Report on Euromech 269

EXPERIMENTAL IDENTIFICATION OF THE MECHANICAL CHARACTERISTICS OF COMPOSITE MATERIALS AND STRUCTURES

(ÉCOLE DES MINES DE SAINT-ÉTIENNE, FRANCE, DECEMBER 3 - 6, 1990)

Composite materials are regarded as tailorable materials in the sense that their properties can be adjusted to fit at best functional requirements. However, till now, this broadly widespread view is wrong since the usual mechanical characterization and designing procedures do not incorporate two prominent features of these materials, i.e. their *anisotropy* and *heterogeneity* , from the starting point of any analysis. The Colloquium aimed to point out *new ways* of approaching the *experimental identification* of such materials or structures in the rational framework of the mechanics of *heterogeneous* and *anisotropic* media.

The Scientific Committee received about 75 proposals within the scope of the Colloquium. About 50 proposals have been accepted for presentation and have been presented according to the final Colloquium programme (5 invited general 60 min lectures, 22 oral 30 min presentations and 24 poster presentations -including a 5 min oral presentation and poster). There were 65 delegates from 15 different countries: France (28), Belgium (12), Italy (3), Netherlands (3), U.K. (3), U.S.S.R. (3), Swiss (3), Czechoslovakia (2), U.S.A. (2), Poland (1), Sweden (1), Denmark (1), Yugoslavia (1), Portugal (1), Japan (1). The Colloquium chairmen regret that despite their personal efforts no scientist from Germany attended the meeting, in particular contacts with.BAM or DLR did not succeed.

Professor J.P. Boehler, who previously accepted to give the introductory lecture, could not attend the Colloquium because of a serious surgical operation. Moreover, Professor H. Sol, co-chairman of the Colloquium, could not leave Brussels at the time of the meeting because of unespected family event. Four authors failed to participate after acceptance of their papers (F. Matthews and G. Davies (U.K.); C. Rey (F); A. Stas (B)).

We were extremely pleased that Professor W.P. De Wilde from Vrije Universiteit Brussel was able to accept our invitation to introduce the meeting by a general lecture on advanced hybrid methods to identify viscoelastic characteristics of composite materials through structural experiments. The chief question of a structural model foundation and control has been arisen with high relevancy since the opening of the meeting. The final general discussion has been jointly led by Professors W.P. De Wilde (B), D. Post (USA) and A. Vautrin (F).

Four main scientific topics have been covered and discussed throughout the oral and poster presentations:

- advanced quasi-static and dynamic mechanical tests for anisotropic media,
- identification methodologies based on new relevant mathematical data treatments,
- displacement and strain fields measurement based on optical methods,
- advances in damage modelling of anisotropic and heterogeneous media.

Any paper can obviously be concerned with several above-mentionned topics.

The *material-structure duality* of composites has been emphasized since the starting of the Colloquium. Stimulating discussions revealed that two chief approachs coexisted, based on:
- *specimen* testing that produced *uniform deformation fields* to identify with reasonable accuracy the material behaviour and to determine specific properties,
- *structure* testing that did not necessary produce uniform deformation but enabled practical identification of the complete set of structural parameters to be determined in the framework of a beforehand fixed anisotropic model.

Identification procedures dealt with *heterogeneous displacement or strain fields* and data treatment technics involved material parameters adjustment by finite element calculation routines and iteration processes in many cases. The least square method with weights and the familiar Euclidian distance are quite often used. When the optimizing procedure required the integration of history dependent tensors, assuming plastic response for instance, it has been pointed out that particular scalar products could strongly enhanced numerical convergence and stability.

Optical technics, such as moiré or holographic interferometry, can easily provide displacement or deformation field mapping. Furthermore they considerably reduce any perturbation of the mechanical response of the system and give a prominent insight into the overall behaviour of the structure, that is quite relevant to mechanical modelling and non-destructive control purposes. Several examples emphasized the high interest of optical technics both for dynamic and quasi-static testing and proved that such technics could now be practised without advanced educational training in optics, even if beforehand skill in optical applications is clearly needed. The dissemination of optical technics is greatly facilitated by the enhancement of the personal computer capabilities and image processing which can lead to routine fringe pattern treatment and first analysis.

Personal computer facilities can be used with profit to continuously control the satisfying running of a given experimental procedure. Several presentations suggested that real time data preanalysis could be introduced. The increasing capabilities of personal computers provide fast data acquisition, data treatment and analysis, involving image processing and finite element calculations and iterations, and flexible editing of any graphic materials.

The chief task which should be started in the field of the experimental identification of composites is probably to fill the gap between experimental data derived from different mechanical tests. Large discrepancies in published data obviously proved that present knowledge in mechanics of composites has to be fairly improved; to reach the target it should be necessary:
- to set up new testing approaches based on *heterogeneous cinematical fields*. These tests seem to be well suited to identifying the *complete anisotropic behaviour*, i.e. taking account of the structural coupling effects due to the anisotropy and two-dimensional loadings, in a given theoretical framework. Advances in the range of large displacements -and large deformations- of structures should be required as well, since the present works were restricted to small displacements and deformations.
- to found *relevant rheological models* in full agreement with the basic mechanical responses and microstructures of composites: what is the true nature of the nonlinear mechanical responses? What is plasticity or viscoplasticity for polymer matrix composites? Can mechanical

modelling ignore the internal state of stress, strain and defects distributions? Can damage occuring in composite laminates be modelled in the same way as metals?
- to identify *transverse mechanical properties* of plates. Much work has been done in the framework of the classical laminated plate theory, however transverse properties of laminates are probably the most restrictive structural parameters in practice and transverse shear properties of laminated and sandwich plates are to be assessed.
- to introduce *optical extensometry* in mechanics of composite structures and to encourage any joint work with specialists of optical technics (development of specific softwares for fringe pattern flexible analysis on personal computer for instance).

The organizers are very grateful to Euromech Committee for approving this Colloquium and are convinced that the stimulating scientific atmosphere of the meeting, due to the caliber of the papers presented and animated debates, will initiate new research opportunities in the field. Several enquiries about the next publication of the Colloquium Proceedings by Elsevier confirm in my eyes that the conference succeeded to maintain a high scientific standard quite within the scope of Euromech Colloquia. The organizers cannot assert that all the senior scientists directly concerned in the Colloquium subject attended the meeting, but all the people invited to contribute by the chairmen, and known by them to be very active in the area, agreed to participate.

The chairmen wish to express all their thanks to École des Mines de Saint-Étienne for its material assistance and hospitality and to the meeting sponsors (French Ministry of Research and Technology, Research Agency of the French Ministry of Defense, French University Mechanics Society, Composite Materials French Society, Loire County Council, Saint-Étienne & Montbrison Chamber of Commerce and Industry, Saint-Étienne City Council, Loire Savings-Bank) who enabled the organizers to support the travel and accomodation expenses of all the scientists from Eastern Europe as well as Professor D. Post of Virginia Polytechnic Institute, who is certainly the world's senior worker in the field of applications of moiré interferometry to composite materials characterization.

Alain Vautrin
Professeur
École des Mines de Saint-Étienne, F - March 4, 1991