UT-VIV/PFC-Damage

TASK-TITLE: STUDY OF DAMAGE MECHANISMS IN PLASMA FACING COMPONENTS

INTRODUCTION

Plasma facing components (PFC) for future fusion reactors have to withstand high heat fluxes. In case of TORE SUPRA, the developed components were made of a high thermal conductivity CFC material (a composite made with carbon matrix reinforced by carbon fibres) mechanically and thermally bonded to a copper heat sink and able to remove incident stationary heat flux of 10 MW/m^2 [1]. In order to reach a value of 20 MW/m^2 for the divertor component of the ITER machine, the lifetime of this assembly submitted to considerable thermal stresses must be increased. The objectives of this activity are:
(i) to provide a study of damage mechanisms of the CFC bond,
(ii) to propose an optimization of the bond and
(iii) to develop a model for predicting the lifetime of the bond under operating conditions.

2005 ACTIVITIES

During this period, the actions foreseen were achieved:

Realisation of mechanical tests on CFC samples in order to identify their constitutive law [2]

Various mechanical tests are necessary in order to identify the damageable constitutive law of the CFC. During this period, a shear test procedure has been developed and validated in order to characterize the non linear shear behaviour of the CFC (figure 1).

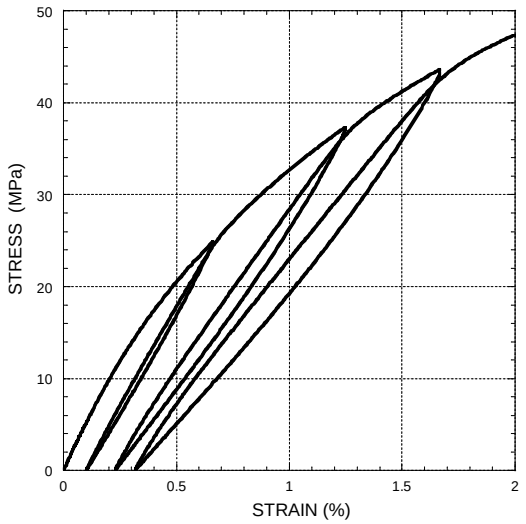
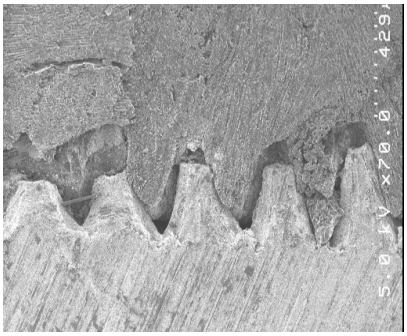


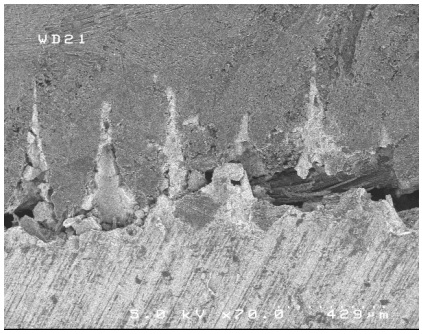
Figure 1: Mechanical response of a HL1 carbon/carbon composite in shear

Observations of damaged tiles to locate damage mechanisms [3]

Damaged tiles obtained from components tested under high heat flux were submitted to micrographic observations. Two damage modes of the interfacial zone were clearly evidenced (figure 2): debonding of the interface and failure of the copper spikes.



a)



b)

Figure 2: The two different mechanisms of failure of the CFC/Cu interface of a PFC tested under high heat flux:
a) debonding of the copper spikes,
b) failure of the copper spikes

Interfacial crack propagation modelling [4], [5]

Numerical simulations were performed to analyse the initiation and the propagation of the interface failure (figure 3). An initiation criterion was used in order to predict the initiation of a crack at the edge of the component as a function of the interfacial properties (figure 4a). A damage model (cohesive zone model) of the interface was identified by comparing modelling results with experimental values obtained from tensile (figure 4b) and shear tests of the bond.

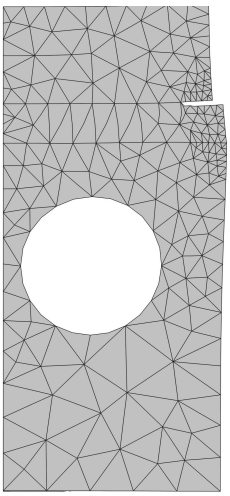


Figure 3: Modelling of the interface : Initiation and propagation of a crack at the CFC/Cu interface

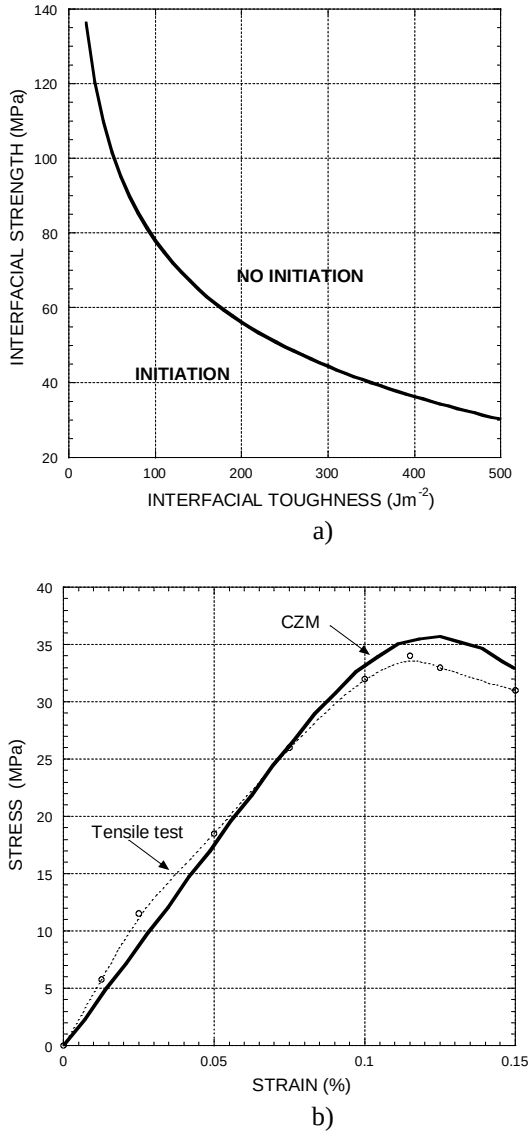


Figure 4: Modelling of the interface
a) Initiation domains as a function of the interfacial strength and toughness
b) Identification of a damage model of the interface with the help of a tensile test on a CFC/Cu specimen

CONCLUSIONS

As detailled before, in 2005, the actions concerning:

- Realisation of mechanical tests on CFC Samples in order to identify their constitutive low;
- Observation of damages tiles to locate damage mechanisms;
- Interfacial crack propagation modelling has been successfully achieved.

The work will continue in 2006 with
(i) tests for thermal expansion measurements of the constituants of the component,
(ii) mechanical tests on CFC samples,
(iii) prediction of the life time of the bond under operating conditions.

REFERENCES

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