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MATERIALS AND MANUFACTURING ACADEMY
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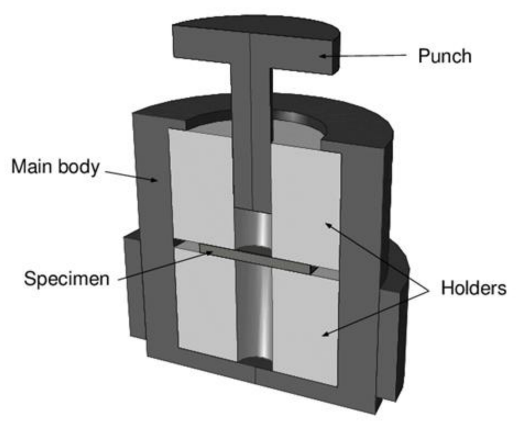
Multiscale Deformation Modelling of Small-Scale Mechanical Tests

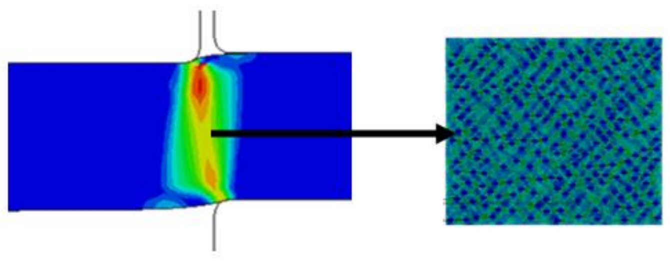
Introduction

Commercial development of new steel alloys is a resource intensive process with long lead times involved. As higher performance targets are being demanded by clients, i.e. downgrading of component sizes, better crash-worthiness in cars and improved formability require the industry to continuously innovate. New development pathways such as laboratory-based Rapid Alloy Prototyping (RAP) using novel miniature testing techniques presents opportunities for large efficiency gains to be made in bringing new alloys to market.

Tests such as Shear Punch (ShP) test can be used to perform many tests using only a small amount of prototype alloy. However, due to complex deformation modes that occur (bending, compression, tensile and shear), making it difficult to extract reliable material properties. It is necessary to model these tests and analyse how damage initiates before then propagating throughout the sample.



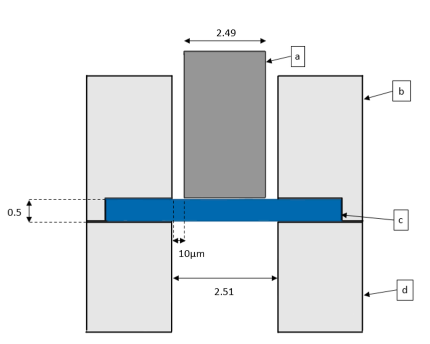
In addition, at these small scales the material properties can no longer be assumed to be isotropic throughout. Particularly for Dual-Phase (DP) steels which consist of a softer ferrite matrix with discrete harder martensite distributed throughout, an uneven phase distribution will impact the deformation response.

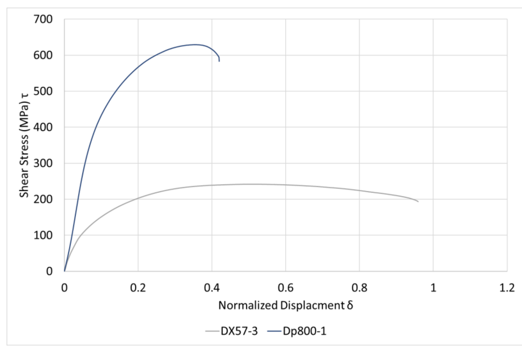


Representative Volume Element (RVE) modelling is used to simulate the effects that microstructure has on the global model, creating a two-scale model. Where the global model is used to derive the loading conditions for the RVE. The model can be used to assess the impacts the microstructure has on prototype alloys as well as compare their material characteristics.

Small Scale Testing

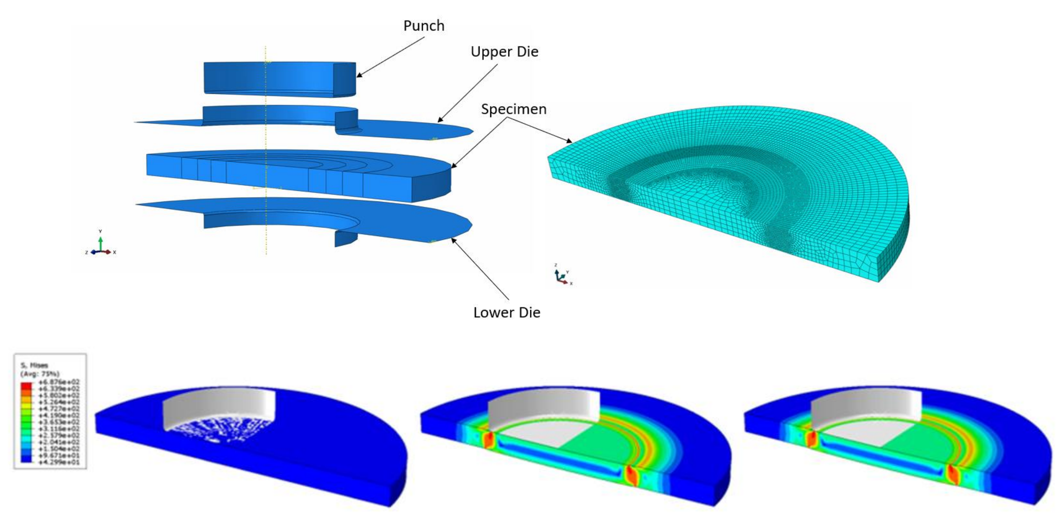
ShP tests uses a disc (0.5mm thickness) that is held in place between two dies. The test uses a flat ended punch that is driven against the specimen. Small clearances are used to create shear dominant deformation. Shear Stress τ and Normalized Displacement δ are used to determine the yield strength and ultimate strength by empirical correlations. 2 alloys, DP800 and DX57 have been tested.





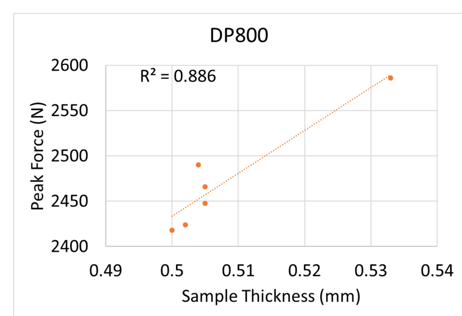
Continuum Modelling

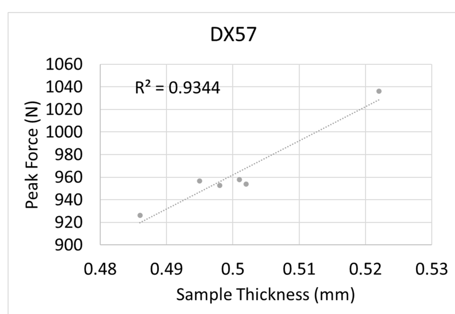
The A 3D ½-Symmetry model is used consisting a deformable disc, rigid clamping components and punch.

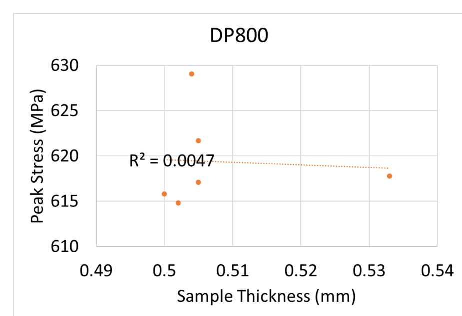


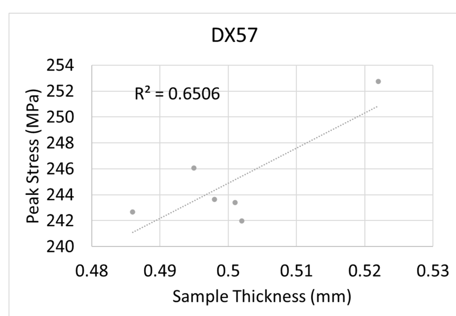
Results

Clearance, friction and sample thickness have been investigated. Due to low punch velocity the system friction has little impact on results up to yield point.





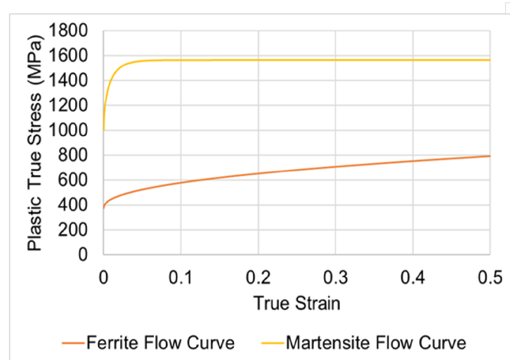


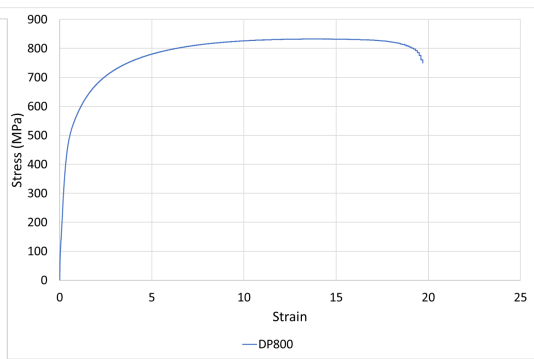


Measured force is dependant on the sample thickness. However, as calculated stress accounts for the thickness. If thickness is within 1% of 0.5mm tolerance its impact is considered negligible. The same is true of the radial clearance when within allowable tolerance of 10%, or 1µm. Clearance is a fixed parameter in the experimental analysis.

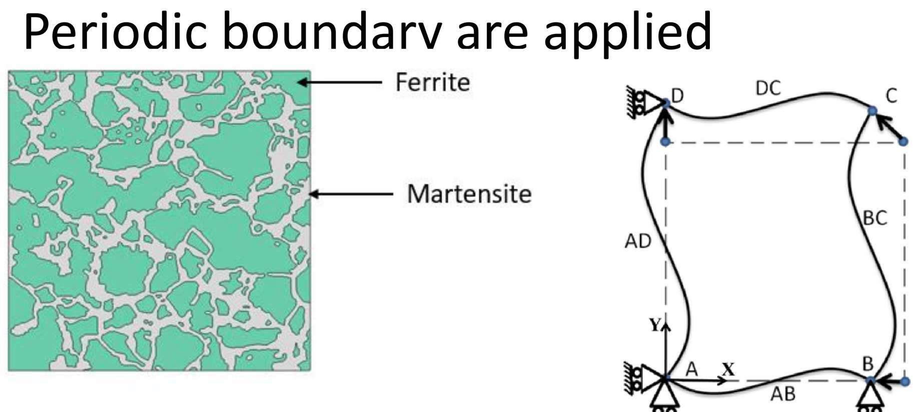
Microstructure Research

As different constituencies will undergo different levels of plastic stress and strain when under the same load it is necessary to model how the different phases will deform. Particular interest is the morphology and grain boundaries.

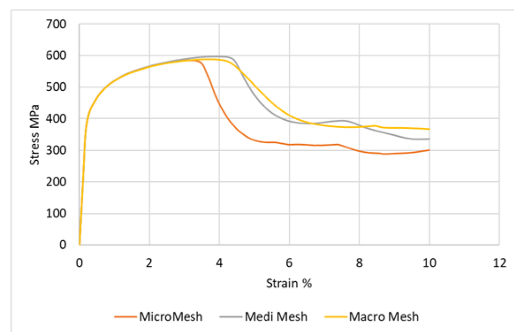


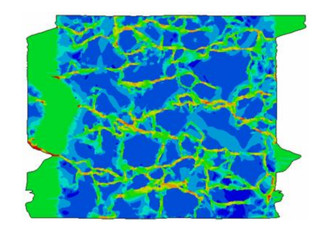


- Ferrite & Martensite are given separate hardening regimes to get global response.
- 2D RVE with 30% martensite has been modelled.
- Periodic boundary are applied

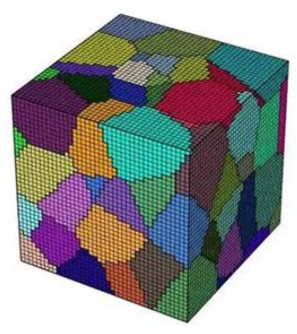


- Stress concentrates in martensite.
- Plastic strain occurs in ferrite phase.
- Damage parameters & work hardening require further development





- Next are using 3D microstructures and pair with global model to define boundary conditions.



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