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Development of a 3D model for the formation of martensite and associated stresses in dual-phase steels

Modelling Ferrite Deformation Using Cellular Automata Technique

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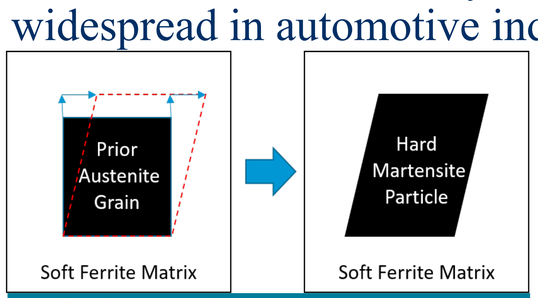
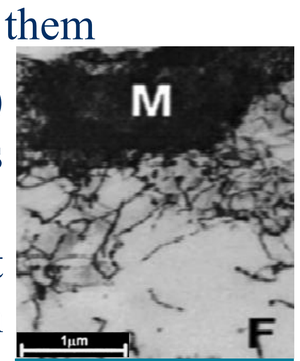
Introduction

- Dual-Phase (DP) steels consist of a mixture of soft ferrite and hard martensite phase, therefore possessing excellent combination of ductility and strength. Their use is widespread in automotive industry



Transformation of austenite into martensite upon quenching, accompanied by a shape and volume change

- The formation of martensite from austenite during quenching deforms the surrounding ferrite regions and introduces stresses in them
- Deformed ferrite (F) near martensite (M) contains high density of dislocations as seen in (TEM) image[1] in the right
- The aim is to develop a model to predict the 3D distribution of transformation induced stresses in ferrite



High dislocation density near martensite/ferrite interface

Experimental Study of Ferrite Deformation

In order to model the stresses in ferrite, qualitative estimates from experiments are made using Kernel Average Misorientation (KAM) values measured through Electron Backscatter Diffraction (EBSD) experiments

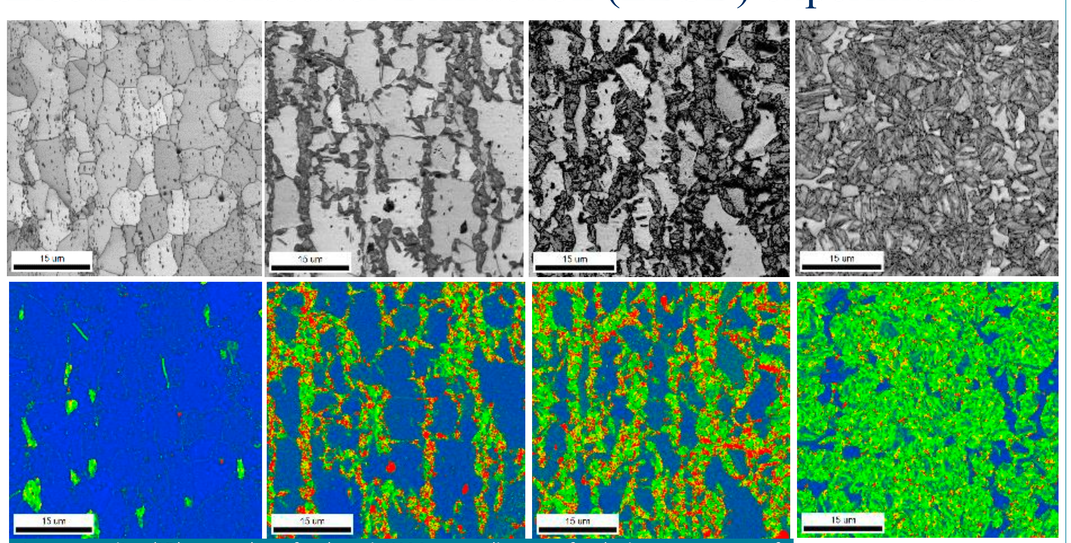
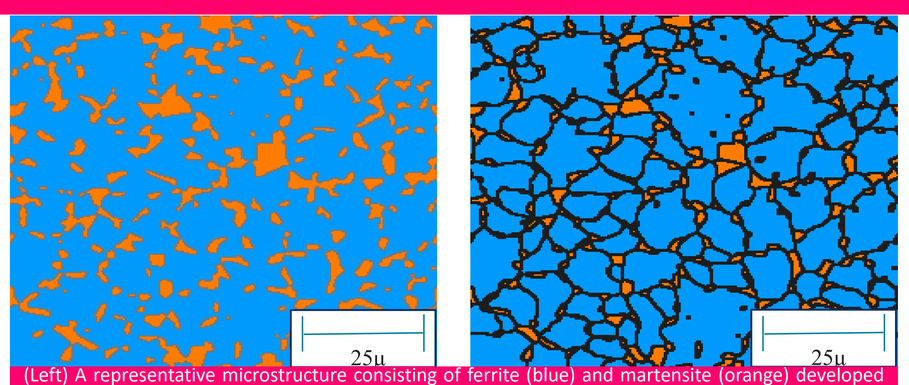


Image quality (IQ) maps (top four) and KAM maps (bottom four) showing extent of misorientation (and hence deformation) in the microstructures containing increasing amount of martensite from left to right. The dark grey regions in IQ maps are martensite, which have higher misorientations inside them. Some ferrite regions near martensite also have high misorientations as can be seen in corresponding KAM maps

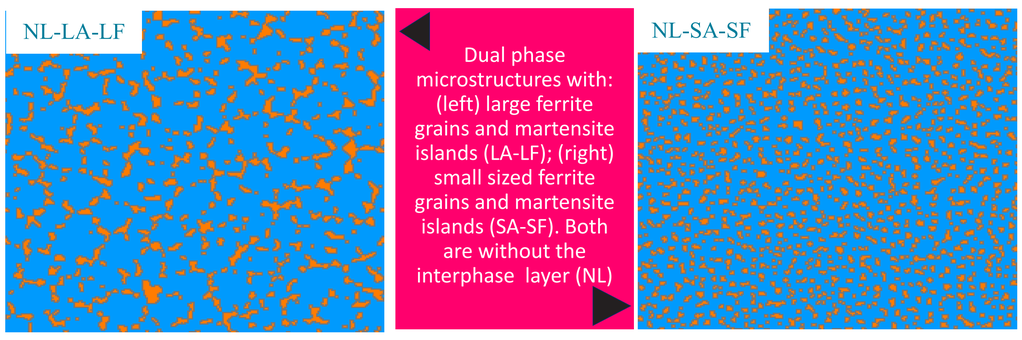
Modelling Using Cellular Automata

- A cellular automata (CA) based approach[2] was used to model deformed ferrite regions (in the form of an interphase layer) in virtual DP steel microstructures
- In CA, a polycrystalline material is discretized into a 2D or 3D grid of cubic cells where every cell belongs to a grain of a specific phase.
- The interphase layer was assigned higher strength than the ferrite matrix, but lower than that of martensite

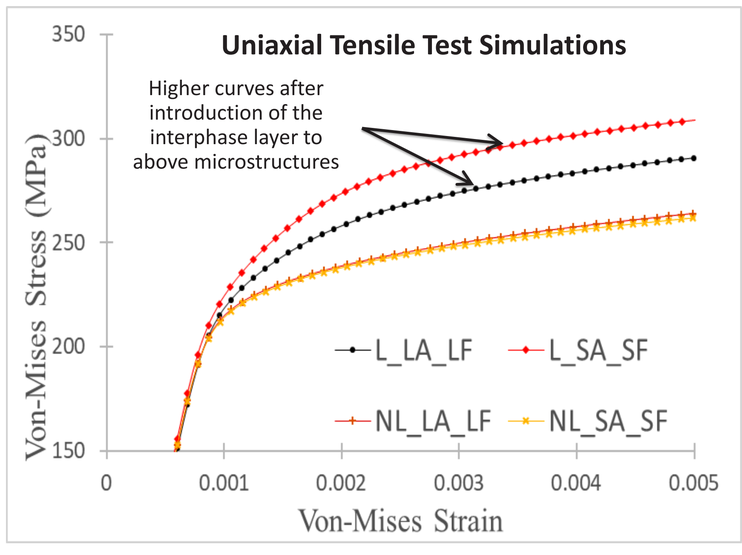
An interphase Layer to Mimic Deformed Ferrite at F/M Interface



(Left) A representative microstructure consisting of ferrite (blue) and martensite (orange) developed using CA. (Right) An interphase layer is introduced at the boundaries to mimic deformed and stressed ferrite regions near martensite. This interphase layer is basically ferrite with higher strength than the ferrite in grain interiors



Dual phase microstructures with: (left) large ferrite grains and martensite islands (LA-LF); (right) small sized ferrite grains and martensite islands (SA-SF). Both are without the interphase layer (NL)



Simulations were performed on 2D representative DP microstructures using crystal plasticity based open source code DAMASK[3]. Phenomenological power law[4] was used as a hardening rule for all phases

Conclusions and Future Work

- Introduction of an interphase layer can be used to mimic deformed ferrite regions and study its effect on macroscopic mechanical behavior of DP steels
- The size effect is a natural outcome of using this technique
- Future work includes linking the formation of hierarchical microstructure of martensite to transformation strains in the microstructure

References

1. Liedl, U., Traint, S. and Werner, E. (2002). An unexpected feature of the stress–strain diagram of dual-phase steel. *Computational Materials Science*, 25(1-2), pp.122-128.
2. C. Bos, M. G. Mecozzi, and J. Sietsma, "A microstructure model for recrystallization and phase transformation during the dual-phase steel annealing cycle," *Comput. Mater. Sci.*, vol. 48, no. 3, pp. 692–699, 2010
3. F. Roters, P. Eisenlohr, C. Kords, D. D. Tjahjanto, M. Diehl, and D. Raabe, "DAMASK: The düsseldorf advanced material simulation kit for studying crystal plasticity using an FE based or a spectral numerical solver," *Procedia IUTAM*, vol. 3, pp. 3–10, 2012..
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Project progress (in years):

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