Introducing Temperature into a Phase Field Model for Martensitic Transformation - a Coupled Approach

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ABSTRACT

Metallic materials often have a complex microstructure. Allotropes, such as iron, show different crystal configurations with distinct material properties. In most applications, the evolution from a metastable austenitic parent phase to martensitic phases is crucial for the overall material properties. The transformation can be induced by heat treatment or by plastic deformation. Cryogenic turning aims at causing phase transformation during the machining process by applying compression on the work piece, and cooling it at low temperatures using a cooling agent [1]. This leads to a locally and temporally dependent temperature field, motivating the finite element study presented here.

Schmitt et. al. [3] introduce a phase field model for martensitic transformations at a constant temperature, where a small deformation plane strain setting is assumed. Two order parameters, varying between 0 and 1, are used to identify the austenitic parent phase, as well as two martensitic orientation variants. The order parameter evolves according to the local minimisation of the total free energy, accounting for an elastic energy density, a gradient potential and a separation potential. The latter is thought to be temperature dependent [2]. In order to consider a transient temperature field, the temperature is introduced as an additional degree of freedom, leading to a coupling of the heat equation and the evolution equation of the order parameter through the separation potential, as well as a coupling of the heat equation and the mechanical field equations through thermal expansion. The model is implemented as a 4-node element with bi-linear shape functions in the finite element code FEAP. Illustrative numerical examples are given to clarify the importance of the temperature with regard to the martensitic transformation.

REFERENCES

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