ILSA schemes for modeling multi-scale processes in hydraulic fracture propagation: a trajectory of research

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Hydraulic fractures (HF) are tensile cracks that propagate in pre-stressed solid media due to the injection of a viscous fluid. Hydraulic fractures are used in a multiplicity of engineering applications, including: the deliberate formation of fracture surfaces in granite quarries; waste disposal; remediation of contaminated soils; cave inducement in mining; and the fracturing of hydrocarbon bearing rocks in order to enhance productivity of oil and gas wells.

Detailed asymptotic analysis in the vicinity of the tip of a propagating HF [1,2] has demonstrated a rich multiscale spatial structure that can occur on multiple time scales. Using a sufficiently refined mesh to capture the finest scale behaviour, while also modeling field-scale HF, would be prohibitively expensive. In this talk I describe a strategy, called the implicit level set algorithm (ILSA) [3,4,5], that has been developed to capture this multi-scale behavior on a relatively coarse mesh. This is achieved by using the local front velocity to construct, for each point of a set of control points, a mapping that adaptively identifies the dominant length scale at which the appropriate multi-scale universal asymptotic solution needs to be sampled. Finer-scale behavior is captured in a weak sense by integrating the universal asymptotic solution for the fracture width over partially filled tip elements and using these integrals to set the average values of the widths in all tip elements.

Implementations of the ILSA strategy have hitherto been restricted to integral equation and extended finite element implementations on structured (rectangular) meshes for planar HF. I will also discuss the recent development of an ILSA scheme on an unstructured triangular mesh with the view to modeling topological changes in the fracture surface.

References

[1] Detournay E. 2016 Mechanics of hydraulic fractures. *Annu. Rev. Fluid Mech.* 48, 311–339.

[2] E.V. Dontsov and A. P. Peirce, A non-singular integral equation formulation to analyse multiscale behaviour in semi-infnite hydraulic fractures, *J. Fluid Mech (JFM RAPIDS)*, vol. 781, R1, 2015.

[3] A. Peirce and E. Detournay, "An Implicit Level Set Method for Modeling Hydraulically Driven Fractures", *Comp. Meth. in Appl. Mech. and Eng.*, 197, 2858-2885, 2008.

[4] A. Peirce, Modeling multi-scale processes in hydraulic fracture propagation using the implicit level set algorithm, *Comp. Meth. in Appl. Mech. and Eng.*, 283, p 881-908, 2015.

[5] E.V. Dontsov and A. P. Peirce, A multiscale Implicit Level Set Algorithm (ILSA) to model hydraulic fracture propagation incorporating combined viscous, toughness, and leak-off asymptotics, *Comp. Meth. in Appl. Mech. and Eng.*, 313, 53-84, 2017.