SYNERGETIC USE OF THERMAL AND ACOUSTIC EMISSION IN STUDYING TENSILE BEHAVIOUR OF FIBRE REINFORCED COMPOSITES

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ABSTRACT

The possibility to combine the use of acoustic emission and thermal emission as real-time monitoring techniques on carbon-epoxy composites is the subject of this paper. Tensile tests are therefore performed, using a cross-head speed not too high so to enable a reliable detection of acoustic emission signals, but suitable also for the needs of the thermal emission technique,.
The latter technique, which requires a quasi-adiabatic loading to be applied on the material, is here employed with a quasi-thermographic concept, with the twofold objective of measuring the thermoelastic limit and investigating the local heat exchange produced by the loading event. The idea is therefore to use thermal emission as a predictive inspection tool and, as a consequence, to correlate in a synergetic way its data with acoustic emission outputs.

1. INTRODUCTION

In previous works by Oliver (1988) and Melvin (1991) thermal emission was applied as an useful assessment technique for crystalline materials undergoing deformation, carrying out the measurement of thermoelastic limit. Moreover, when the emissivity of sample surface is appreciably constant, this technique can be suitable for black-body temperature calculation. Dealing however with temperature variations due to stress gradients, experimental arrangements are necessary can be disposed in order to limit the environmental heat exchange during the test.

On fibre reinforced composite materials, as pointed out by Melvin, Lucia & Solomos (1993), a sudden appearing and progressively growing local heating on the specimen indicates the reaching of yield level. Furthermore, the presence of other damage phenomena (e.g., delaminations) are indicated from heat dispersions at during the test. The main requirement to be fulfilled in order to successfully apply thermal emission consists of the creation of a quasi-adiabatic environment around the specimen, which would signify a very fast load application, generally using displacement control. Other monitoring techniques e.g., acoustic emission would conceptually fit to be applied in close comparison with thermal emission, but require instead that loading lasts for enough time to permit stresses distribution throughout the material (Marini & Solomos, 1994). In fact, the level of stresses has a not negligible influence on acoustic emission data and hence on the capabilities of that technique. To reduce adiabatic nature of thermal emission would mean to make it closer to a thermographic real-time monitoring, losing of course spatial resolution since each thermistor allows a thermal measurement on a single point, but compensating this by its greater precision and reliability.

2. MATERIALS AND METHODS

Two series of 8-plies carbon/epoxy coupons have been considered, with stacking sequences respectively of (0/90/0/90)*2 and (0/+45/90/-45)*2. All the specimens have been submitted to tensile loading in displacement control with a cross-head speed of 1 mm/min. Thermal and acoustic emission have been both monitored on each specimen through the application of one 30 Ω thermistor at the centre of the 120 mm grip length and two 150 kHz peak frequency piezoelectric transducers at 40 mm each from the thermistor. Test chamber was completely isolated through a Plexiglas structure and the adiabatic conditions were verified by a continuous temperature measurement, that does not allow the test to start, if the temperature is not stable. Thermal emission and mechanical data were acquired by DITE program, described by Melvin (1991), while acoustic emission signals were detected and treated through PAC LOCAN-AT system.

3. RESULTS

3.1 Data from (0/90/0/90)*2 stacking sequence laminates

Dealing with results from the first series of tests on unbalanced stacking sequence specimens, one may observe that the stress-strain curve, showed in fig.1, does not indicate a consistent plastic deformation through the test. Such a consideration can be reported also for the further series of quasi-isotropic specimens, but for other aspects the situation seems to differ in that case, as showed below.

Acoustic emission data instead, as it appears in fig.2, allow one to calculate from cumulative counts vs. stress curve a proportional limit. The value obtained is confirmed with good approximation from thermoelastic limit, shown from temperature-stress curve in fig.3. Here, also a second limit is shown from the change of curve slope at about 480 MPa. This second limit, which indicates the passage from a rather constant to a rising temperature is presumably related with the onset of a consistent fibre pull-out. This interpretation is confirmed again by acoustic emission data, where a peak in average duration, most probably associated to large surface involving phenomena (delaminations), is appearing exactly from that stress level, as indicated in fig.4.

We may note that in the case of this specimen the failure, as indicated in Prépin, Cazeneuve & Pluvinage (1988) seem to be due to the precocious breaking of many 0° fibres, rather frequent phenomenon in composites with unbalanced stacking sequences.

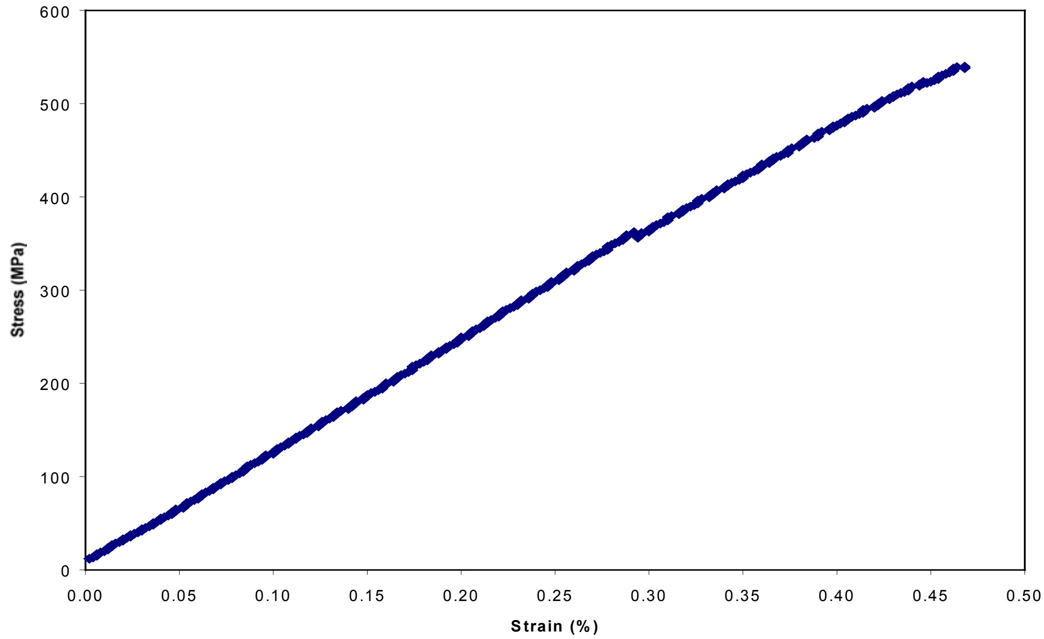

fig.1 Stress (MPa) vs. Strain (%) curve

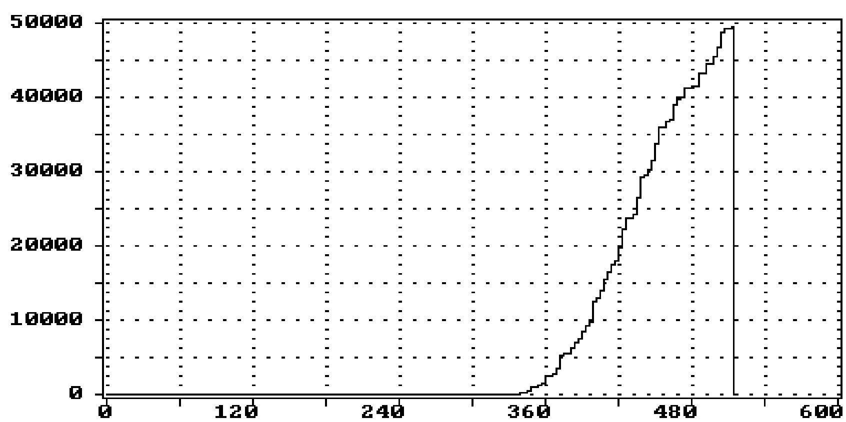

fig.2 Acoustic emission cum. counts vs. Stress (MPa) curve

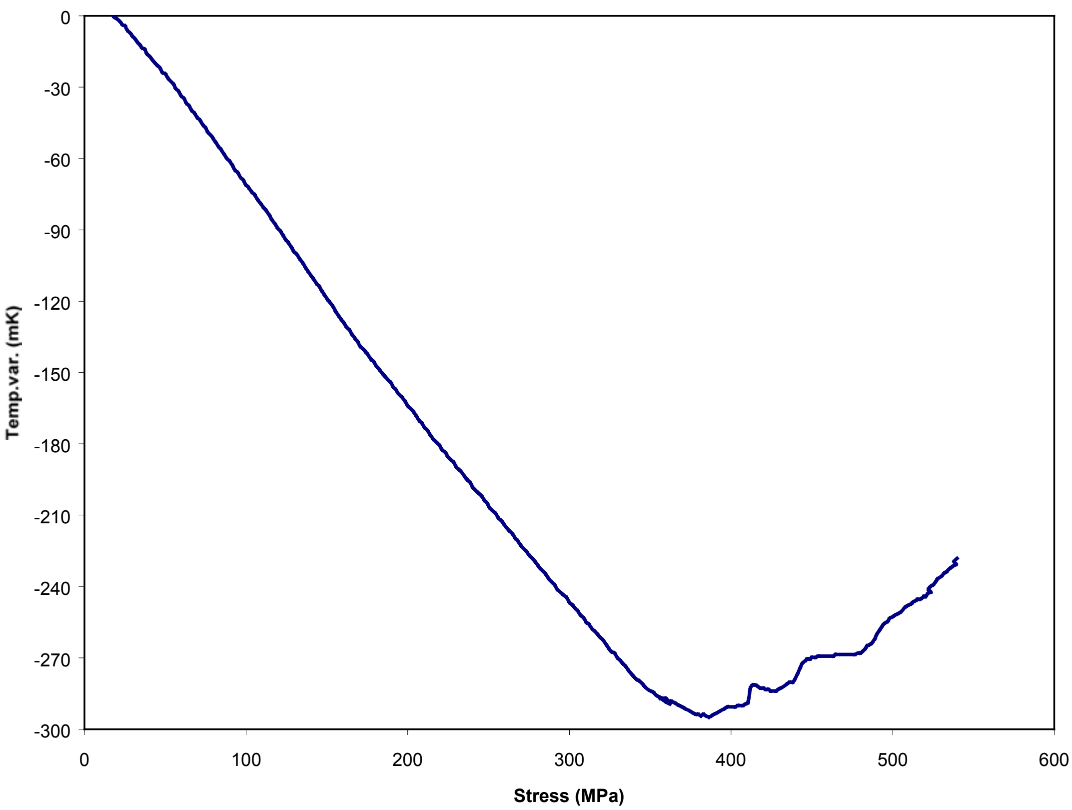

fig.3 Temperature variation (mK) vs. Stress (MPa) curve

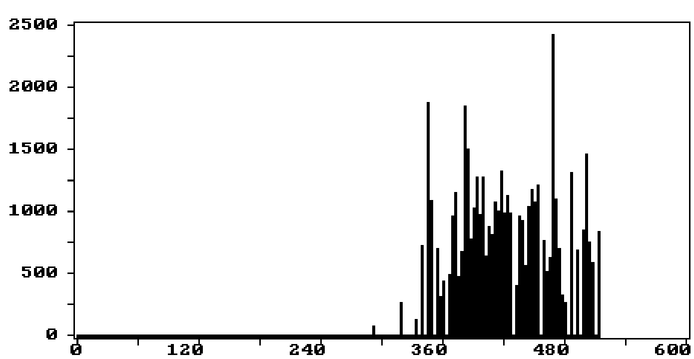

fig.4 Acoustic emission average duration (μs) vs. stress (MPa) curve

<u>3.2 Data from (0/+45/90/-45)*2 stacking sequence laminates</u>

A rather different behaviour is instead shown in the second series of specimens, where some acoustical activity is detected only in proximity of the ultimate load, due probably to the presence of an efficient stress distribution through the quasi-isotropic material. Here, the failure appears to be rather sudden: with hardly any premonitory circumstance once again the thermoelastic limit is clearly revealed, this time at about 365 MPa (fig.5). An interesting observation could furthermore be sorted out from repeated tensile loading on these specimens without exceeding the elastic zone: the sensibility of the thermal emission technique, shown by temperature decrease prior to thermoelastic limit, appears (fig.6) to be reduced progressively as the specimen is reloaded. This indicates that heat is progressively accumulated in the surface and in the sub-superficial region of the material. However, it is not easy to correlate this phenomenon to damage propagation.

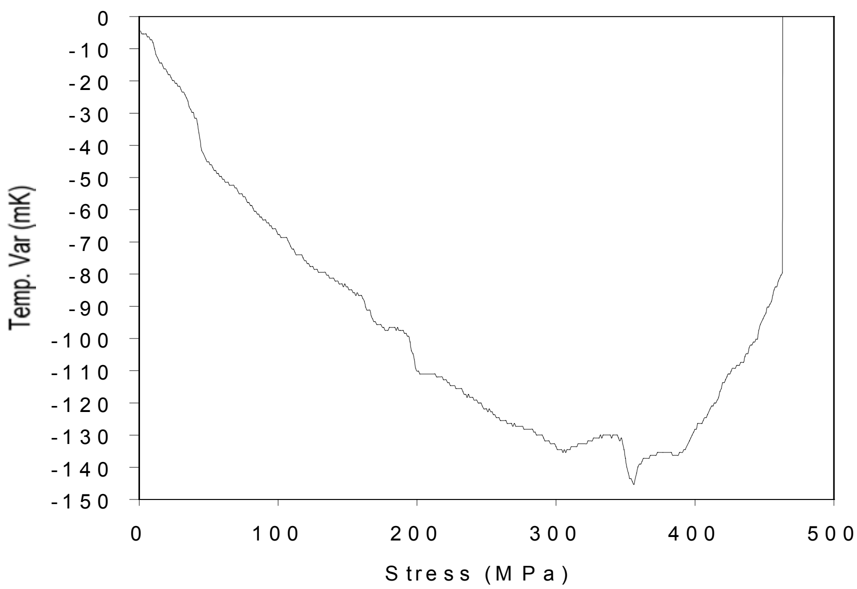

fig.5 Temperature variation (mK) vs. Stress (MPa) curve

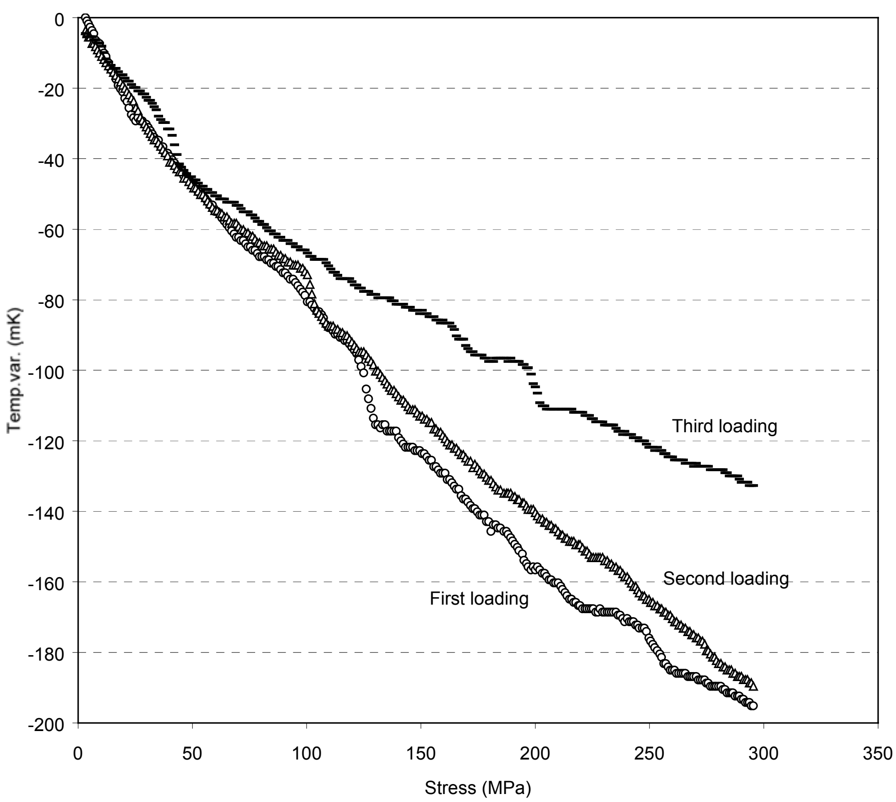

fig.6 Temperature variation (mK) vs. stress (MPa) curve for multiple loading

CONCLUSIONS

The aim of this work consisted mainly in defining a method to compare data from two monitoring techniques during tensile tests on widely used composite materials, in order to envisage a global strategy to enhance the knowledge of their behaviour under stress, more than shown from their mechanical properties.

Establishing a correlation between thermal and acoustic emission can be promising so to recognise the change of behaviour of carbon/epoxy materials in real time during tensile tests. Here, thermal emission is able to supply information even in loading periods exceeding 1-2 minutes to failure, provided of course that the test chamber is fully insulated. Limitations are due nevertheless to the reduced sensibility of that technique if the test is repeated, due to some heat accumulation on the specimen. Acoustic emission can complete such data, even if its predictive nature is greatly affected from stacking sequence and/or from initial conditions of the material, so that no general conclusions could be traced at this subject.

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