Explicit versus implicit front advancing schemes for the simulation of hydraulic fracture growth

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ABSTRACT

Tracking the free boundary of a hydraulic fracture constitutes one of the major challenges of numerical schemes for hydraulic fracture propagation. Peirce and Detournay[1] developed an Implicit Level Set Algorithm (ILSA) that incorporates near tip hydraulic fracture asymptotic solution with a finite discretization to efficiently determine the evolution of fracture with time. This scheme does not require a-priori knowledge of the fracture front velocity. It is obtained as a by-product from the fracture front position after the growth step is taken. The algorithm advances the front via an implicit time-stepping scheme, i.e. the correct position of the front is determined via an iterative process.

We present here a variant of this hydraulic fracture propagation algorithm that advances the front explicitly i.e. with the velocity from the last time step, instead of determining it iteratively. A predictor-corrector version is also presented where a better first guess of the new front position for the iterative process is obtained by first doing an explicit front advancing step. Our goal is to investigate the potential gain in computational speed of these schemes and their cost in terms of loss of accuracy. It is clear that if their performance is reasonable, they would provide numerically efficient alternatives to the implicit scheme. It is important to note –however– that the elasto-hydrodynamics coupling (for a given fracture front position) is solved implicitly due to the stringent CFL condition of such system.

To test the accuracy of the presented approaches, we compare them to available growth solution for a penny shaped hydraulic fracture. The stability of the approaches is also tested on a challenging test case where the front steeply accelerates or decelerates after entering a layer with lower or higher confining stress respectively. Finally, to test the overall ability of the mathematical model and the algorithm including the presented front advancing approaches, a laboratory experiment is successfully replicated numerically.

Our results show that the solution obtained from the presented schemes matches closely with the fully implicit scheme but typically incur approximately 400 percent less computational cost for the explicit version and from 25 to as much as 50 percent less cost for the predictor-corrector version. The accuracy of the explicit version decreases by a few percentage points in the case of fine scale heterogeneities in material properties. The accuracy of the predictor corrector version is virtually the same as the fully implicit scheme.

REFERENCES

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