Composite Behavior of Composite Material Involving a Source of Heat

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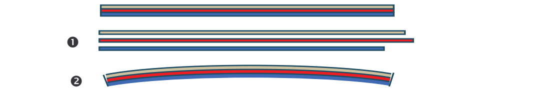
Introduction and working mode:

Nowadays, to control the deformation of structure, actuators are integrated in or on it. These ones are generally piezoelectric, magnetostrictive materials or smart memory alloys (SMA).
Generally they induce an increase in the weight, the volume, and stress concentration problems which can involve damage phenomena. Moreover, the process of integrating the actuators in a structure must be done carefully to avoid adhesion or cohesion problems.
This is why a new kind of concept has been developed with the CBCM which use the intrinsic properties of composite materials



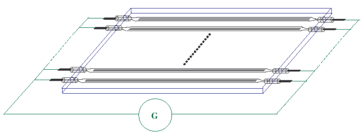
Example with a three layer composite:
❶ During a temperature rise, each separate layer has a different behavior represented here by a different dilatation.
❷ However the layers are perfectly bonded to each other so internal stresses appear to deform this material

The working principle of the CBCM is to add a stress in a multi-layered composite material to remove or to impose a deformation by combining the anisotropic behavior of composite materials and a increase of the temperature.

In other words, the dilatation properties of a composite structure are used to control its deformation: during a temperature increase, the difference between the thermo-mechanical properties of the layers generates internal stresses. These stresses are homogeneous in each layer and deform the structure.

The advantages of the CBCM are to reduce the stress concentrations and the whole structure becomes an actuator, so the useful power is higher.

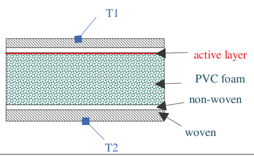
Detail of the source of heat: a polymer layer is made electrically conductive with the adjunction of carbon fibers or pellets .This layer is called the active layer. When it is connected to a current generator, it warms up according to the Joule law.



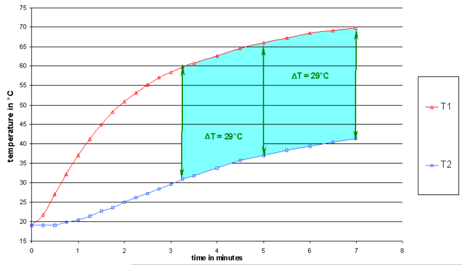
Experimental protocol and results:

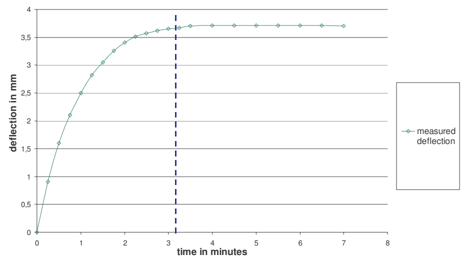
The experimental procedure consists of measuring the bending deflection at the plate center versus time, for a given constant voltage applied to the active layer. This plate is simply supported at its the edges. During the experiment the temperature is measured on the faces and is recorded with an acquisition system. The supplied energy to the active layer is controlled with a generator which voltage and current are adjustable. The figure on right describe this measurement protocol. The mechanical power is determined with the weight necessary to give the same deflection obtained by the increasing temperature.

Sandwich plate



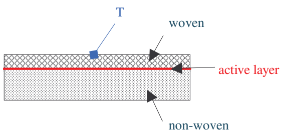
- 100 * 500 mm² and 6.7 mm thickness
- Skin: 2 layers of non woven glass fibers and 1 layer of woven glass (t = 0.85 mm)
- Core: PVC foam (t = 5mm)
- Handmade lay up molded with epoxy resin
- Active layer : carbon fiber with R= 7.8 W
- Applied voltage: 20.4 V



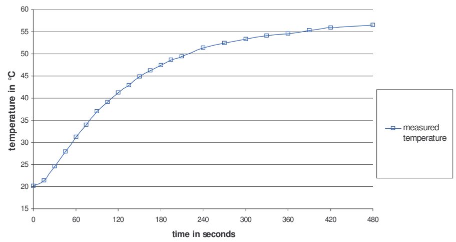


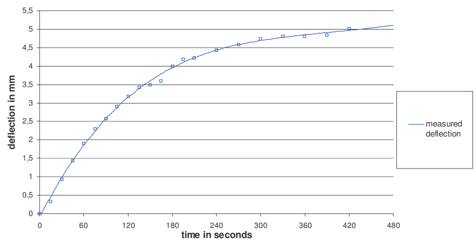
energy balance:
- Electric power : 53 W → 1060 W/m²
- After t = 195 s, the deflection d = 3.7 mm   this deflection is equal to a load of 3370 g

Thin plate



- 100 * 300 mm² and 1.6 mm thickness
- 4 layers of non woven glass fibers and 2 layers of woven glass
- Handmade lay up molded with epoxy resin
- Active layer : carbon fiber with R=7.8 W
- Applied voltage: 20.3 V

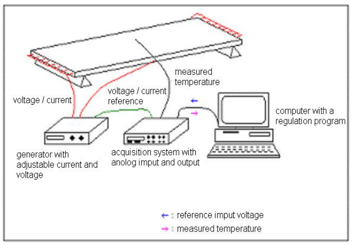




energy balance:
- Electric power : 32.1 W → 1070 W/m²
- After t = 330 s, the deflection d = 4.8 mm   this deflection is equal to a load of 535 g.

Current and future works:

A control of the deformation is implemented: the supplied intensity to the active layer is modulated depending on the wished deformation and the rate of deformation. The control parameter is the temperature or the strain of a stress gauge. The control is realized with a PID program on a computer. With this control, cycling tests can be carried out to study the deterioration or not of the ageing behaviour of the composite material. Indeed, during its use, this material is sustained to mechanical and thermal fatigue. This one is important to determine the life time of the material. Mechanical tests, such as traction, flexion tests made at different time during the experiment will quantify the variation of the behaviour.



References:

[1] R. Lane & B. Craig: Materials that sense and respond: An introduction to smart materials, The AMPTIAC Quarterly, Volume 7, Number 2.
[2] V. Piefort: Finite Element Modelling of Piezoelectric Active Structure, Thesis report, 1st chapter.
[3] I. Hunter, S. Lafontaine, J. Hollerbach and P. Hunter: Fast Reversible NiTi Fibers for Use in Microrobotics, Proc. 1991 IEEE Micro Mechanical Systems – MEMS '91, Nara, Japan, pp 166– 170.
[4] Terfenol-D Etrema Products.
[5] S. Park and T. Shrout: Ultrahigh Strain and Piezoelectric Behavior in Relaxor Based Ferroelectric Single Crystals, J. Applied Physics, Vol 82, pp 1804 – 1811.
[6] R. C. Wetherhold & J. Wang: Controlling thermal deformation by using laminated plates, Composite Part B,Volume 27 B, Number 1, 1996, Elsevier Science Limited.
[7] H. Drobez, G. L'Hostis, F. Laurent, B. Durand, G. Meyer : *Composite Behavior Controlled with a Source of Heat*, 4th International Forum on Advandced Material Science and Technology, 4-7 July 2004, Troyes, France.