A finite strain discrete dislocation plasticity model

A Finite Strain Discrete Dislocation Plasticity Model

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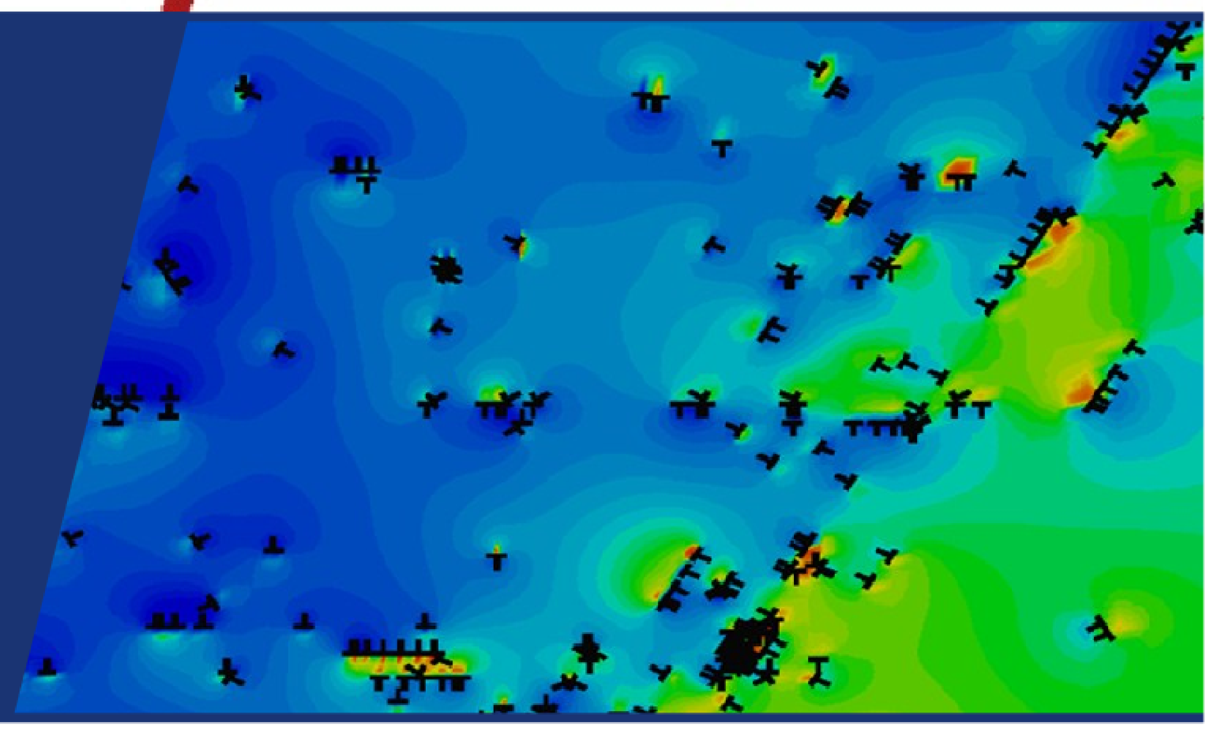

Introduction

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, nevertheless **discrete dislocation plasticity framework has been restricted to infinitesimal deformations.**

Goal

Our goal is to develop a discrete dislocation 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).

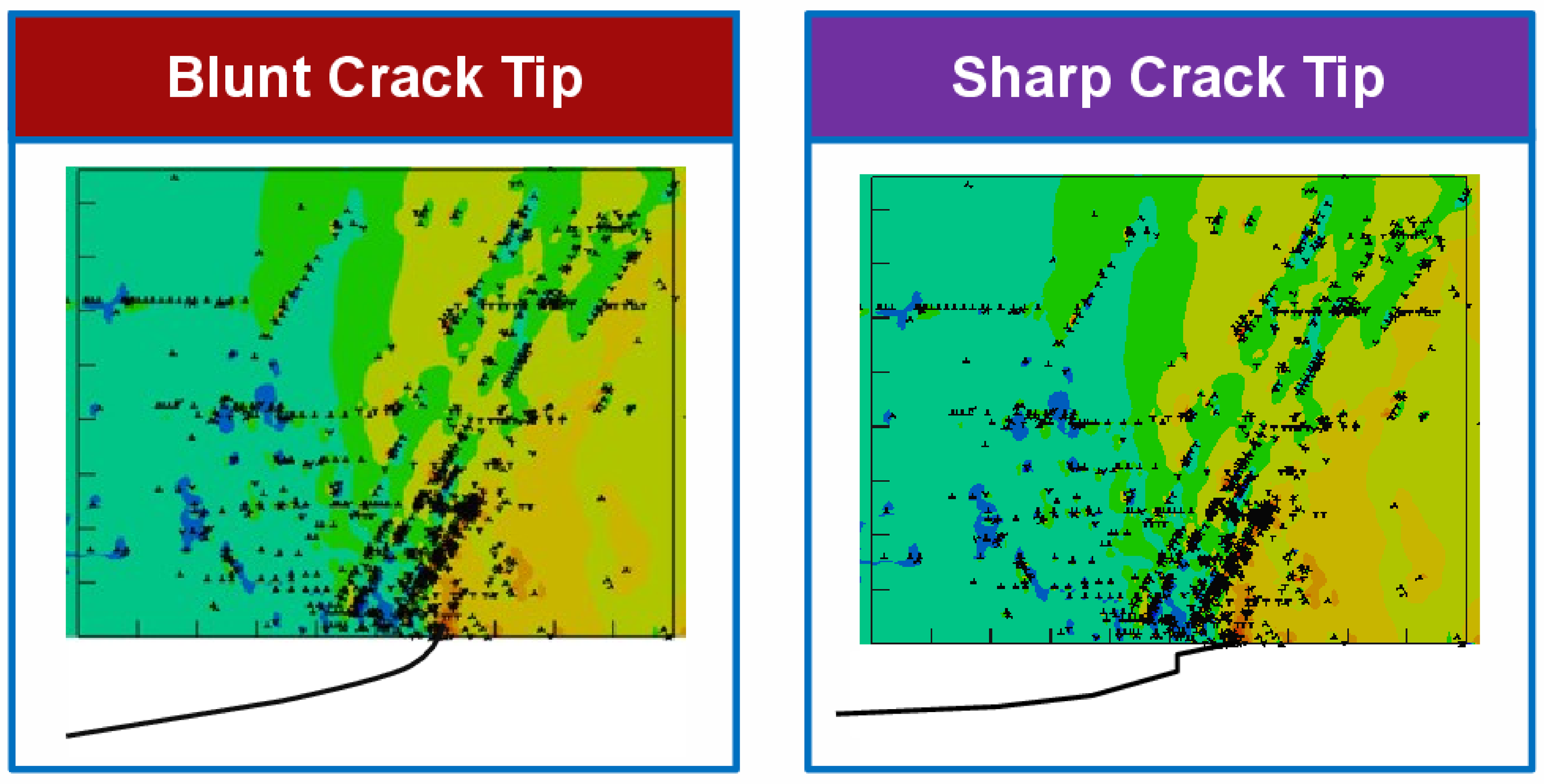

Figure 1: Sharp and blunt crack resemble the possibility of brittle and ductile fracture, respectively. By using small strain theory we can only model sharp crack tips.

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** (Fig. 2). Hence when solving for these fields we have to deal with singularities.

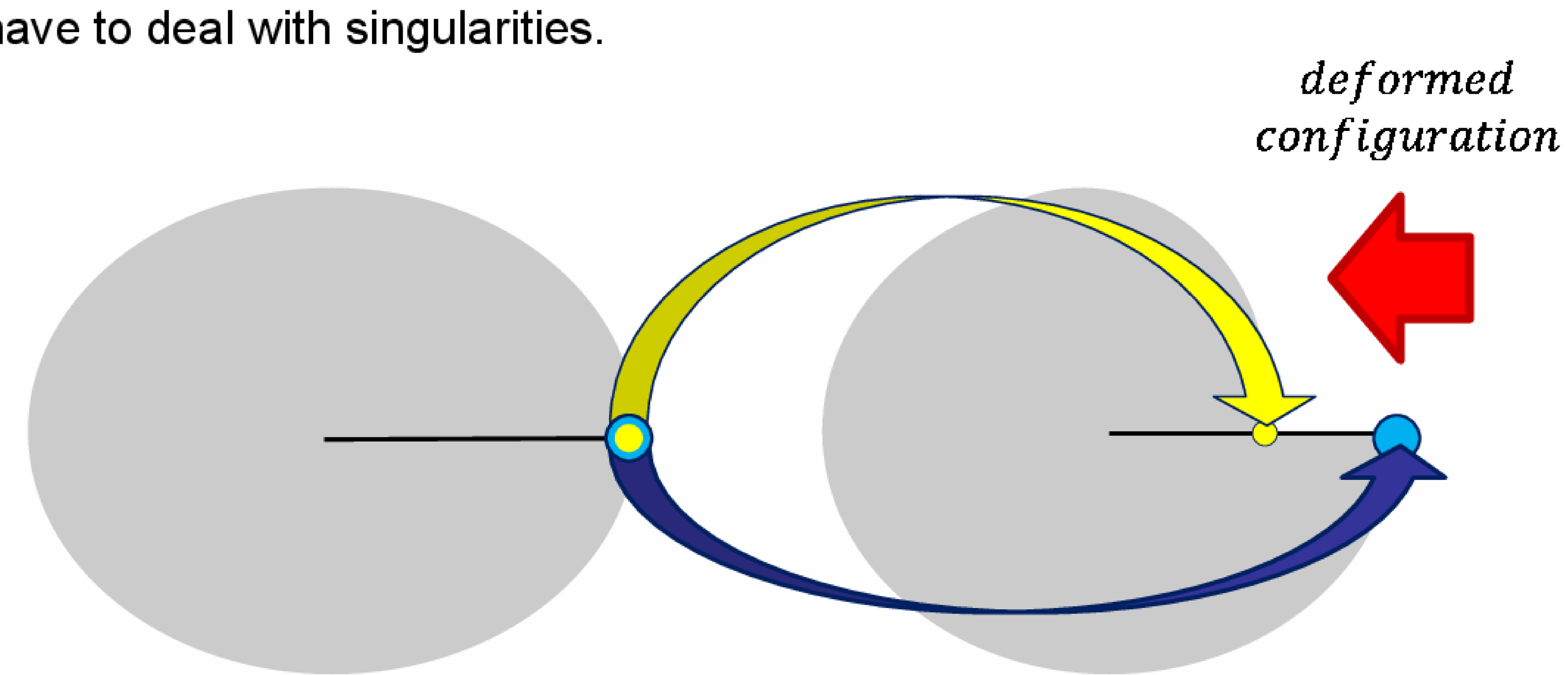

Figure 2: The body at its initial configuration (Left). The body after deformation due to dislocation glide (Right). One may observe that the displacement field on the slip plane is not unique.

Method

The nonlinear finite deformation problem is solved by extending the superposition method of Giessen and Needleman [1] and applying a Total Lagrangian setting. 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. 3). At time $t = t_0$, our domain is in its undeformed configuration. As we increase the loading, dislocations start to appear in our material. These dislocations continue to deform our domain by gliding on slip planes and as they reach the free surface they disappear.

The areas which were touched by dislocations during their slip, are the areas which displacement field becomes singular. One must remember that applying this method, even if a dislocation has exited the domain, the displacement field of the areas which were touched by that dislocation remains singular.

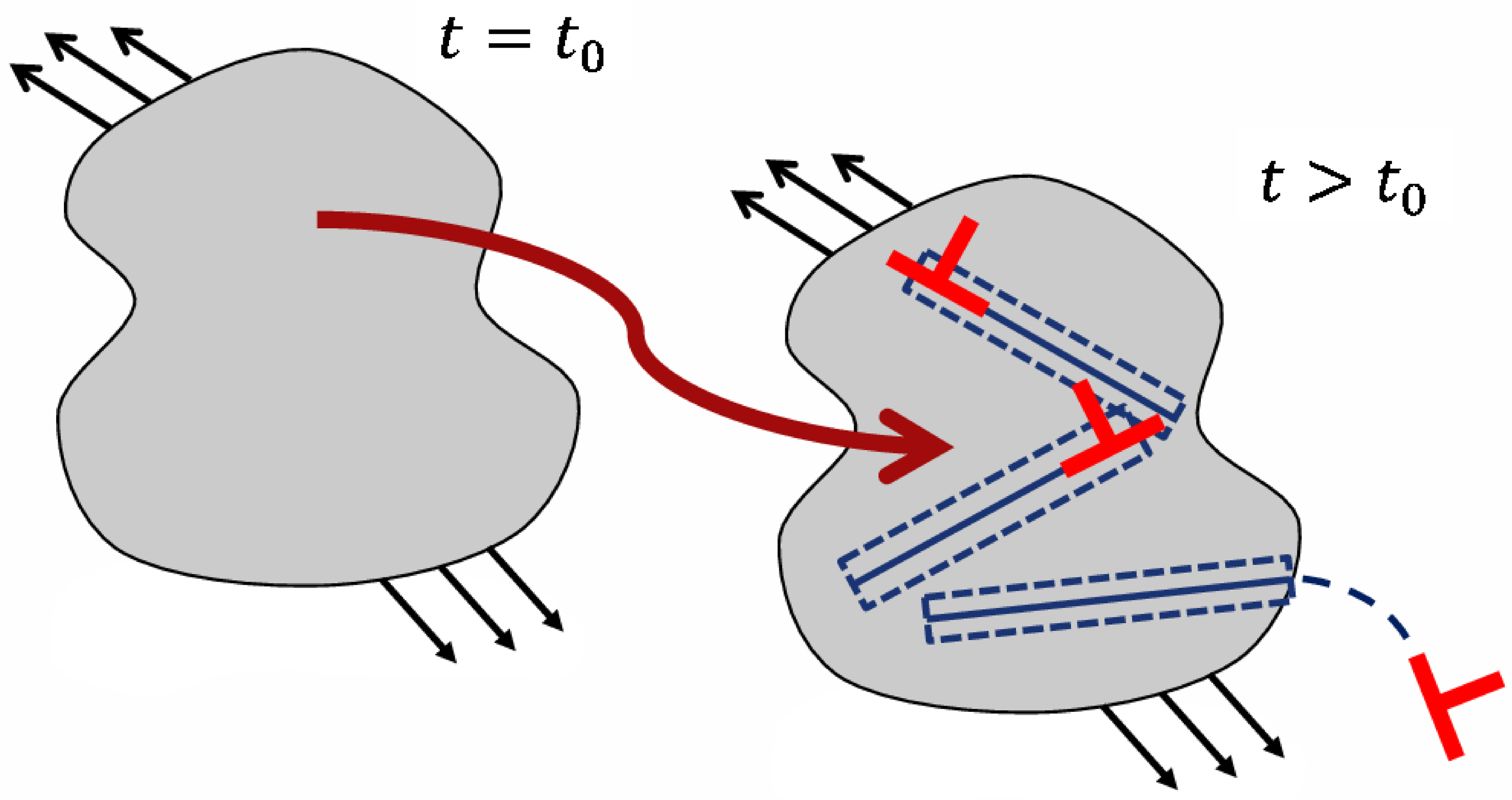

Figure 3: We must keep track of all areas which were subjected to slip. These areas consist of the points which were touched by dislocations during their slip.

Results

Using the new framework we have analyzed the behaviour of a simple shear problem for a rectangular domain with one dislocation source (Fig. 4). We have compared the 2nd Piola-Kirchhoff stresses in Fig. 5. Left: we have neglected the singularities and therefore the stress contour is continuous. Right: we have included the singularities in our calculations. One may notice that in this case the stress field is not continuous.

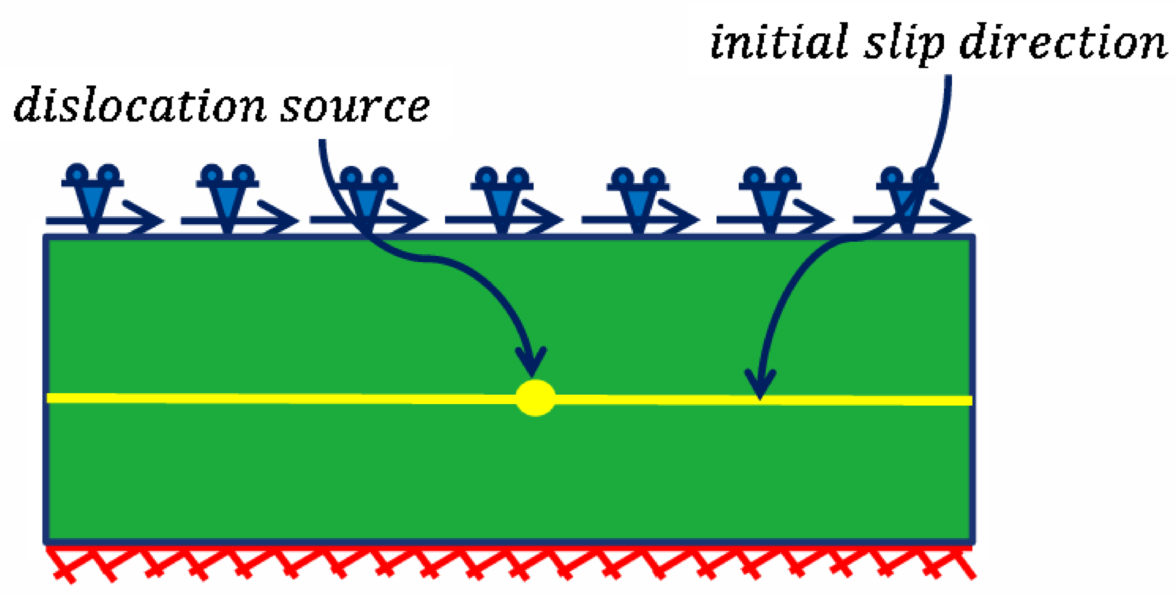

Figure 4: Description of our model.

The line where the discontinuity in the stress field appears is the line on which the dislocations were able to glide. Our results prove that applying the new framework **we have been able to capture the slip effects successfully.**

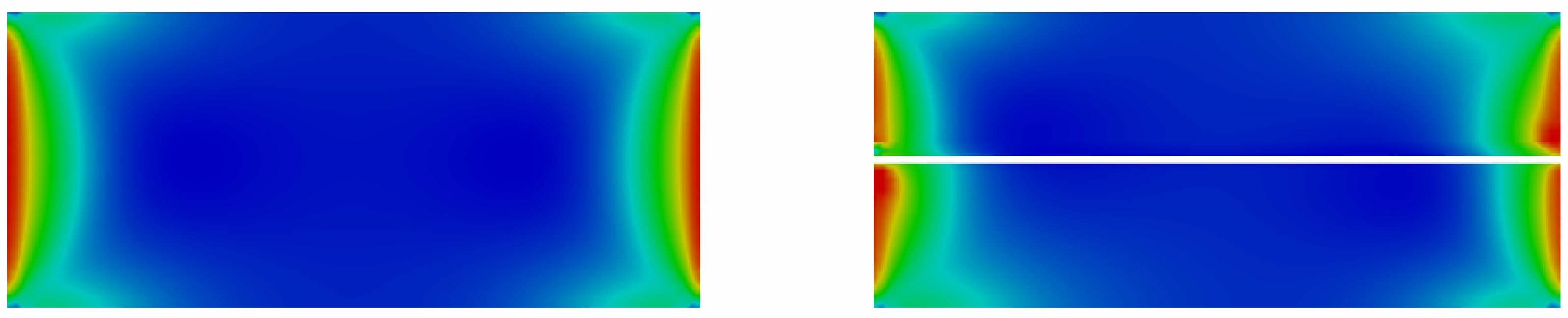

Figure 5: 2nd Piola-Kirchhoff stress contours for a simple shear problem. Left: we have neglected the singularities and therefore the stress contour is continuous. Right: we have included the singularities in our calculations.

References

[1] E. van der Giessen, A. Needleman, 1995

[2] V.S. Deshpande, E. van der Giessen, A. Needleman, 2003