ADVISE project
FP7-SST-2007-RTD-1 Safety and security by design
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Outline project report on website

Partners involved: EMPA, AUK, DD, JRC, UNIL, LTSM-UP, HPS, MSU, CRF

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1 Executive summary

The three-year project ADVISE (Advanced Dynamic Validations using Integrated Simulation and Experimentation) was accomplished within the European Commission 7th Framework Programme (FP7) under the Sustainable Surface Transport Activity. The ADVISE consortium included research laboratories, universities, instrument suppliers, and companies from the automotive and aerospace industry[1].

ADVISE was a pre-normative project for quantitative validation of numerical simulations of dynamic events using image-based methods of deformation measurement. Dynamic events such as impact and crash are especially important in considering the safety aspects of means of transportation. Recent advances in modelling the impact of two- and three-dimensional composite structures were brought together with tests using optical techniques for deformation measurement.

To ensure the reliability of the experimental instruments reference materials for dynamic calibration have been developed. The ADVISE reference materials allow to calibrate full-field optical methods of deformation measurement in cyclic, transient and non-linear dynamic events, and to establish traceability of the measurement results. In addition, methodologies for optical measurement and computational modelling have been optimised towards application in impacts.

A draft standard for experimental validation of dynamic simulations based on a unified approach to comparison of data-rich fields has been issued. This methodology allows for a quantitative assessment of a comparison of simulation results with experimental results and hence can be used for substantiating the claim of "good" representation; or for a quantitative assessment of the extent of damage when compared to an undamaged structure.

Finally, industrially relevant test cases, including aerospace sandwich panels and a car bonnet frame, have been taken through the methodologies to demonstrate their viability.

Constant dissemination through technical, professional and trade conferences and exhibitions was performed to reach both the scientific audience as well as the European industrial base. Links to standardization bodies were established to foster the uptake of the ADVISE outcome in future standardization activities.

[1] see www.dynamicvalidation.org

2 Summary description of project context and objectives

Project framework

The three-year project ADVISE (Advanced Dynamic Validations using Integrated Simulation and Experimentation) was accomplished within the European Commission 7th Framework Programme (FP7) under the Sustainable Surface Transport Activity "Improving Safety and Security; Area: Integrated safety and security for surface transport systems (SST.2007.4.1.1: Safety and Security by design)" in response to the call SST-2007-RTD-1. The project also contributed to AAT.2007.3.3.1 Aerostructures, because the project objectives are generic for all engineering disciplines involved in design and testing of structures. Partners from six countries plus the European Commission's Joint Research Centre (JRC) were involved in the project. The partners had been selected to provide complementarity both in their role in the innovation process and their expertise. The project consortium included industrial partners (Airbus UK; Dantec Dynamics, DE; High Performance Space Structure Systems, DE; Centro Ricerche Fiat, IT), government supported research laboratories (EC-JRC-IHCP; EMPA, CH), and universities (Michigan State, US; Liverpool, UK; Patras, HE).

Project motivation

The increasing number and capacity of transportation systems means an increasing risk of accidents. Thus a major issue in transportation systems is to provide safety during critical events, while at the same time design optimisation of primary structures leads to lighter and more energy efficient products. In this context, it is important to thoroughly understand the reaction of a manufacturing material to the strains expected to be placed upon it. While for elastic deformations this is state of the art, the forces at work in a dynamic, destructive event are not easily captured. In engineering modelling the analysis of impact on homogeneous materials has been mastered; recent advances have been made in modelling the impact on two-dimensional composite structures, but a full three-dimensional analysis is still under development. When such advances in structural and materials designs are being made, they need to be validated in order to demonstrate their reliability and provide confidence in the design and manufacturing processes used. While numerical simulation is an essential and indispensable tool, for design verification an experimental check is a fundamental requirement. In order to accelerate the developments in modelling composites, these should be brought together with advances in full-field optical techniques. A comparison of simulated data to experimental results could establish high levels of confidence through rigorous validation which would represent a step change in the subject.

For a static assessment, defined stresses are imposed on test structures, and the resulting data is used to validate associated simulations. But how can you define a standard impact or crash? And how can you measure the response of the structure in time and space? When a structure is hit or a plate is punched through, the crack pattern would vary each time the experiment is performed. One cannot hope to simulate the event numerically in such a way as to predict exactly the length and location of the cracks observed in the real test. But nevertheless, one is forced to decide whether the simulation was good enough based on such limited assessments. The problems to be tackled can thus be summarized as follows:

- Define standard dynamic events to offer repeatable situations for the experiment
- Measure deformations and strains of the structure in a calibrated way
- Simulate a dynamic, destructive event for lightweight structures
- Compare numerical and experimental results to validate the simulations

Optical techniques of deformation and strain measurement can make a substantial contribution to the measurement of dynamic response. They constitute a generic technology and support safety, reliability and life cycle assessments, as well as design optimisation of structures, components, and devices varying in scale from microsystems to ship hulls. Europe possesses world-leading technology in this area. There are substantial benefits to be gained from providing reference materials used to establish traceability for such dynamic optical measurement systems. These in turn can be used in experimental validation of sophisticated modelling procedures of dynamic and destructive events.
When the numerical simulation cannot predict the exact crack pattern, the essential of the behaviour must be extracted from the data, i.e. the data must be reduced to the essential content. There is a lack of accepted standards for the comparison of the experimental and numerical data, although several initiatives within the engineering community have suggested procedures for the verification and validation (V&V) of numerical models, for example the V&V committee of the American Society of Mechanical Engineering. While best practice guides exist for numerical modelling and static measurements of stress and strain, there are no international standards covering the calibration of data from dynamic experiments and their use to validate numerical results in stress, vibration and impact response, i.e. to correlate finite element results with full-field experimental observations.

ADVISE objectives

ADVISE is a pre-normative project for experimental validation of simulations of dynamic events using full-field optical methods of deformation measurement. The quality of the data generated is strongly dependent on the procedures employed and set-up of both the instrumentation and the simulation. Today there is a lack of unified approaches for both fields. Thus, there is a significant need to provide standards both for procedures and instrumentation in order to prevent technical barriers to trade, to promote the compatibility of approaches, and to provide traceability. ADVISE can be seen as an extension from static strain to dynamic events of the successful "Standardization Project for Optical Techniques of Strain measurement" (SPOTS[2]). SPOTS generated a draft standard for "Calibration and Assessment of Optical Strain Measurement Systems" which has been submitted to ISO for dissemination. The objective of the ADVISE project is to provide standardised procedures that allow confidence levels to be defined both for experimental methods via calibration and numerical models via validation. The objectives of the project are:

- development of reference materials that allow traceability and calibration of full-field optical methods of deformation measurement in cyclic, transient and non-linear dynamic events;
- optimisation of methodologies for both optical measurement and computational modelling and simulation of non-linear, transient dynamic events;
- contributions to standardisation activity for experimental validation of dynamic simulations.

The ADVISE objectives were pursued in three strands of activity that defined three technical work packages. "Advanced Tools for Simulation and Experimentation" focused on image processing, numerical modelling and measurement instrumentation to improve the dynamic measurement 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 crashing damaging event in a simulation tool.
"Dynamic Calibration" focused on the development and design of reference materials for the calibration of optical instrumentation, i.e. to provide something dynamic the deformations of which are exactly known. This needed not be a destructive event but one that allows for

[2] FP 5 Growth Programme GRD1-2002-70014, ,see www.opticalstrain.org

calibrating the instrument that subsequently would be used to measure an impact event. 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 applied and the deformation generated are not directly proportional to each other.
Finally, "Experimental Validation" was to develop methods to compare the two results in a quantifiable manner. So, not just say you get what you expect, but say to which extent do the experiments and the simulations agree or disagree. Specific case studies provided by industrial end-users were used to perform simulations and experimentation and to compare the results in a unified manner. Further, collaboration with VAMAS TWA 26, which has thus far focused on static measurements, CEN, ISO, and NAFEMS was envisaged to ensure that the pre-normative material can become quickly accepted in Europe and on global level. C

ADVISE outcomes

The innovative aspects of the project included the first attempt to provide a unified approach to experimental validation of engineering simulations of primary structures, the development of reference materials for optical dynamic deformation measurement, and a major contribution to standardisation.
In the process of developing reference materials that allow traceability and calibration of full-field optical methods of deformation measurement in cyclic, transient and non-linear dynamic events, the following results were obtained:

- *a list of essential attributes for the reference materials;*
- *prototype reference materials based on vibrating plates.*

For the optimisation of methodologies for both optical measurement and computational modelling and simulation of non-linear, transient dynamic events the following results were obtained:

- *improved methods for simulation of impact testing of composites;*
- *a draft standard guide for deformation and strain measurement techniques;*
- *industrially relevant case studies from the automotive and space industries.*

To optimise rigorous methodologies for the experimental validation of dynamic structural simulations results include:

- *a guide to damage assessment based on using strain components*
- *a guide for validation of simulations by experiments based on comparison of shape descriptors.*

To disseminate the project results and to contribute to international standards the project has been made visible through

- *a project web site www.dynamicvalidation.org;*
- *contacting international standardization bodies; and*
- *publications and presentations in journals and at international conferences.*

Constant dissemination through technical, professional and trade conferences and exhibitions is being performed to reach both the scientific audience as well as the European industrial base.