A Thermodynamically Consistent Phase Field Framework for Anisotropic Structural Damage

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ABSTRACT

Phase-field damage models have gained large attention as an efficient way of modeling crack propagation, specially for avoiding the sharp interface between the material and the cracks (Dal et al. 2017). Phase field models based on a variational approach including anisotropic damage growth have been applied to different materials exhibiting complex cracking mechanisms such as unidirectional laminates and biological tissues(Li, Peco, Millán, Arias & Arroyo 2015, Dal et al. 2017, Teichtmeister & Miehe 2015, Mozaffari & Voyiadjis 2015, Clayton & Knap 2015, Nicoli & Karma 2013, Li, Peco, Millán & Arias 2015, Nguyen et al. 2017). But in some of these models the thermodynamic consistency is unclear, while others consider just isothermal case. Therefore, to overcome these deficiencies and to contribute to the development of damage models for anisotropic materials such as composite laminates we present in this work an thermodynamically consistent non-isothermal model for anisotropic structural damage. The hypothesis of small deformation was considered.

This model is an extension of the approach developed by Boldrini et al. (2016) by including the fracture anisotropy in a similar manner as described by Clayton & Knap (2015), Nguyen et al. (2017). The ideas presented by these authors were chosen due to the easiness of implementation and ability to capture the crack path dependency on the material symmetry.

The model was implemented in Matlab and simulations of tensile tests in I-shaped and notched specimens showed that the model is capable to recover the isotropic damage evolution and to reproduce the expected crack propagation pattern for a material with one or two preferential direction of fracture oriented at 45^o and -45^o.

It is worth mentioning that in this approach the crack orientation is predefined based on observations of the morphology of the material and is not a consequence of the anisotropic material response to the boundary conditions and applied load. In an attempt to address this problem and make the model more general, we are working on the transformation of the degradation function into a symmetric tensor with its own evolution equation, as an internal variable, with dependence on the damage scalar variable.

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