The increasing number and capacity of transportation systems means an inevitable rise in the number of harmful accidents unless there are substantial advances in structural and materials design. Innovative approaches to design are being utilised, but need to be validated in order to demonstrate reliability. The **ADVISE** project developed and validated materials simulations through experiments using advanced optical techniques

Know the risks

The recently completed three-year project Advanced Dynamic Validations using Integrated Simulation and Experimentation (ADVISE) was a research project operating within the European Commission 7th Framework Programme (FP7), a part of the European Union's Lisbon Strategy to become the "most dynamic competitive knowledge-based economy in the world." The Seventh Framework Programme groups all EU research initiatives together in thematic categories. ADVISE comes under the theme of Transport and is geared toward technological and operational advances within European Sustainable Surface Transport policy.

It is important that any manufacturing material be understood in terms of how it will cope with the stresses expected to be placed upon it. This becomes even more crucial if these materials are used in the automotive and aerospace industries. Testing to destruction and then simulating the forces at work leads to understanding and reference points, which then feed back into design and simulation, and so the world becomes a safer place. At pre-normative stages of testing it is not possible to design simulations without also measuring against real experiments in order to see if what you calculate is also what you get. Typically, defined stresses are placed on closely observed materials and the resulting data is used to validate associated simulations. In ADVISE the experimental arm of the project used a drop-weight impact tower and a high-speed impact experiment in which a bullet was fired at a car bonnet to see how it deflects, reacts or cracks under the increasing energies being used. Measurements were taken using newly developed, full-field optical techniques based on high speed cameras running at 5000 fps.

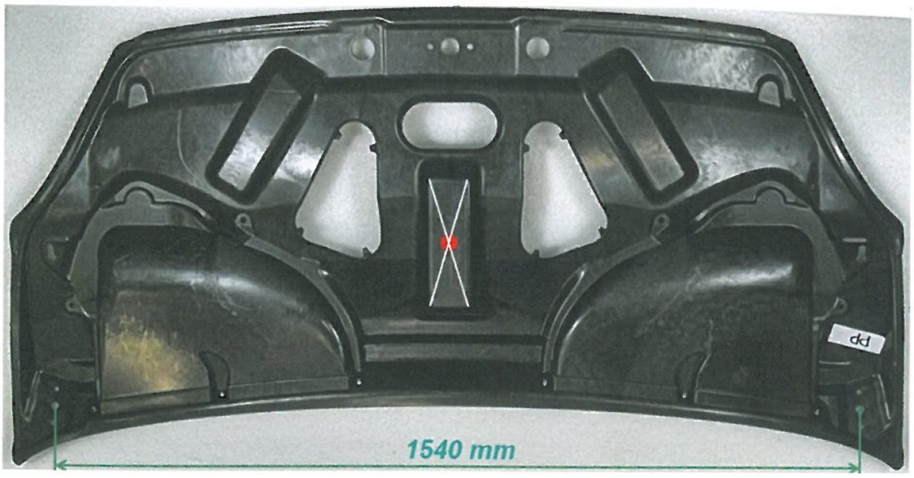
Previous calibrations and testing had been carried out on static, simple events and homogeneous materials, but ADVISE gathered data on cyclic, transient and non-linear dynamic events on widely used fibre polymer composites. ADVISE differed from its predecessor SPOTS in that it focussed on simulating and testing these dynamic, rather than static events.

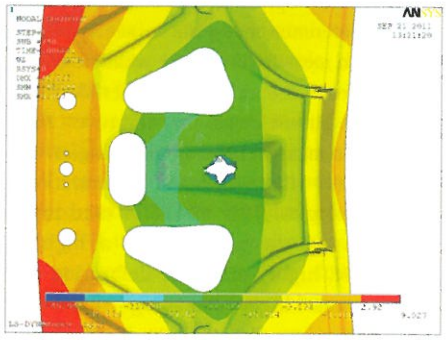
Dynamic events in this instance were defined as: a vibration with small amplitudes, deformations or deflections with large amplitudes, and non linear events in which the force that you apply and the deformation you generate are not directly proportional to each other. This of course is not necessarily a destructive event but one that allows you to calibrate the instrument you would use to measure an impact event, so that in the end you can have a calibrated instrument to do the real test.

ADVISE, explains the project's chief scientist, Erwin Hack, had three strands of activity. "One was the design of reference materials for the experimental test to answer the question: how can we provide something that's dynamic and we know exactly what's going on in terms of deformation or deflection? Then we can test all these optics based methods against these reference materials to see if what they can measure is exactly what we offer them from the reference material. The second strand was to improve the dynamic measurement methodologies as well as the dynamic simulation methodologies. This meant to take into account all the processes of a highly dynamic, highly plastic or deforming or even cracking, damaging event in a simulation tool. The third was to develop methods to compare the two results: how can I do that in a quantifiable manner? So, not just say you get what you expect, but say to which extent in a quantitative manner do the experiments and the simulations agree or disagree, and what could be the reason for that."

> *" The challenges were to first define such classic dynamic ev and secondly make a comparis of millions of data points.*

The forces at work in a non-destructive event, such as a vibration, must be relatively predictable, but what about a dynamic, destructive event? How do you define a standard crash? If you hit something or punch through a plate the crack pattern





The test object is a car bonnet frame made of fibre reinforced polymer (top), the car body it belongs to is a Fiat (above left), the impact testing using the projectile is displayed in a simulation (above right).

or the hole diameter that you would generate would easily scatter round some average values. Did their work look for an archetypal crash and, if so, how could you hope to meaningfully model that? Erwin explains, "You cannot hope to do a simulation that would predict the crack at exactly the same length and location as a real test would demonstrate, but you would still want an assessment to say that the simulation was nevertheless a good one because what you have generated in the experiment, although not being identical, is of the same nature."

How then, if the simulation cannot hope to predict the length or location of a crack, does million point optical analysis help the simulations? The answer, it would seem, is to reduce the large amount of values generated into a small number of essential coefficients that provide a means to measure agreement between these two sets of data.

Erwin explains, "By doing such a data reduction from the full field to the essential, for instance of the deformation field of an object before you have the damage and after you have the damage, would allow you then to compare the essentials of deformation, rather than involve too many details. The challenges were to first define such classic dynamic events and secondly make a comparison of millions of data points."

So, deliverables delivered and objectives achieved. The team has also started the long process of international standardisation for these validation methods and reference materials. However, there is always, of course, further research to be done.

"We would definitely carry on with these comparison routines - on the data reduction coefficients rather than millions of points - to bring that to the software developers as well as the users. Three years back people were not used to being able to compare millions of points on technical structures. Maybe it was possible on circles or rectangles or flat objects, but we have managed to do these things with curved surfaces and random boundaries, applying the same techniques to these industrially important structures rather than just the academic square and circle."

So the next time you travel in a transportation vehicle made of modern light-weight material, think of ADVISE and hope that the structure was validated for its crashworthiness. ★

At a glance
Project Information

Project Title:
ADVISE – Advanced Dynamic Validations using Integrated Simulation and Experimentation

Project Objective:
ADVISE is a pre-normative FP7 SST project for quantitative validation of simulations of dynamic events using image-based methods of deformation measurement. The project delivers reference materials fo dynamic calibration of image-based instruments, optimised methodologie for such measurement and computational modelling and generic draft standards for experimental validation of simulations.

Project Duration and Timing:
Three year project, Dec 2008 to Nov 2011

Project Funding:
7th framework Transport programme; SST.2007.4.1.1 Safety and Security by design; SCP7-GA-2008-218595

Project Partners:
- EMPA - Swiss Federal Laboratories for Materials Science and Technology (CH)
- Airbus UK (UK)
- Dantec Dynamics GmbH (DE)
- European Commission's Joint Researc Centre (Ispra, IT)
- University of Liverpool (UK)
- University of Patras (EL)
- High Performance Space Structure Systems GmbH (DE)
- MSU - Michigan State University (USA)
- CRF - Centro Ricerche Fiat S.C.p.A. (IT)

Dr Erwin Hack

Dr Erwin Hack is a physicist working on image-based measurement methods and NDT. He is deputy head of the Electronics/ Metrology/Reliability Laboratory and member of EMPA's research commission. He is vice-president of the „Swiss Society for Non-destructive Testing", and a member of the Editorial Board of Optics and Lasers in Engineering.

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