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MULTI-SCALE ANALYSIS OF MARTENSITIC TRANSFORMATIONS IN TRIP-ASSISTED MULTI-PHASE ALLOYS

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Many technologically-relevant multi-phase alloys display a combination of high yield strength and elongation at failure, stemming from a variety of deformation mechanisms acting at the material's microstructure – namely, slip plasticity and martensitic phase transitions. Well-established examples of such materials include TRIP (*transformation-induced plasticity*) steels, who undergo *mechanically-induced* martensitic transformations that play a key role in the observed mechanical response.

The modelling of their mechanical behaviour presents a number of challenges due to aforementioned complexity of interdependent microstructural mechanisms over multiple phases. Many constitutive models have been proposed accounting for the major features of their macroscopic response; however, these often require the extensive experimental calibration of numerous parameters. In this context, multi-scale models fit naturally due to their ability to directly capture the relevant fine-scale crystalline features.

In this contribution, a fully-implicit FE^2 multi-scale approach is employed, based on continuum constitutive models at the crystalline micro-scale. Slip in FCC and BCC lattices is described using classical crystal plasticity; for the latter, non-Schmid effects are also taken into account. Martensitic transformations are modelled using a recently formulated extension of Patel and Cohen's [1] transformation criteria, extended to large-strains and general stress states. The model considers the simultaneous evolution of austenite slip plasticity and martensitic transformations at a given material point, allowing the description of the so-called *strain-induced* transformation regime.

Application examples are presented using both RVE homogenisation and fully-coupled multi-scale analyses, where the models are calibrated using data from micro-pillar experiments performed on the individual phases of a TRIP steel microstructure. Results show that the employed constitutive models successfully capture the experimentally-observed effect of the martensite transition in these alloys, causing an initial softening in their overall response, followed by significant hardening once a substantial amount of martensite is formed.

REFERENCES

[1] J.R. Patel and M. Cohen, Criterion for the action of applied stress in the martensitic transformation. *Acta Metall.*, Vol. **1**, Issue **5**, pp. 531–538, 1953.