Extension of an anisotropic damage model for CMCs to non-proportional multi-axial loadings accounting for crack closure and friction

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Ceramic matrix composites (CMC) are good candidates for the manufacturing of civil aeronautical engine parts or in the nuclear domain regarding their good specific properties at high temperature and under irradiation. In both cases, engineers should have in hand mechanical models in order to size parts. Regarding the SiC/SiC composite family, different crack networks can develop depending on the loading and of the manufacturing process. Some cracks are orientied by the reinforcement directions while others can be oriented by the loading direction which is not known a priori. This is generally the case for inter-yarns cracks. The description of this last network has led to the development of anisotropic damage models in the litterature with the introduction of tensorial damage variables. For example, in [1, 2] second order damage tensors are used while in [3] a fourth order damage tensor is introduced. A major difficulty then resides in accounting crack closure [4] and respecting the good properties of the thermodynamical potential used. In fact, three main phenomena have to be modeled : crack creation, unilateral contact and friction between crack lips in contact. The present paper focuses on the improvement of the model from [3] to account for experimtal data obtained by [5] and [6] on SiC/SiC tubes under multi-axial loadings. Indeed, while based on a very rich damage kinematic represented by compliance tensors, the previous model is based on a scalar isotropic description of the history. In alternate torsion, the principal direction of loading turns of 90 degrees when the sign of shear changes leading to the creation of two orthogonal networks. The modification proposed in [7] is based on the work of [8]. The last author introduces a scalar variable representing the active part of damage as a projection of the damage tensor on the normalized loading direction. Consequently, it is possible to predict an alternate torsion response as illustrated on figure 1. Another evolution of the model concerns the description of friction within cracks loaded in compression and shear. Following the work of [9], a plasticity model coupled to damage is proposed and illustrated on the test of [5] on complex loading paths.

Références

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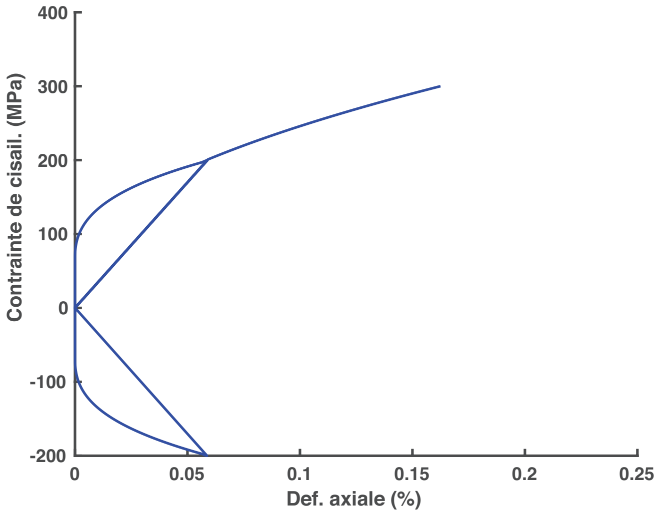

Fig. 1.: *Réponse du modèle amélioré en torsion alternée.*

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