Assessing and improving the crashworthiness of composite transportation structures: challenges and opportunities

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The latest generation of 'all-composite' wide-body passenger aircraft has brought to the fore the need to ensure a level of crashworthiness commensurate with that of similarly-sized metallic aircraft. Even though there are no aircraft-level survivable crash conditions specified in airworthiness regulations, experience has shown that there is a high probability of occupant survivability within certain impact parameters for metallic aircraft and that a similar level of safety should be expected of composite aerostructures. As the automotive industry transitions to the use of lightweight composite materials in mass-produced vehicles, to meet increasingly strict emission guidelines, the issue of crashworthiness is arguably of even greater importance. To date, even high-end road vehicles with carbon-fibre composite passenger cells resort to metallic elements for their primary energy absorbing capability. The railway industry, while recognising the considerable potential advantages of adopting composite materials in load bearing passenger rail cabin sub-structures, is prevented from doing so by current European legislation, citing a lack of suitable certification procedures.

It is often claimed that carbon-fibre composites have higher specific energy absorption than steel and aluminium but this is not an intrinsic material property. Composites will deliver superior energy absorption provided that structural elements are designed to fail in a manner which maximises energy dissipation. Add to this the currently incurred high development costs and relatively slow production rates, associated with composite structures in general, and it becomes apparent that there is an urgent need to address these shortcomings if the level of utilisation is to continue on an upward trajectory. The extent of physical testing currently required in development programmes, to meet certification or statutory requirements, is seen as a primary factor hindering their wider utilisation.

The increased use of simulation at all stages of the development cycle provides an opportunity to meet these shortcomings. The aerospace and automotive industries have been at the forefront of incorporating computational tools in development programmes but the emergence of load bearing (primary) composite structures has brought with it new challenges in ensuring the reliability of such tools. The prediction of composite crushing for crashworthiness assessments is seen as particularly challenging but an indispensable requirement if highly crashworthy structures are to be developed without the need for extensive testing.

This presentation reports on the development of a finite-element-based composite damage model, for crashworthiness assessments, which mitigates the need for model calibration to match physical testing. A number of validation cases, based on experimental results reported in the literature and an in-house experimental test programme, confirm the model's predictive capabilities. This will be followed by a brief overview of a new Horizon 2020 European project, 'ICONIC – Improving the Crashworthiness of Composite Transportation Structures' under the coordination of the presenter. ICONIC brings together a consortium of nine partners, across six European countries, to explore new and innovative strategies for enhancing the energy absorption of composite materials and structures; develop improved experimental techniques to enable the reliable characterisation of novel materials, improve on the state-of-the-art in the virtual testing of composite structures under crushing loads; assess the role of fasteners in energy absorption; and develop new optimisation tools for the effective design of crashworthy structures.

KEYNOTE SPEAKER

Prof Brian G. Falzon

Professor Falzon graduated from the University of Sydney with a BSc in Physics and Pure Mathematics, a first-class honours degree in Aeronautical Engineering and a PhD in Advanced Composite Aerostructures. He joined Imperial College London as a postdoctoral research fellow in 1996, was appointed to a Lectureship in 2000, a Senior Lectureship in 2005 and Reader in 2007. In 2008, Prof Falzon took up the Inaugural Chair of Aerospace Engineering at Monash University where he was the Head of the Aerospace Engineering Programme, Director of Research and Deputy Head of the Department of Mechanical and Aerospace Engineering. In 2013 he joined Queen's University Belfast as the Royal Academy of Engineering – Bombardier Chair in Aerospace Composites, where he is also the Director of the Advanced Composites Research Group. In 2015 he assumed the role of Head of the School of Mechanical and Aerospace Engineering. Prof Falzon is a Chartered Engineer and Fellow of the Royal Aeronautical Society. He is internationally renowned for his work on advanced composite structures and in 2008 was awarded the George Taylor Prize, by the RAeS, for the best paper published on aircraft structures. In 2009 he was honoured with an Australian Leadership Award in recognition of his contribution to issues of national importance and demonstrated leadership in his field. Prof Falzon is Associate Editor of The Aeronautical Journal and on the editorial boards of Applied Composite Materials and Advances in Aircraft and Spacecraft Science, An International Journal.