

Going beyond necking: Using surround DIC to extract true stress–strain curve from uniaxial tension experiments

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Uniaxial tension experiments are amongst the most common mechanical experiments and allow the direct extraction of the material stress-strain curve up to the onset of diffuse necking (Fig 1). Depending on the material, the strain reached at the onset of necking can be a fraction of the strain at fracture, therefore greatly limiting the amount of data available from this type of experiment for behavior parameter identification.

The mechanical behavior at large strain – or in the post-necking range - is of great importance to many engineering processes (metal forming, impact engineering or structural safety design), and many approaches – both experimental, numerical and hybrid - have been established to obtain the stress-strain curves after the onset of diffuse necking and up to fracture. Amongst them, the iterative experimental-numerical method can be used in order to update the hardening model parameters on a detailed finite element model of the tensile experiment until the simulation fits the experimental results.

Other experimental methods such as the bulge, compression, or torsion experiments are typically employed to reach larger strains at the cost of greater experimental complexity.

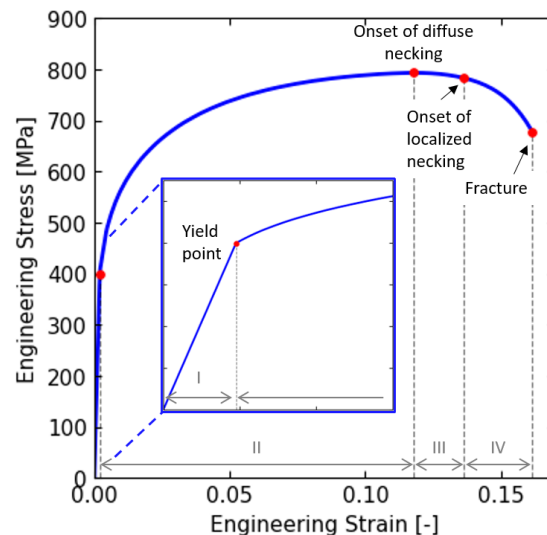


Fig 1: Typical engineering stress–strain curve obtained from a monotonic uniaxial tension experiment featuring four distinct phases until fracture

Here we introduce an experimental protocol combining four 3D-DIC setups (Fig 2), called surround DIC, to obtain accurate specimen shape measurements – particularly the average axial stress - of uniaxial tensile specimens with rectangular gage section [1].

A series of detailed three-dimensional finite element simulations of standard uniaxial tension experiments (ASTM E8) have been performed on a variety of steel and aluminum behaviors. Taking advantage of the measurement capabilities of the surround DIC setup, it is proposed to combine the history of the axial strain

on the surface at the specimen center with the average axial stress to extract the stress–strain curve for strains larger than the onset of diffuse necking, up to a value of 1.

The stress–strain curves obtained with this approach reveal an estimation uncertainty of the same order of magnitude as that of the associated experimental uncertainties. This result has been further empirically validated through an additional computational study of more than 100 distinct hardening behaviors.

Lastly, a surround DIC system is built and used to determine the stress–strain curve for a uniaxial tension experiment of a 1.5 mm thick DP780 steel using the proposed experimental method. The result is compared with the hardening law calibrated using the hybrid experimental-numerical approach and with a bulge experiment of the same material. The proposed method reveals good agreement of the post-necking hardening behavior with the two established methods (Fig 3).

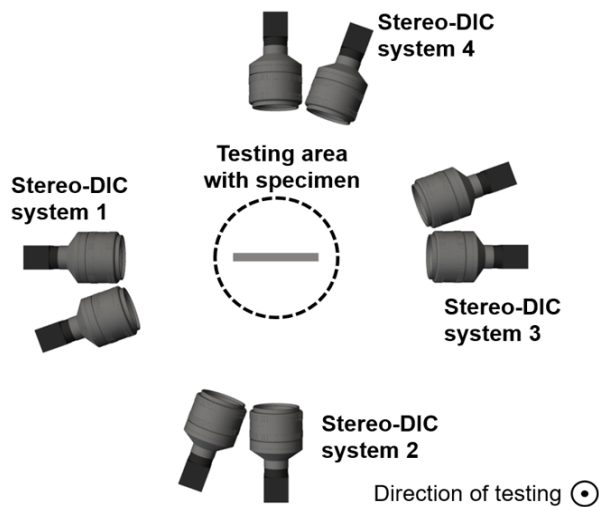


Fig 2: Sketch of the surround DIC system as seen from above

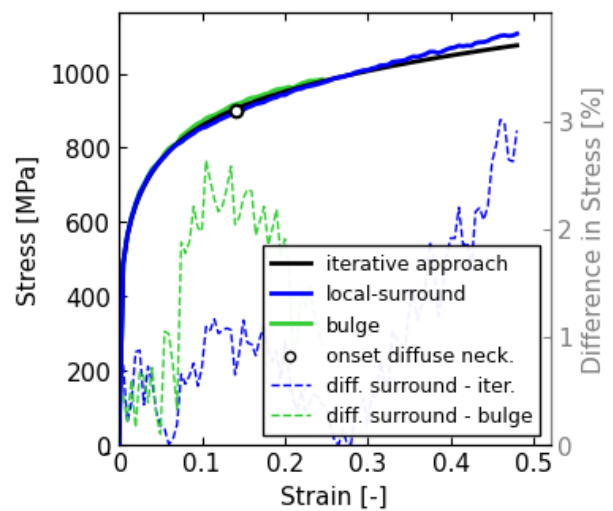


Fig 3: Stress-strain curve for a DP780 steel as determined from a uniaxial tension experiment with the proposed method (blue), a bulge experiment (green) and an iterative experimental–numerical approach (black).

References

- [1] B. Jordan, V. Grolleau and D. Mohr. *Using surround DIC to extract true stress – strain curve from uniaxial tension experiments*, International Journal of Solids and Structures, Vol. 268 (2023), 112171.