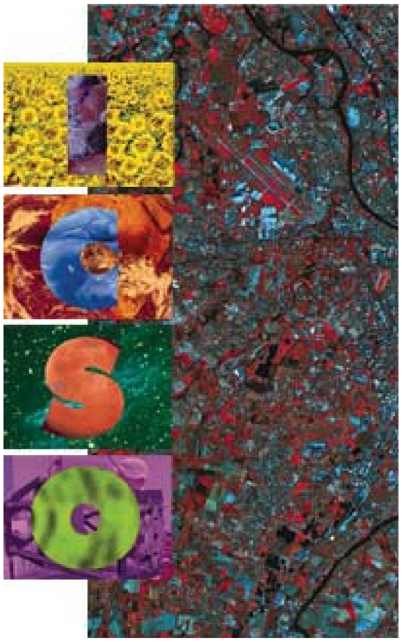
**International Conference on Space Optics—ICSO 2000**

Toulouse Labège, France

5–7 December 2000

*Edited by George Otrio*



# *Stability study of MMC tubes and advanced assemblies for telescope structures*

*Martine Nivet-Lutz, Gilles Pommatau*

International Conference on Space Optics — ICSO 2000, edited by George Otrio, Proc. of SPIE Vol. 10569
105691L · © 2000 ESA and CNES · CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2307925

# Stability study of MMC tubes and advanced assemblies for telescope structures

**Martine NIVET-LUTZ(*)(1) – Gilles POMMATAU(*)(2)**

*(*)ALCATEL SPACE INDUSTRIES 100 boulevard du midi*
*06156 CANNES-LA-BOCCA – France. Fax : (0)4.92.92.74.60*
*(1) Phone : (0)4.92.92.77.13 - e-mail : martine.nivet@ space.alcatel.fr*
*(2) Phone : (0)4.92.92.76.47 - e-mail : gilles.pommatau@ space.alcatel.fr*

**RÉSUMÉ** – Ce document présente les nouveaux acquis concernant l'application de Matériau Composite à Matrice Aluminium à des structures stables de satellites. L'étude a permis de conclure à la faisabilité de tubes de faibles épaisseurs à dilatation quasi-nulle. Les contrôles ont portés sur l'examen de la santé-matière et sur la mesure du coefficient de dilatation. La mesure de Limite Elastique de Précision a permis de quantifier la stabilité mécanique du tube brut d'élaboration.

Dans l'optique d'ajuster le domaine de stabilité thermo-mécanique du matériau aux besoins, 3 cyclages thermiques de relaxation de contraintes sans macro-endommagement ont été testés. Les résultats obtenus sur les courbes de dilatation et les micrographies montrent que ce calage est possible. Par souci de compréhension des phénomènes, les contraintes internes ont été mesurées expérimentalement par diffraction de neutrons sur des tronçons de tubes après cyclages thermiques. Les résultats montrent qu'un traitement dans le froid relaxe les contraintes internes.

Afin de minimiser le poste du à l'assemblage dans le coefficient de dilatation, un nouveau concept de liaison integrée a été développé. Sa réalisation consiste en une infiltration commune de l'aluminium dans différentes préformes de carbone superposées. Cela se traduit par supprimer un collage, qui nécessite des traitements de surface et des temps de polymérisation pour génèrer , au final, des instabilités.

Cette étude a été soutenue par le CNES (Centre National d'Etudes Spatiales) et la DGA (Direction Générale de l'Armement).

**ABSTRACT** – This paper presents new advances concerning the development of an Aluminum Matrix Composite for dimensionally stable satellite structures. Feasibility of thermally stable thin-walled tubes have been acquired through microstructure observation and Coefficient of Thermal Expansion measurement.

In order to fit the thermo-mechanical stability domain of tubes on specifications, 3 thermal cycles have been tested, regarding to relaxation of internal stress and changes in macroscopic thermo-mechanical properties. Experimental expansion curves and microstructure observation show that thermal treatments permitts such a good fitting. For a better understanding of physical internal phenomena, internal stress has been measured by neutron diffraction on tube samples after each thermal treatment. Results show a significant decrease of stress due to cycling in cold temperature.

In order to decrease the absolute value of CTE of assemblies, a new concept of thermo-mechanical stable linkage has been developped, which consists in a common alumlinum infiltration of superposed carbon preforms. Structural bonding, which usually affects stability properties and impose surface treatments and polymerization, can so be avoided.

The study has been achieved through CNES (Centre National d'Etudes Spatiales) and French Ministry of Defense (DGA) supports.

## 1 - Introduction :

Carbon fiber reinforced aluminum alloy is the Metal Matrix Composite (MMC) which properties suit best for thermally stable satellite structures : no moisture instability (compared to Carbon/Resin), high stiffness (compared to Carbon/Carbon), optimized coefficient of thermal expansion (CTE) to near-zero value (compared to SiC).

## 2 – Material choice :

Fiber and matrix have been chosen accordingly to previous studies performed for small plates :
- reinforcement with UltraHighModulus pitch-based carbon fabric.
- matrix composed of aluminum alloy with a low solidification temperature, so as to ensure a low time of contact between fibers and liquid aluminum during infiltration.

## 3 - Feasibility of near-zero CTE MMC thin-walled tubes :

The lay-up has been defined with the two following criteria :
- a symetric lay-up with 0° angles
- a minimized calculated CTE value.

In order to reduce overall dimensions of small truss structures, thermally stable thin-walled (1.6mm) tubes with low diameter (32mm) have been manufactured by pressure infiltration casting.
Concerning the feasibility of thin-walled tubes, critical points are identified by comparison with already made thick-walled (5mm) tubes with large diameter (60mm) :

- Preform manufacturing : the thinner is the tube, the more difficult is the compaction of dry fabric, necessary to obtain the 60% fiber content.
- Infiltration parameters : the ratio length/diameter has been decreased, so that thermal behaviour should differ during infiltration.
- Material health : swelling of fabric in the mould could cause waving of fibers, which could increases standard deviation of CTE values. Moreover, fiber content is measured in different points to control homogeneity along the tube.

### Preform manufacturing :

Rolling of fabrics on the mandrel

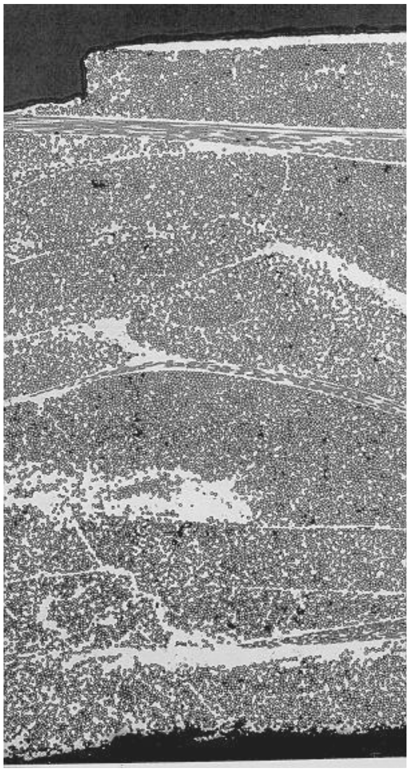
Preform in the mould before closing
(With titane sheet)

**Infiltration parameters :**

- aluminum T°C : 720°C
- preform T°C : 700°C
- pressure : 60 bars
- cooling rate : about –50°C/min

**Micrography :**

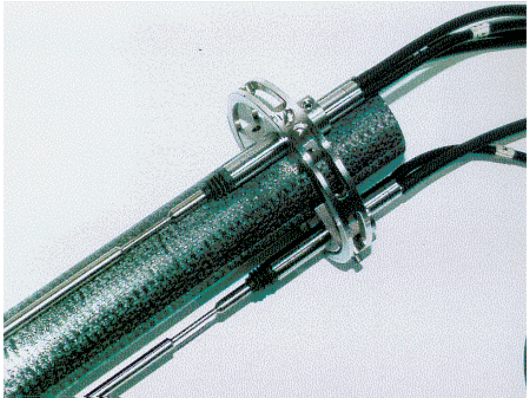
Titane sheet defect



**Conclusion :**

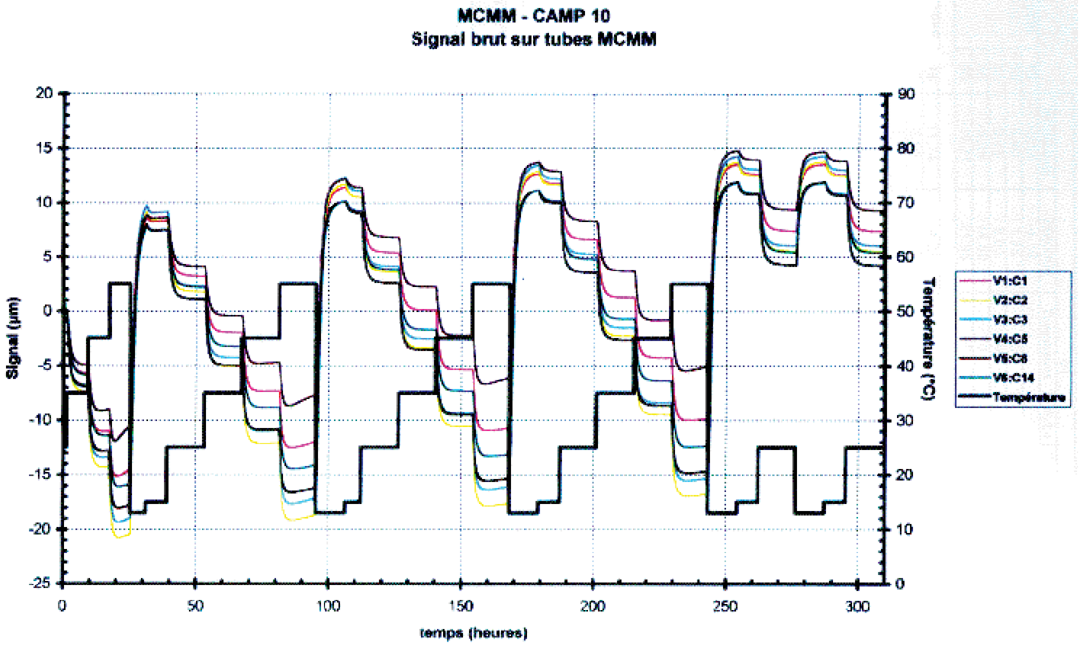
The two steps of manufacturing of carbon fiber reinforced aluminum alloys (wrapping and infiltration) are now well-mastered for single shape elements (tubes, plates,..) either thin or thick.

## 2.3 - CTE measurement



LVDT sensor

Equipped samples



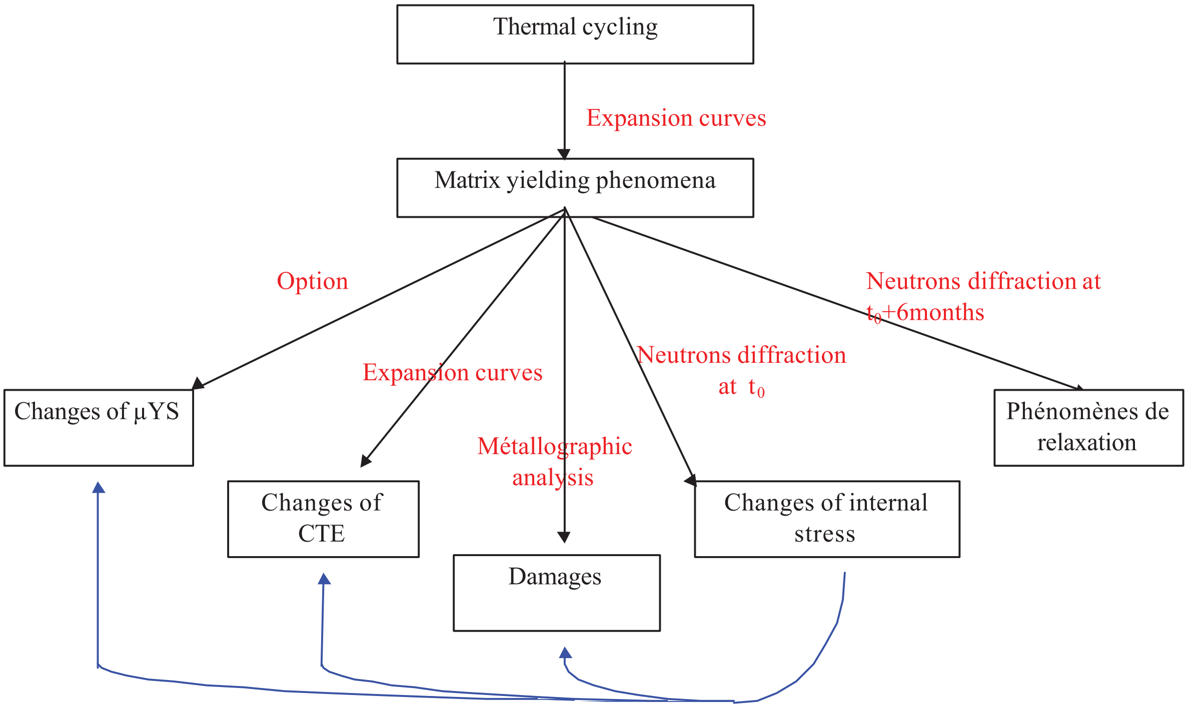
Experimental curves

## Conclusion :

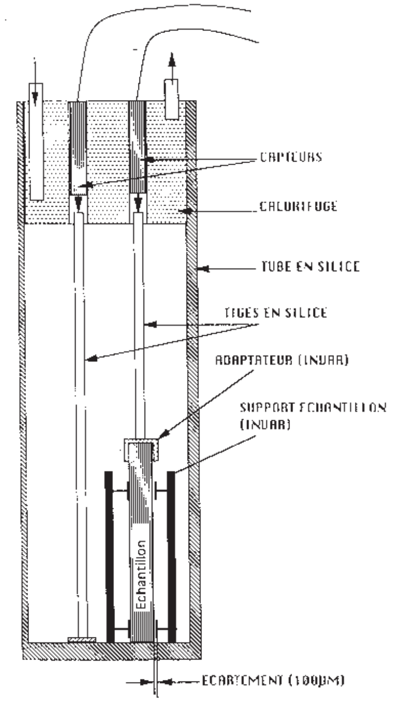
CTE = 0.1 +- 0.24 µm/m/°C on [+20°C;+50°C] (3 cycles, 2 samples).

## 3 – Internal stress

### 3.1 – Framework

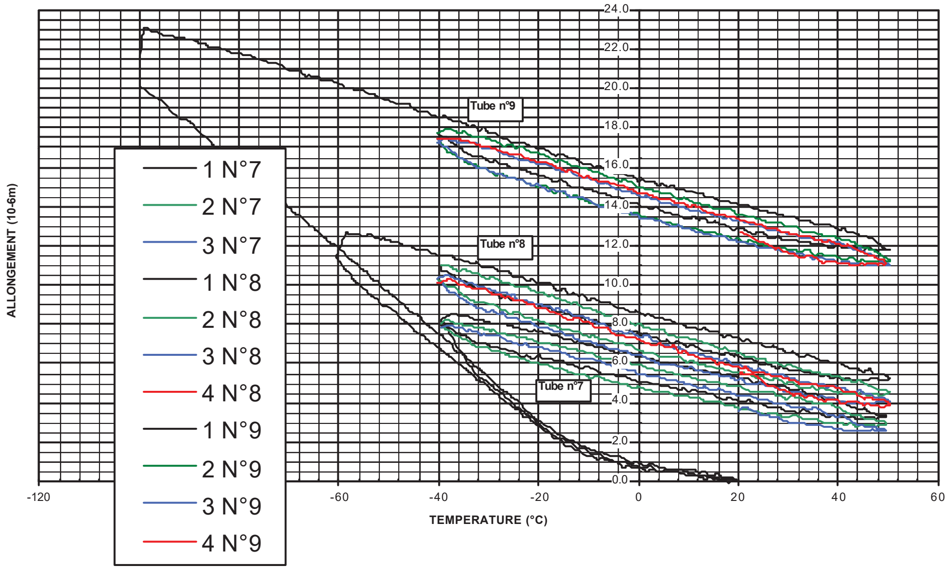


### 3.1 – Expansion curves



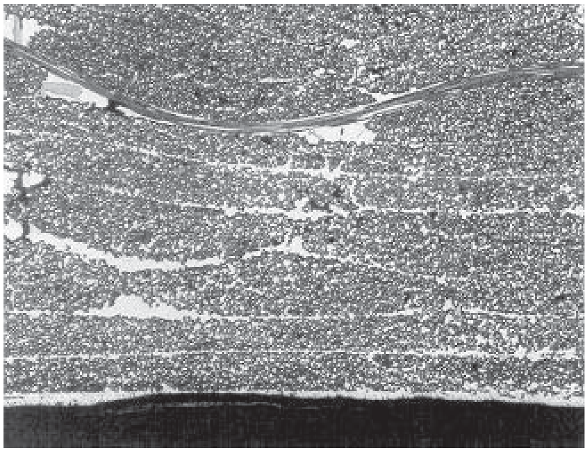
Experience principle

Fig. RESULTATS DU CYCLAGE THERMIQUE SUR TUBE N°7, N°8 ET N°9

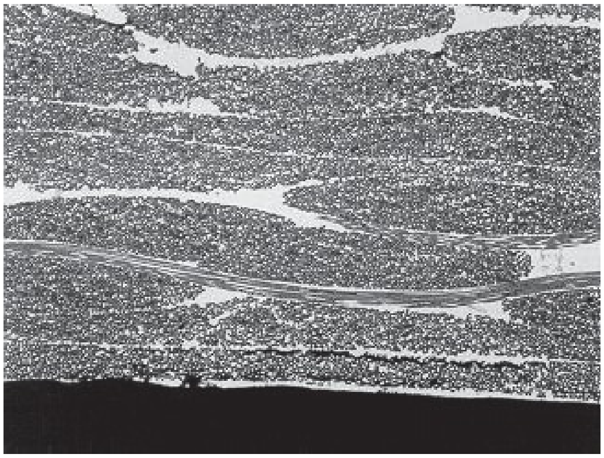


Experimental curves on as-received samples

## Micrography :

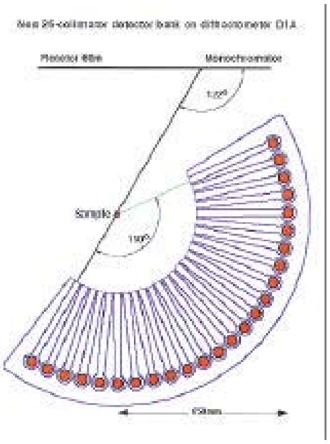


-40°C heat-treated

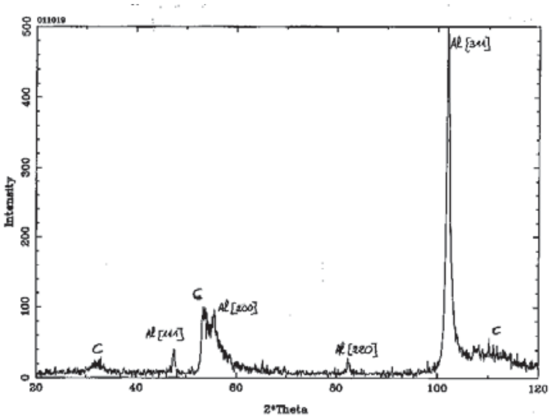


-100°C heat-treated

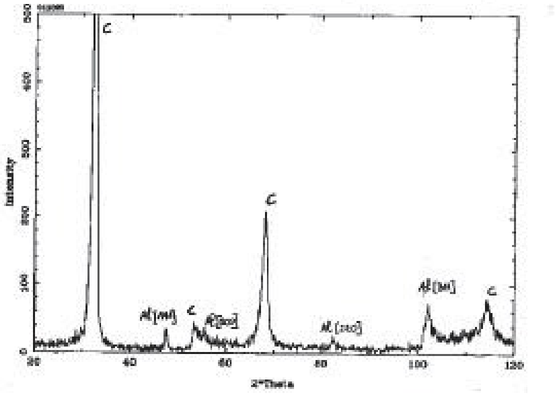
### 3.2 – Internal stress measurement



measurement principle



Axial measurement



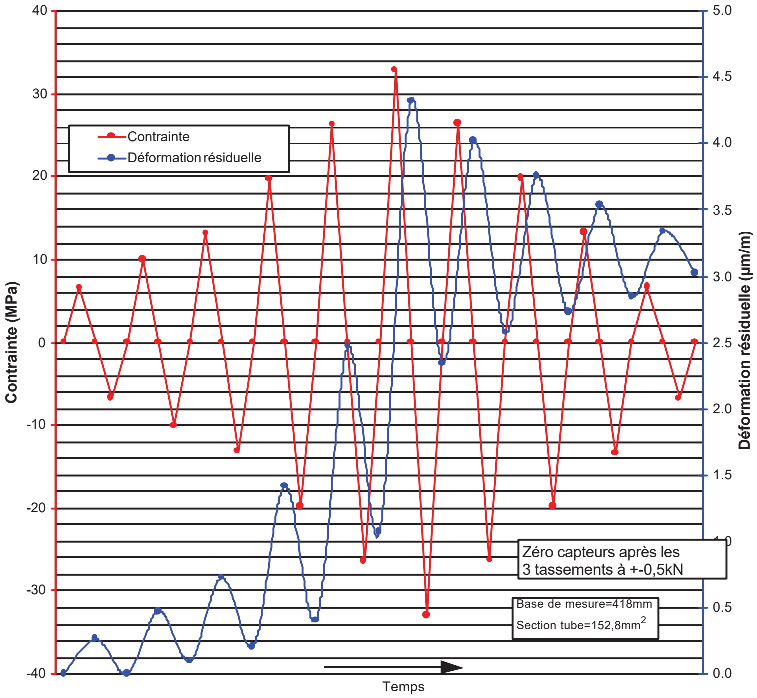
Radial measurement

**Results :**

- Axial stress is always tensile, while radial and hoop stress are compressive
- Thermal cycling decreases internal stress (axial, radial and hoop)
- the lower is the cold temperature, the more internal stress is relaxed

## 3.3 – MicroYield Stress measurement

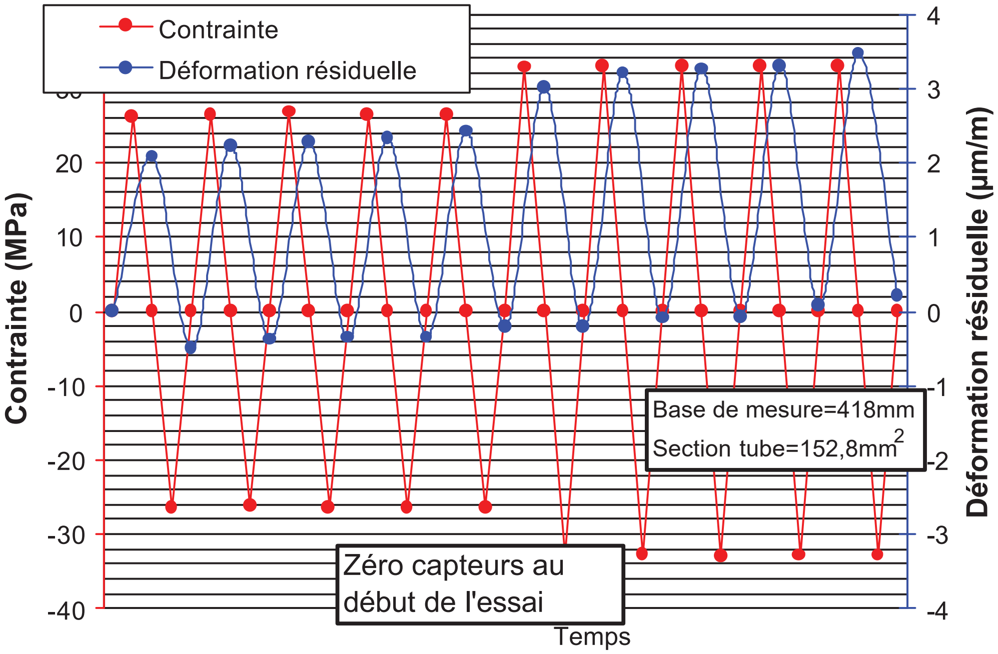
Sample in the Global Device



Zéro capteurs après les 3 tassements à +-0,5kN

Base de mesure=418mm
Section tube=152,8mm$^2$

Coupling beetwen applied stress (alternatively tensile and compressive) and residual strain



Effect of 2 high level of repeated tensile/compressive stress

**Conclusion :**

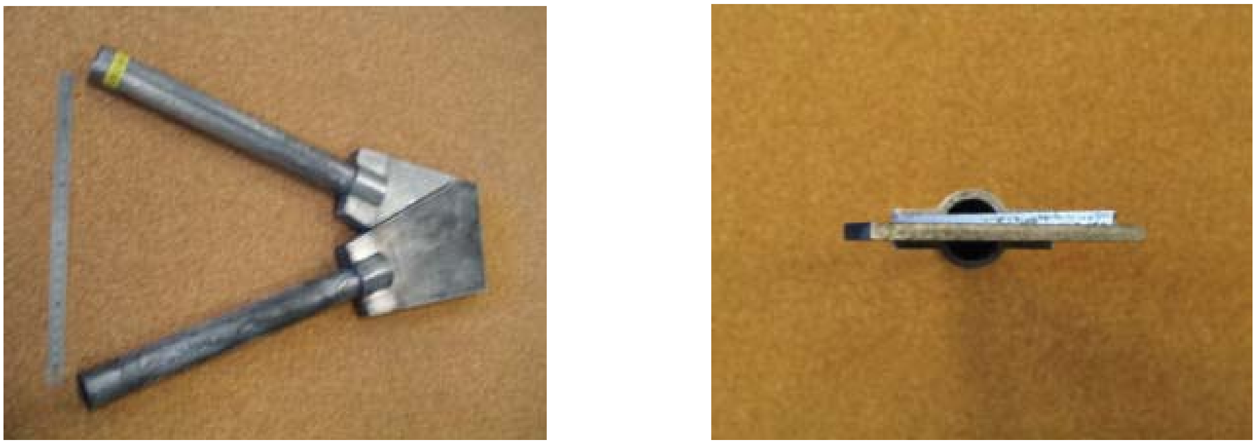
- tensile and compressive MicroYield Strenght are low : the material is hysteretic
- tensile / compressive MicroYield Strenght is just sufficient for stable structure : 56 MPa
- no effect of strength hardening or strength softening

## 3.4 Conclusion

MicroYield Strenght should be increase by thermal cycling. Experience is planned in the beginning of 2001.

## 4 - Linkage studies

### 4.1 – Feasibility of a new stable linkage



tube-plate superposition principle

Feasibilty has been acquirred.

### 4.2 – Gluing MMC / metal

Results have shown delamination of MMC in each case. It has been shown that shear stress concentration in the glue due to the different stiffness of MMC and metal can cause delamination. The further is the ratio of stiffnesses from 100%, the earlier happens delamination of MMC.

### 4.3 – Friction betwwen MMC and metal (or MMC)

Results have shown that friction coefficient is low (about 0.1) compared to classical metal / metal interface (about 0.2). This can be sensitively improved by an adequat surface treatment