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Introduction: A comparison of discrete fracture and explicit fracture models for single-phase flow in fractured porous media using COMSOL Multiphysics® is presented to understand the contribution of each individual fracture to fluid flow, and the exchange between fracture and surrounding medium at a scale such that the fractures could be modeled explicitly.

Single Phase Flow Model in a Porous Medium: A single phase flow model in a homogeneous and isotropic porous medium for a slightly compressible fluid is obtained by a fluid mass balance equation in terms of the pressure as follows

\[ \frac{\partial \phi}{\partial t} - \nabla \cdot \left( \frac{k}{\mu} \nabla p \right) = q; \quad \phi = -\frac{k}{\mu} \nabla p \]

Explicit Fracture Flow Model: In this model two different porous media, represented in separated subdomains, are considered. One of them is a fracture and the other one is a porous matrix, as are schematically presented in the Figure 1.

Domain Decomposition Approach: The model consists in two separated subdomains divided by an internal boundary. Each subdomain represents a porous media and the internal boundary represents a fracture, as can be seen in the Figure 2.

Governing equations

\[ \frac{d\phi}{dt} + \nabla \cdot \left( \frac{k}{\mu} \nabla p' \right) + q' = \frac{d}{dt} \left( \frac{k}{\mu} \nabla p' \right) \]

\[ q' = \int_{\partial\Omega} \psi' d\Sigma; \quad p' = \int_{\partial\Omega} \psi' d\Sigma \]

Internal boundary conditions

\[ -\frac{1}{2} \left( \vec{u} \cdot \vec{n} \right) = -\frac{1}{2} \left( \vec{u} \cdot \vec{n} \right); \quad \alpha' \vec{p'} = \alpha' \vec{P'} \]

\[ \alpha' = \frac{2k}{\mu d} \]

Embedded Fracture Approach: This embedded fracture approach is very similar to the domain decomposition approach. The main difference is that there is a single porous matrix domain in which the fracture is embedded, as can be seen in the Figure 4.

Internal boundary conditions

\[ p' \big|_{\Omega} - p' \big|_{\Omega} = \frac{2k}{\mu} \left( \vec{u} \cdot \vec{n} \right) \]

Results: Discrete fracture models compared to explicit fracture model have the advantage that for the same order of accuracy the number of elements in the mesh are reduced significantly and, consequently, they have a better computational performance since it involves fewer degrees of freedom (unknowns). The number of mesh elements for each configuration of the fracture is presented in Table 1.

<table>
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<th>θ</th>
<th>Explicit fracture</th>
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<th>Embedded fracture</th>
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</tr>
</tbody>
</table>

Table 1. Number of triangular elements for the discrete fracture and explicit fracture models; Single fracture configuration.

Conclusions: Since in oil recovery process modeling, the case where the fracture has a higher permeability than the surrounding porous medium usually is more significant than the case where the fracture has lower permeability, the embedded fracture approach could represent a viable alternative to model flow through a fracture network of porous media.

References:

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