Multiphysical fatigue of organic matrix composites for aircraft applications:

Thermal cycling, thermo-mechanical fatigue

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Experimental tools: thermo-mechanical fatigue and thermal cycling testing machines under controlled gaseous environment (neutral, oxidative, humid…), micro/nano indentation, Interferometric microscopy, SEM, X-ray micro-computed tomography, thermal cycling 'in-situ' micro CT

Context: The aim of this operation is to characterise and to model the coupling effects of environment and cyclic thermo-mechanical loadings (fatigue) on the behaviour of organic matrix composites (constitutive law, damage evolution, failure), in order to predict their durability in structural aircraft applications. Specific experimental testing devices have been developed in order to carry out thermal cycling tests, thermo-mechanical fatigue or creep experiments… in neutral (N_2) or oxidative (air, O_2) gaseous atmospheres, in order to identify the effect of environment on the fatigue damage mechanisms and kinetics. A special effort is made to quantitatively analyse the damage evolution with number of cycles (onset of matrix cracks, multiplication, propagation...) in connection with the composite architecture and the behaviour of the polymer matrix. This aim is carried out by building and developing specific experimental protocols (coupled, uncoupled, multi-scale, 'in-situ'…), by 3D RX micro CT imaging and image processing, and by interpreting the results through numerical FEM simulations.

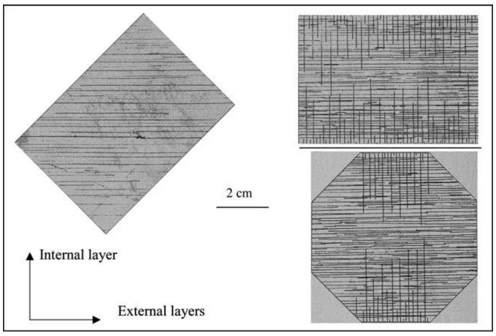


Fig. 12. X-ray pictures of large specimens after 1000 cycles (−50/150 °C) in oxygen.

Thermal cycling

- ✓ Experiments of thermal cycling in controlled gaseous environment
- ✓ Observations of damage development with number of cycles by means of radiography or RX Computed Tomography
- ✓ CFRP laminates and 2D and 3D textile composites
- ✓ FE simulation of cyclic thermal loading with a visco-elastic and thermo dependent behaviour law of the matrix.

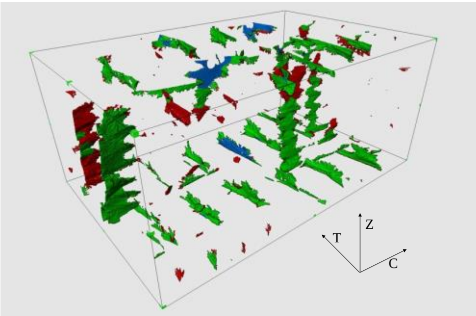
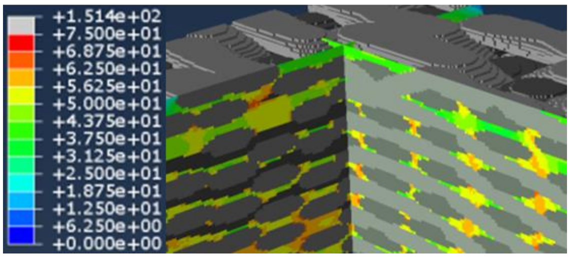


Figure 4 : Evolution des microfissures dans un composite tissé 3D C/époxy au cours d'un essai de cyclage thermique (-55°C/120°C) sous air ;
bleu : 0-100 cycles, vert : 100-475 cycles , rouge : 475-700 cycles

Champ de contraintes hydrostatiques (MPa)



Vue en double coupe du champ de contraintes hydrostatiques dans la résine d'un échantillon interlock calculé par la simulation d'un refroidissement entre 160°C et -55°

COMPTINN' "multi-physical" experimental setup: INSTRON 1251 fatigue setup equipped with an environmental climatic chamber

Thermo-mechanical fatigue

- ✓ Fatigue tests in a climatic chamber with controlled gaseous environment (gas pressure and temperature)
- ✓ Observations and quantitative analysis of damage development with number of cycles by means of 'in situ' microscopy and RX Computed Tomography
- ✓ CFRP laminates and 2D and 3D textile composites
- ✓ Development of FE models starting from micro-tomographic images: segmentation, meshing, analysis

Publications:

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