Simulation of Cusp Formation in a Polymer Matrix Loaded in Shear Using the Thick Level Set Method with Plasticity

L.A.T Mororó*† and F.P. van der Meer†

* Federal Institute of Education, Science and Technology of Ceará (IFCE)
Campus Morada Nova, Brazil
e-mail: l.a.taumaturgomororo@tudelft.nl / luiz.mororo@ifce.edu.br

† Delft University of Technology
Faculty of Civil Engineering and Geosciences, P.O. Box 5048, 2600GA, Delft, The Netherlands
e-mail: f.p.vandermeer@tudelft.nl

ABSTRACT

The most mentioned cause for the difference in fracture energy between mode I and mode II loading condition is that, on microlevel, in mode II delamination growth cusp or hackles are being formed. This process starts with an array of inclined cracks which are perpendicular to the direction of maximum principal stress. As these cracks evolve, S-shaped cracks may be formed and eventually merge leading to a single crack on a higher level of observation and debond from the upper and lower boundary of the resin regions in the inter-fiber spacing. Therefore, computational tools that can predict this process on the microscale may lead to a better understanding of this mechanism behind the variability in fracture energy.

The Thick Level Set (TLS) method has been shown to be suitable for the modeling of damage growth. In the TLS, the location of the front of a damaged zone is implicitly represented as the zero level set of an auxiliary field and its evolution is handled with the level set method. Unlike conventional continuum damage models, in which the damage variable is a direct function of local strain field, the TLS considers a band of damage with a predefined characteristic length where the damage variable is an explicit function of the level set value. Because the damage evolution is separated from computation of displacement, the TLS is a robust method which can handle multiple branching and merging cracks. The robustness of the TLS is particularly relevant for the simulation of cusps formation which involves multiple merging cracks.

When loaded in shear, polymers behave plastically prior to failure. Therefore, plasticity in cannot be ignored in an investigation into fracture energy. However, adding plasticity to the TLS is not a straightforward task, because the current solution procedure [1, 2] depends on the assumption of secant unloading behavior.

This work seeks to simulate the cusp formation process more realistically. For this purpose, the TLS method as proposed in [2] is evaluated with respect to its ability to predict cusp formation until the final failure. To represent the plastic behavior of polymers, a pressure dependent plasticity model is implemented in the TLS framework in conjunction with a criterion for damage initiation and a new loading scheme is devised, such that it allows for permanent deformation. Results obtained with the proposed model are quantitatively and qualitatively compared with experimental ones.

REFERENCES

[1] Bernard, P.E., Moës, N. and Chevaugeon, N. Damage growth modeling using the Thick Level Set (TLS) approach: Efficient discretization for quasi-static loadings. *Comp. Methods Appl. Mech. Engrg.* (2012) **233-236**:11-27.

[2] Van der Meer, F.P. and Sluys, L.J. The thick level set method: sliding deformation and damage initiation. *Comput. Methods Appl. Mech. Engrg.* (2015) **285**:64-82.