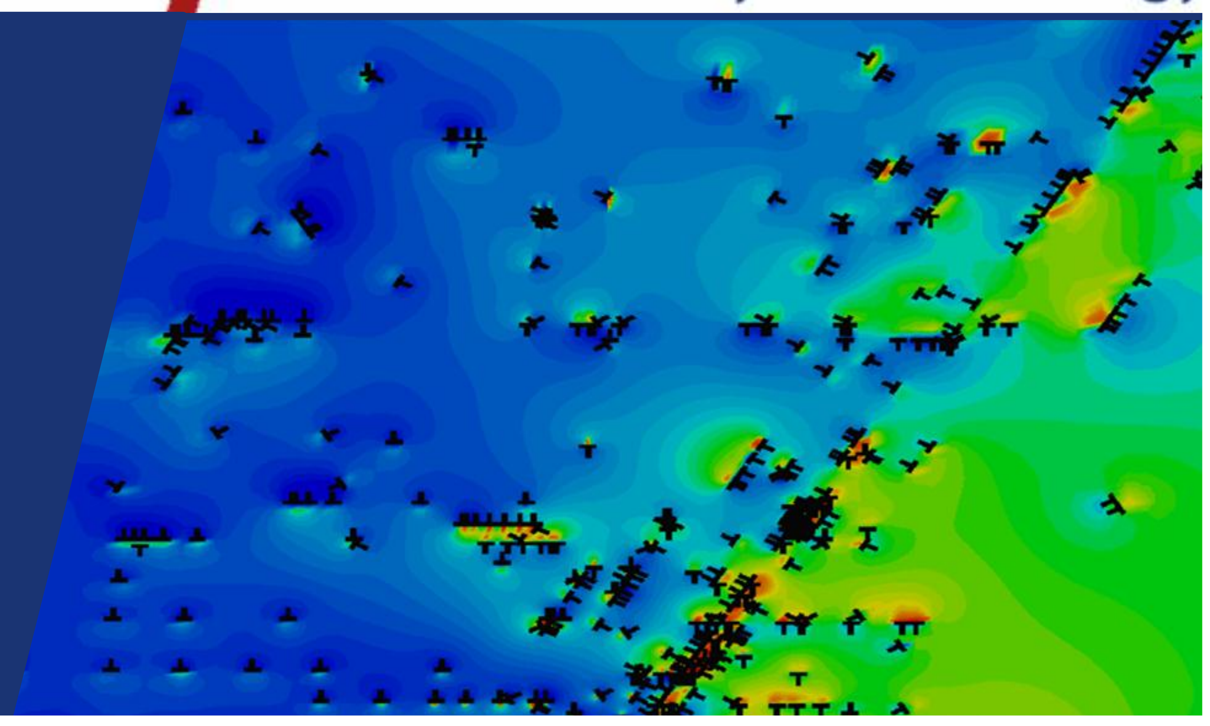
A finite strain discrete dislocation plasticity model

A Finite Strain Discrete Dislocation Plasticity Model

Nilgoon Irani, Joris J.C. Remmers, Vikram S. Deshpande



Introduction

For a wide range of ductile materials, plastic deformation occurs as a consequence of the **collective motion of dislocations gliding on slip planes**. **This motion may lead to finite lattice rotations**. Although the significance of lattice reorientations has long been recognized, **discrete dislocation plasticity framework has been restricted to infinitesimal deformations.**

Goal

Our goal is to develop a discrete dislocation (DD) framework which is capable of capturing **finite lattice rotations** and **shape changes due to slip**. This method gives us the tools for modelling different phenomena such as crack tip blunting, where the lattice rotations are not negligible (Fig.1).

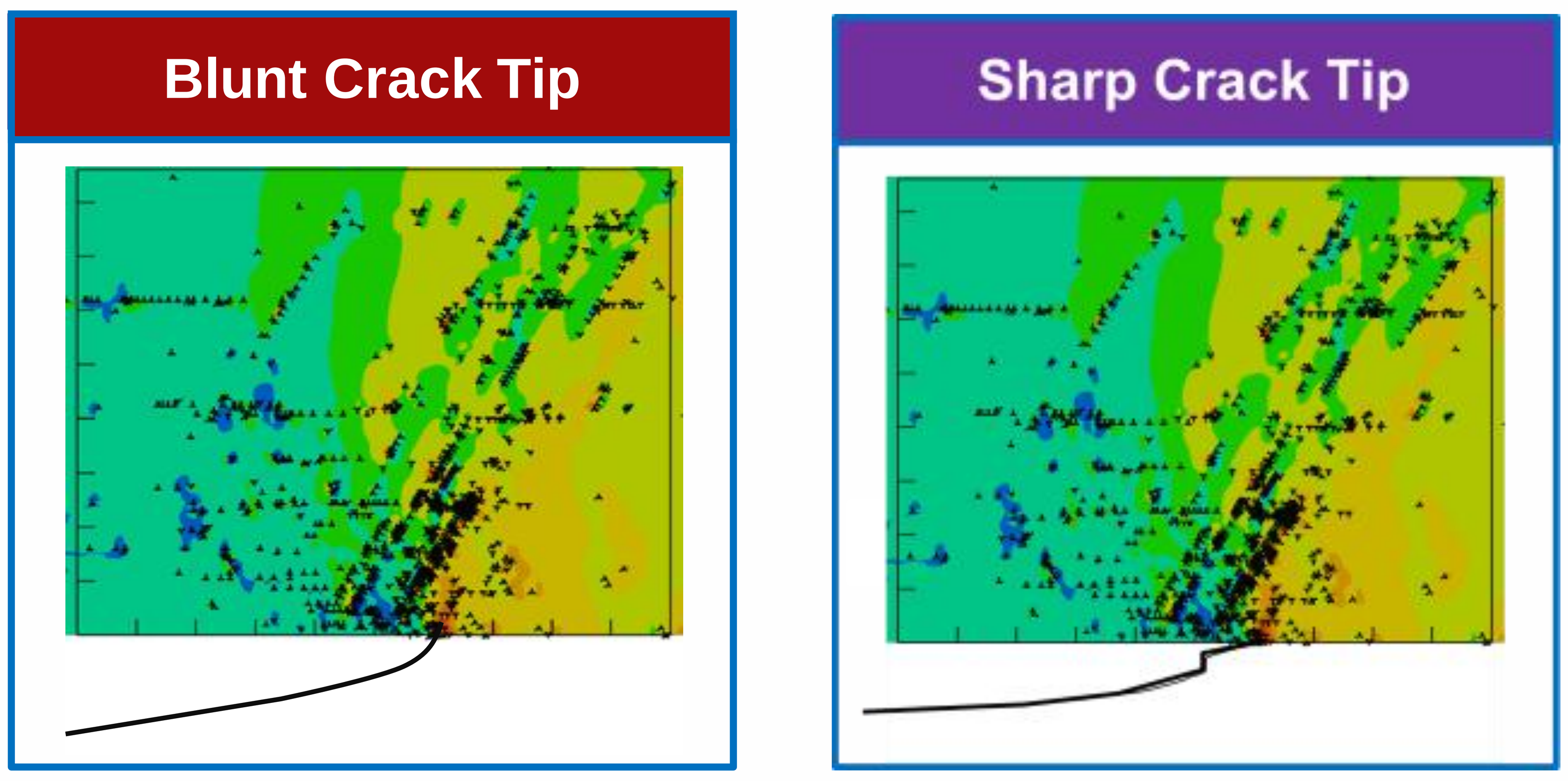


Figure 1: Sharp and blunt crack resemble the possibility of brittle and ductile fracture, respectively. **By using small strain theory we can only model sharp crack tips.**

Challenges

As **the displacement field on the slip plane is not unique**, the derivatives of the displacement field and therefore the strain and stress fields become singular. Hence when solving for these fields we have to deal with singularities.

Method

The nonlinear finite deformation problem is solved by extending the superposition method of Giessen and Needleman [1] and applying a **Total Lagrangian** setting.

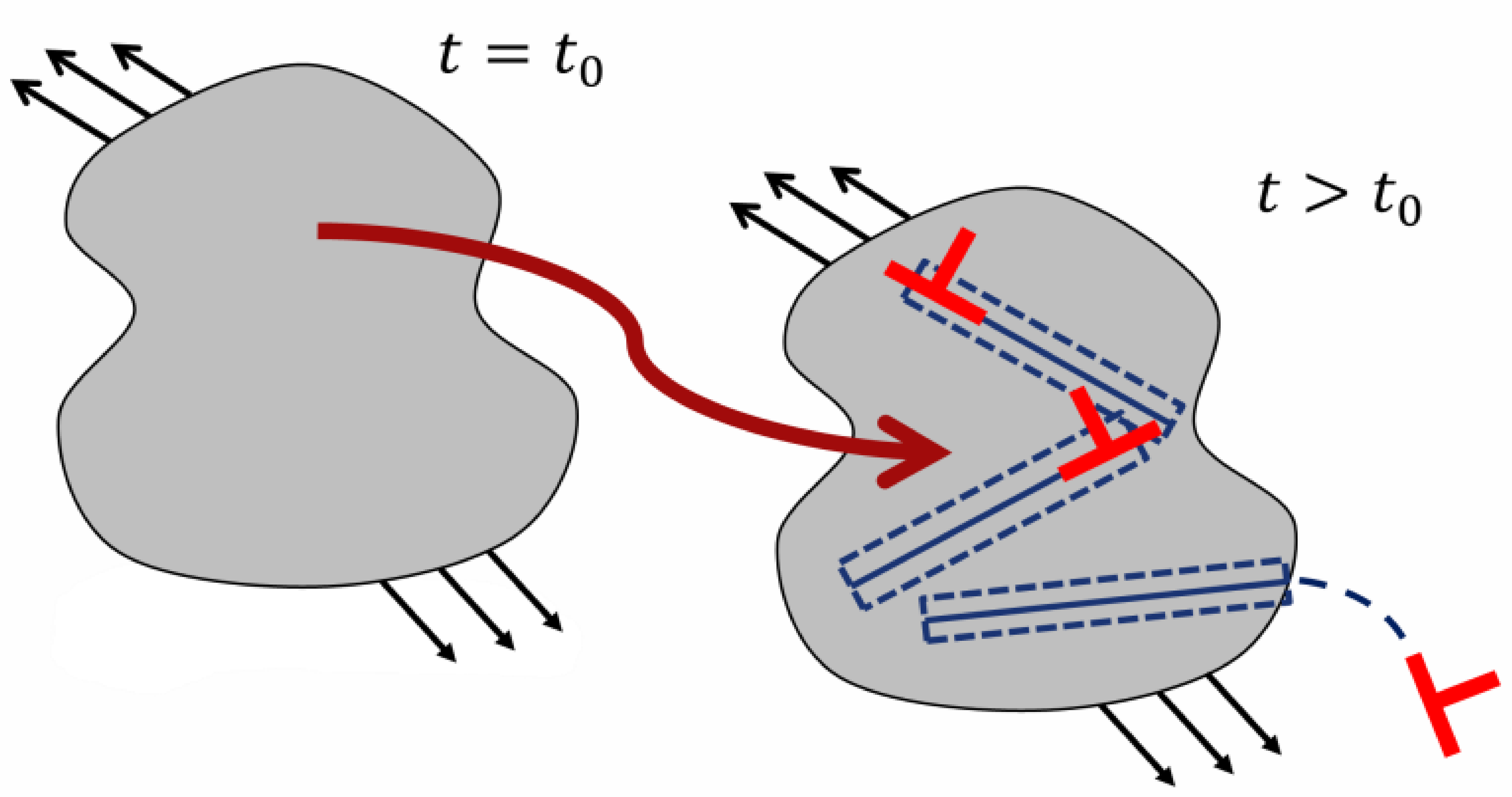


Figure 2: We must keep track of all areas which were subjected to singularity. These areas consist of the points which were touched by dislocations during their slip.

As it was mentioned the displacement field is only piecewise continuous and therefore an iterative **finite element** procedure which is **capable of detecting areas with singularities** is needed (Fig. 2). At time $t = t_0$, our doamin is in its undeformed configuaration. As we increase the loading, dislocations start to appear and they continue to deform our domain by gliding.

Results

Using the new framework we were able to capture the shape changes due to slip and finite lattice rotations. Fig. 3 and 4 compare the results obtained for a tension-compression simulation based on small strain and finite strain assumptions respectively.

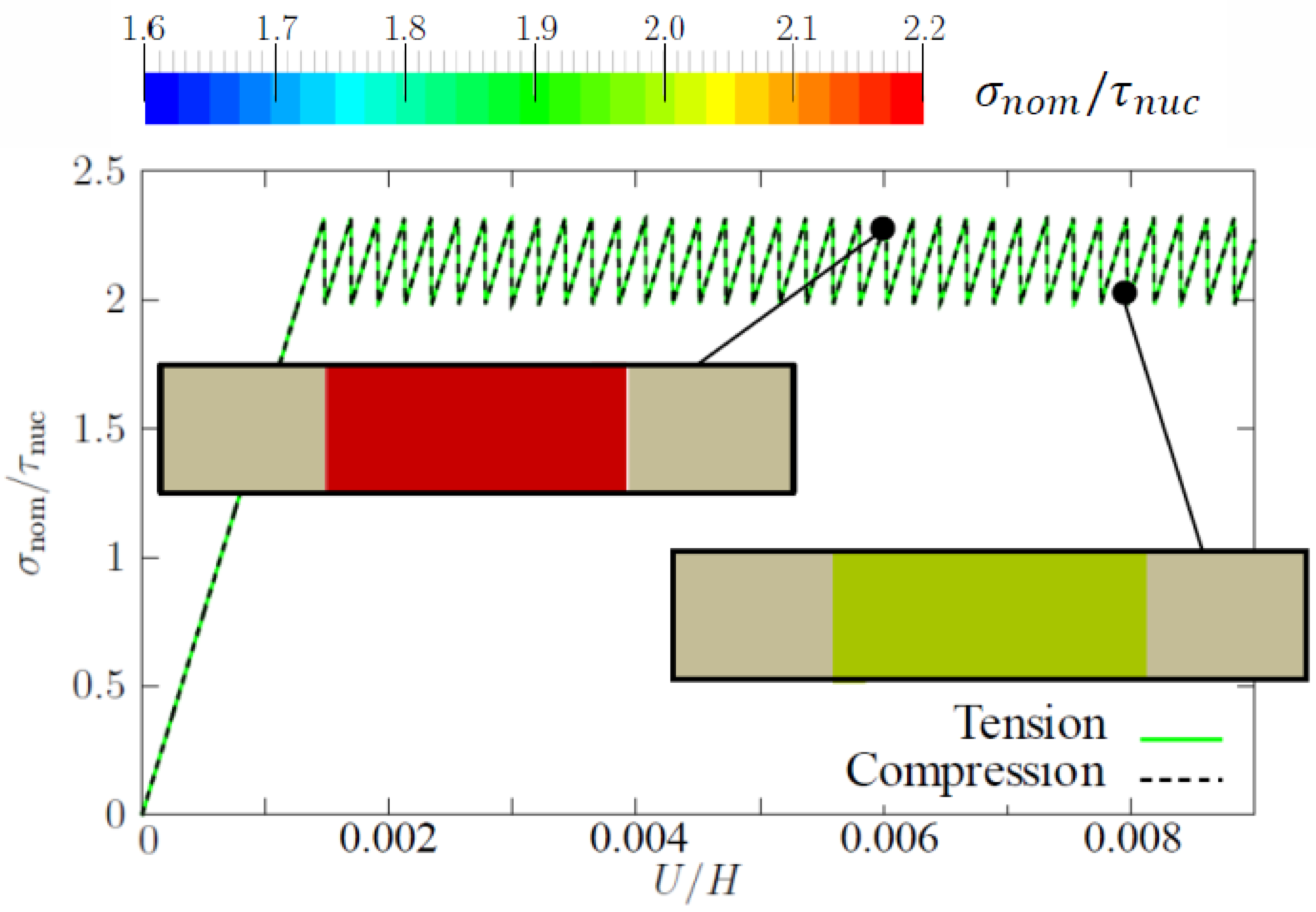


Figure 3: Small Strain predictions of the tensile and compressive response of an initially rectangular specimen.

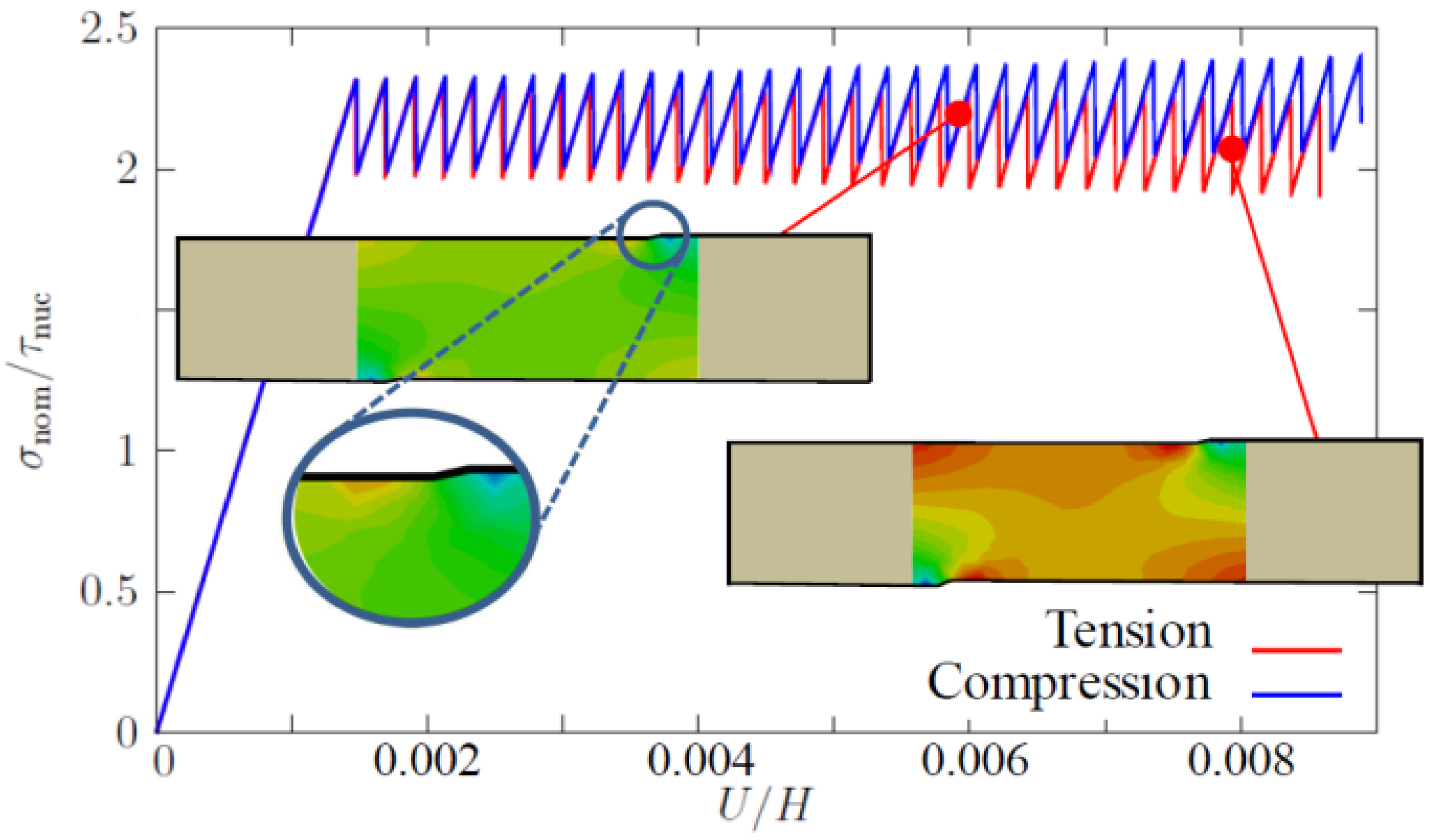


Figure 4: : Finite Strain predictions of the tensile and compressive response of an initially rectangular specimen.

Conclusions

1) We have presented a finite strain DD formulation capable of capturing shape deformations caused by dislocation slip.

2) Our results show that unlike in small strain DD, finite strain effects result in a size dependent tension-compression asymmetry.

/ Department of Mechanical Engineering

References

[1] E. van der Giessen, A. Needleman, 1995
[2] N.Irani, J.J.C. Remmers, V.S. Deshpande, 2015