Titre

Modelling Strain Gradient Effects Induced by Microstructure on the Mechanical Behaviour of Multiphase Steels

Directeur de thèse

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Résumé

Classical homogenisation methods in the mechanics of heterogeneous materials are not sufficient to predict the influence of the morphology of complex microstructures on the global mechanical behaviour of the material. At present, these methods are not able to account for size effects induced by the characteristic lengths of the microstructure (grain size, thickness of lamellae...). The mechanics of generalised continua incorporating additional degrees of freedom is a good candidate to model effective properties depending on absolute sizes of the constituents. The corresponding elastic-plastic constitutive equations will be based on concepts of physical metallurgy, for instance the notion of geometrically necessary dislocations.

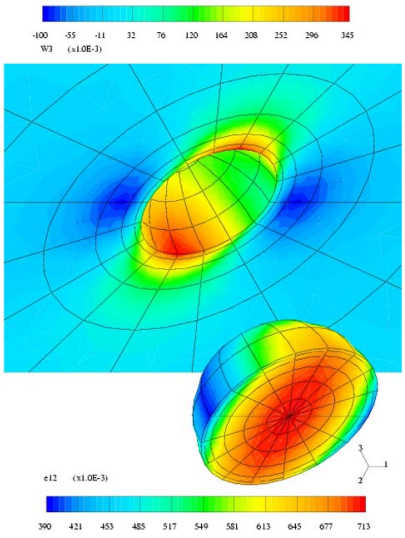
microstructure lamellaire d'un acier perlitique

The development of high-strength steels involves more and more efficient use of metallurgical possibilities existing in ferrous alloys. To improve the performance of novel materials, the microstructure becomes more and more complex, involving small-size constituents having various mechanical properties (ferrite, bainite, carbides, austenite, martensite...). To predict the mechanical behaviour of these complex microstructures, one has to take into account the individual behaviour of each constituent as well as constraint effects due to the refinement of the microstructure. Typical microstructures considered in this work are multiphase alloys like dual-phase steels, and lamellar (or lath) structures such as bainitic steels or pearlitic steels. A mixture of such microstructures is found in TRIP steels. Numerous experimental data are already available concerning microstructure description and mechanical properties of these materials.

The thesis tackles theoretical and numerical problems (mechanics of generalised continua, physical metallurgy, homogenisation methods, Finite Element methods) but also requires experimental observations of the deformation mechanisms of the microstructures. Some tools, methods and results are already available at IRSID and at the Centre des Matériaux. Accordingly, the work will take place alternatively at IRSID and at the Centre des Matériaux, when necessary. The approach could be as follows:

- Choice of a continuum model accounting for size effects in crystalline solids, and numerical implementation of efficient algorithms.
- Application to two-phase polycrystalline morphologies : a self-consistent-like homogenisation model could be developed taking a Cosserat or second gradient constitutive behaviour for the constituents.
- Application to lamellar morphology . In this particular case, the nature of local work hardening (i.e. kinematic or isotropic) will be questioned.
- Experimental identification of deformation mechanisms in lamellar microstructures, especially of the nature of activated slip systems. This may be very different from the systems observed in the bulk phase.

Required Background: Continuum mechanics, Finite Element Methods, Mechanics of Heterogeneous Materials.



Calcul d'inclusion de Cosserat dans une matrice infinie

Relations contractuelles

IRSID, USINOR Group