gary White.

He found that the stoichiometric ratio for CNG is directly related to its methane content, which led him to investigate of the use of a methane sensor and back-up oxygen sensor in the control and feedback of electronic fuel injectors.

China Australian Alliance for New Energy Vehicle Innovation

The AutoCRC has signed a Memorandum of Understanding with the China Australian Alliance for New Energy Vehicle Innovation). This Alliance is addressing the future challenges of road transport, including resource utilisation, energy efficiency and the reduction of both economic and environmental costs.

The Alliance provides a framework for joint projects between Australian and Chinese researchers and their industry partners allowing for shared intellectual property and creating commercial opportunities.

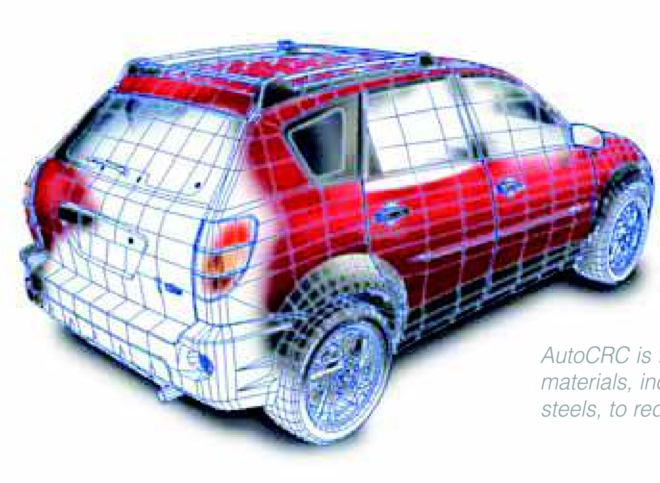
Lightweight Vehicle Research

Following several years' support for doctoral student research in lightweight components of vehicles AutoCRC has now developed a significant amount of understanding of the properties of metals foams, composites and high strength steels, including crash performance, fatigue behaviour, modelling techniques and tooling issues.

We have moved to create even more understanding of the potential for light weighting Australian vehicles through the Lightweight Modular Vehicle research project involving Swinburne University of Technology, Australian National University, RMIT University, Deakin University and VPAC.

Together these researchers are looking at novel techniques for joining new materials and vehicle design strategies for increased light material usage. It is planned to report some of this pioneering work in future issues of Autoengineer.

Other research themes supported by the AutoCRC include sustainable manufacturing, power trains, fuels, emissions, safety, intelligent vehicle systems and virtual design and manufacturing.



AutoCRC is facilitating research on the application of a range of materials, including metals foams, composites and high strength steels, to reduce weight in vehicles.

Possible use of metallic foam-filled structures for side intrusion beams

By Shigeaki Kinoshita E: shigeakikinoshita@swin.edu.au
Supervisors: Dr Dong Ruan and Prof John Beynon of Swinburne University of Technology, Australia, and Prof Guoxing Lu of Nanyang Technological University, Singapore

Increased occupant safety, fuel efficiency and greater power are a few of the demands that consumers expect of the automobile industry. Increased occupant safety and efficiency are also demanded by federal and government bodies. A recent example is the update to the dynamic portion of the Side Impact Protection (FMV214) by NHTSA in USA [1, 2]. The automobile industry has always met and continues to meet these demands, in addition to its own in-house standards.

At Swinburne University of Technology we are studying the energy absorption of "structural composites", which are structures composed of various discrete sub-structures. Some of the structures being studied are metal frames filled with metallic or polymer foams. Carbon fibre reinforced polymer structures used in conjunction with foam fillers are also being analysed.

The work presented here involved the study of aluminium foam-filled tubular structures under three-point bending tests. Alloy AA 6060 T5 was used for the tube. Although this tube type is not used in the automobile industry, the aim was to look generically at the effect of the foam filling on the overall energy and deformation profile of tubular structures.

Commercially available Alporas® closed-cell aluminium alloy foam was used for the filling. Alporas® is the trade name for the foam manufactured under licence from the Shinko Wire Company [3]. It is manufactured by introducing the blowing agent titanium hydroxide TiH2 into the molten aluminium melt [4]. The blowing agent separates into titanium and hydrogen gas, the latter forming the cavities. The foam used was purchased from Gleich Aluminium, Germany [5].

Previous work

Metallic foam is an excellent candidate for energy absorption due to its ability to absorb energy over a wide range of compressive strain. The idea is to use this behaviour of the foam to enhance the energy absorption of a structure as it deforms in a crash. Metallic foams, such as Alporas®, are also known to be sensitive to strain rate [6]. With increasing compaction speed, the compaction stress, or force, is known to increase.

Much work has been undertaken with aluminium foam-filled structures under axial crushing [7-9], targeting the use of such structures as energy absorbers in frontal impact [10, 11]. Work on foam-filled structures under bending has also been carried out, but with the majority of the work on rectangular hollow sections filled with foam [12]. Most of these studies focused on the mass specific energy absorption (SEA), the energy absorbed per unit mass of the specimen.

There is general consensus that the use of metallic foam fillings yields greater force, and hence more energy, to deform the specimen in comparison to the unfilled structure. However, as the mass of the filling is changed through its density or the amount of tube filled, the SEA of the system changes. There is an optimum density and quantity of foam before the gain in energy absorption becomes negated by the weight introduced by the foam. However, SEA does not necessarily give the overall picture on the benefit gained.

Swinburne work

Work at Swinburne has shown that with partial filling with the Aploras® foam, the structure was able to absorb greater energy in relation to the displacement of the structure. Furthermore, it was found that the strain-rate behaviour of the foam has a beneficial effect on increasing the energy absorption of the overall structure with increasing indentation speed.

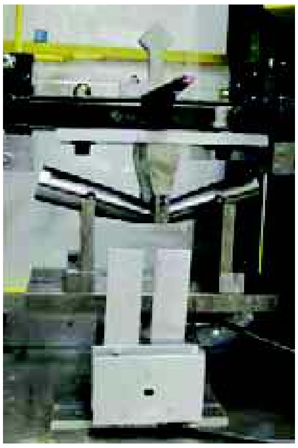


Figure 1 > The thee-point bending rig using the drop weight test system.

Both experimental and corresponding numerical simulations were completed. Quasi-static tests were conducted using an MTS universal testing machine, while dynamic tests were done using a drop weight test system. The set-up for the latter is shown in *Figure.1*.

Corresponding finite element (FE) models were produced and analysed using the explicit FE analysis software package LS-DYNA. Verification of the model was carried out for both the quasi-static [13] and dynamic loading. The FE models were then used to obtain greater insight into the deformation and energy absorption capabilities of the tubes.

A visual comparison of the bent foam-filled specimen and corresponding FE simulation is shown in *Figure 2.*

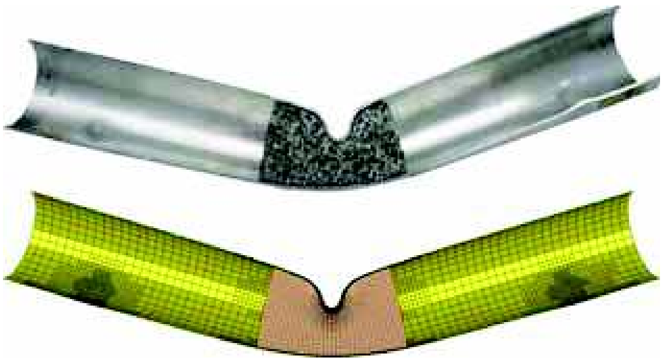


Figure 2 > Foam-filled test specimen after dynamic testing (top) and corresponding FE simulation model.

A typical comparison of the force-indenter displacement curve obtained from the experiment and FE simulation is presented in Figure 3. There is a visible difference between the experimental and simulation results for the foam-filled tubes. This is due to the difficulty in modelling the inherent variation in the foam itself, which can be seen to be coarse in its cavity structure as shown in *Figure 2*.

Findings

It was observed that with foam filling, the travel of the lowest surface of the tube was more than that of the unfilled tube. This is expected with the foam acting as a medium transferring the deformation of the top to the lower surface of the tube. However, the amount of energy absorbed by the foam-filled structure is greater than that absorbed by unfilled tubes.

In terms of a side impact bar, this means that a foam insert results in more energy absorbed for less intrusion into the passenger space. These findings were confirmed with the validated FE models. Results also showed that with greater impact speed, the strain-rate of the foam played a significant role in increasing the energy absorption of the overall structure.

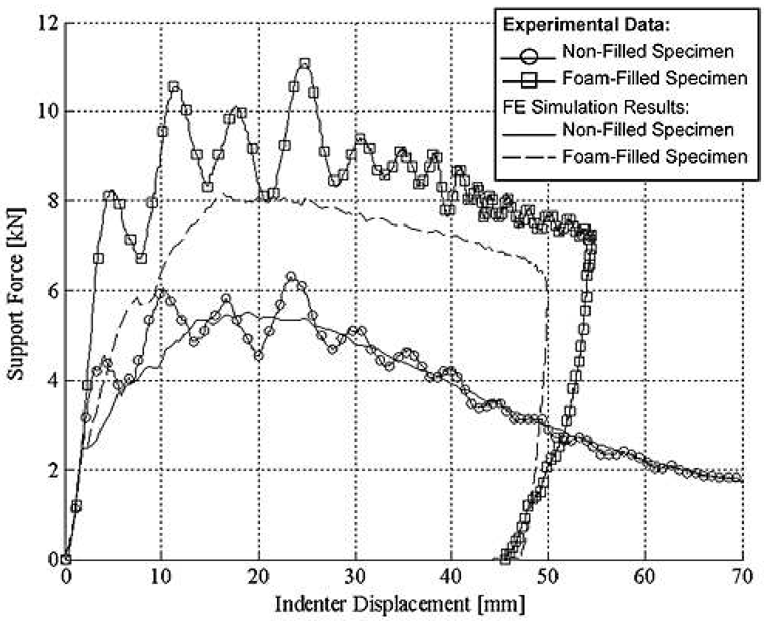


Figure 3 > Typical "force-indenter displacement" curves from experimental and FE simulation.

Acknowledgements

The author would like to acknowledge the support of the Commonwealth of Australia through the AutoCRC and Swinburne University of Technology. Acknowledgment of the collaboration in the experimental work for dynamic tests is given to Gayan Rathanwera.

References

[1] D. Winkelbauer, P. Miller II, H. Kaleto, J. Gall, S. Naik, D. Gotwals, and N. Brzuch, "FMVSS 214 Dynamic NPRM-An Overview of the New Procedure, Component-Level Development Tests, and Vehicle Design Changes," 2005.

[2] Y. W. Kim, B. R. Ham, I. H. Choi, and H. I. Bae. 18th November 2010). Study on improving occupant injury performance for FMVSS 214. Available: http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0100.pdf

[3] T. Miyoshi, M. Itoh, S. Akiyama, and A. Kitahara, "ALPORAS Aluminum Foam: Production Process, Properties, and Applications," Advanced Engineering Materials, vol. 2, pp. 179-183, 2000.

[4] J. Banhart, "Manufacture, characterisation and application of cellular metals and metal foams," Progress in Materials Science, vol. 46, pp. 559-632, 2001.

[5] GLEICH Aluminiumwerk GmbH & Co. KG. (2010, September 2010). Available: http://www.gleich.de/en/

[6] A. Paul and U. Ramamurty, "Strain rate sensitivity of a closed-cell aluminum foam," Materials Science and Engineering A, vol. 281, pp. 1-7, 2000.

[7] A. G. Hanssen, M. Langseth and O. S. Hopperstad, "Static and dynamic crushing of square aluminium extrusions with aluminium foam filler," International Journal of Impact Engineering, vol. 24, pp. 347-383, 2000.

[8] T. Y. Reddy and R. J. Wall, "Axial compression of foam-filled thin-walled circular tubes," International Journal of Impact Engineering, vol. 7, pp. 151-166, 1988.

[9] S. A. Meguid, M. S. Attia and A. Monfort, "On the crush behaviour of ultralight foam-filled structures," Materials & Design, vol. 25, pp. 183-189, 2004.

[10] H. R. Zarei and M. Kröger, "Crashworthiness optimization of empty and filled aluminum crash boxes," International Journal of Crashworthiness, vol. 12, pp. 255 - 264, 2007.

[11] A. G. Hanssen, A. Reyes, O. S. Hopperstad, and M. Langseth, "Design and finite element simulations of aluminium foam-filled thin-walled tubes," International Journal of Vehicle Design, vol. 37, pp. 126-155, 2005.

[12] H. R. Zarei and M. Kröger, "Bending behavior of empty and foam-filled beams: Structural optimization," International Journal of Impact Engineering, vol. 35, pp. 521-529, 2008.

[13] S. Kinoshita, G. Lu, D. Ruan, and J. Beynon, "Experimental and FE analysis of quasi-static bending of foam-filled structures," SAE International Journal of Materials & Manufacturing, vol. 3, pp. 44-54, 2010.