The covariogram: the link between a heterogeneous medium microstructure and its non-local damage behavior.

Hicham El Mansouri*†[1], Mikaël Gueguen‡[1], Damien Halm§[1], and Nait-Ali Azdine¶[1]

[1]Pprime Institute, – UPR CNRS 3346 - ISAE-ENSMA – Poitiers University, France – France

Abstract

The main interest here is to create for composite -e.g. fiber reinforced composites and porous materials- a macro-scale damage model enriched with the micro-scale mechanical behavior field at the initial state, considering for each point and its neighborhood its local microstructure. For this concern, the model must describe precisely the microstructure, including the non-local interactions between the phases due to the local distribution of the inclusions. This description fully summarizes the local morphology, which gives the micro-scale mechanical behavior field when combined with a homogenization method. By consequence, the macro-scale behavior is enriched by the mechanical behavior field, without any hypothesis at the macro-scale, enabling damage simulations on the plain microstructure.
The covariogram is utilized in the process of describing the local morphology by considering the neighborhood around each point. A key point of this process is the neighborhood scale, called meso-scale, which is the location of the non-local interactions: greater scales tend to classic homogenization methods, giving only the mean non-local interaction, and smaller scales tend to full field methods, hiding the non-local interactions at the meso-scale. The scale transition is directly linked to this meso-scale, the dimensions of which are defined by the covariogram on the entire studied medium. The main local informations are the inclusions volume fraction, and the quadratic moments of the local covariogram, reflecting the local morphology.

By incorporating this information to a homogenization method, the mechanical behavior now depends on the local features: the meso-scale is larger than the phase inclusions scale, then it is possible to use classic Eshelby homogenization schemes, by precising on each point the real local microstructure, instead of a homogenized equivalent medium. The result is the actual mechanical behavior field of the studied composite material: full field methods only give the mechanical behavior corresponding to the phase in which the point is located.

In damage simulations for composites, at the initial state, local heterogeneities -e.g. local geometry, mesh or boundary condition- are set arbitrary to initiate a crack where it is supposed to happen. The covariogram approach naturally introduces these stress heterogeneities without resort to these local heterogeneities, thanks to the micro-scale behavior

*Speaker
†Corresponding author: hicham.el-mansouri@ensma.fr
‡Corresponding author: mikael.gueguen@ensma.fr
§Corresponding author: damien.halm@ensma.fr
¶Corresponding author: azdine.nait-ali@ensma.fr

field -which means that they are also quantitative.
In practice, the mechanical behavior field serves as the initial state for a FEM tensile test performed on an isoparametric square mesh. To simulate the composite damage, the 2D Hashin model which considers independent damage modes -i.e. fiber failure and matrix damage- is used here. The damage values soften the initial mechanical behavior of the composite. Results show cracks initiation, propagation and coalescence at the weak points of the studied medium, in a smeared way, enlightening the role of the non-local interactions.