Heterogeneous microstructure informed computational unit cell modelling of the plastic behaviour of dual-phase steels

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Dual-phase steels have long been used in the automotive industry for their excellent mechanical properties in terms of strength and ductility balance combined to a low processing cost. The good compromise between strength and ductility results from the very different properties of the constituent phases, namely ductile ferrite and hard martensite. Dual-phase steels can be produced with either equiaxed or platelet-like second phases.

Even though the behaviour of dual-phase steels is well understood as for the effects of martensite volume fraction, composition and grain size in the case of equiaxed microstructures, the impact of morphology of martensite particle and of its orientation with respect to the loading direction has not been much investigated. Effects of structural heterogeneities and of martensite interconnectivity on plasticity are also incompletely established. A better understanding of the latter variables is needed to guide the generation of steels with improved mechanical properties.

This work investigates therefore the effects at single grain level and at the multigrain level, using a two-scale strategy based on FE calculations performed on unit cells, bypassing the large computational cost of full-field models on RVEs, following earlier works in [1] and [2].

An important outcome is that, although structural heterogeneities - among others morphology - have a limited impact on the effective plastic behaviour until necking, they considerably influence the mechanical fields at the micro-scale and thus largely impact the damage behaviour. An island of interconnected martensite constitutes a particular morphology that does however significantly impact the effective plastic behaviour. Furthermore, taking into account martensite interconnectivity leads to an improved prediction of experimental curves.

References

[1] *Ognedal, A.S., Clausen, A.H., Berstad, T., Seelig, T. and Hopperstad, O.S., "Void nucleation and growth in mineral-filled PVC – An experimental and numerical study", International Journal of Solids and Structures, **51**, 1494-1506 (2014).*

[2] *Hatami, M.K., Pardoen, T., Lacroix, G., Berke, P., Jacques, P.J. and Massart, T.J., "Towards ultra-high ductility TRIP-assisted multiphase steels controlled by strain gradient plasticity effects", Journal of the Mechanics and Physics of Solids, **98**, 201-221 (2017).*