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An extension of the fault two-layer reduced model accounting for the flow properties of the core and damage zones

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Modelling flows within faults is crucial for various applications such as the control of faults on overpressure development or hydrocarbon migration
in sedimentary basins, the recovery of hydrocarbon components, subsurface gas storage, and
the appraisal of the risk of groundwater contamination following an underground nuclear waste disposal.
Faults can be characterized as extended fractures along which there has been significant displacement of the sides relative to one another. They are rarely only geometrical discontinuities but rather zones of deformed rocks with particular fluid flow properties.
Following [Fredman et al, 2007] conceptual model, a fault is mainly made of two parts: the core area and the outer surrounding damage zone. These different parts have specific flow properties that can
change over time. For instance, the core part filled by clay can behave as a barrier while the fractured damage zones act as conduits to fluid flow.

Since the characteristic width of faults is much smaller than the dimensions of the surrounding studied area, modelling these objects for flow simulations is not simple and different approaches have been considered.
Reservoir simulators usually define transmissivity multipliers that account for the change of permeability induced by faults, but,
intra-fault vertical fluid flows are neglected. To simulate these flows, reduced models have been proposed as a trade-off to avoid
building grids representing the complete 3D architecture of the fault zones, which require specific mesh generators and increase significantly the computing times. These reduced models consist in modelling a fault with one or two layer(s) of interfaces of dimension N-1 immersed in an N-dimensional domain.
More precisely, the double-layer approach introduces interfaces on both sides of the fault
which are conformal with the neighbouring matrix blocks but non-matching in the middle, thus enabling one side of the fault to slip or to have slip with respect to the other side.

Another important ingredient for the aforemetioned applications is the choice of a space discretization scheme which should provide a consistent approximation
of the fluxes. The grids are indeed usually built following the geological layers leading to distorted mesh elements. The use of such numerical schemes
is also essential when coupling flows between the matrix block and the fault area through reduced models containing non-matching interfaces.
Previous works have already demonstrated that the hybrid finite volume scheme allows one to perform this coupling properly.

In this work, we propose an extension of the double-layer reduced model to take the flow properties of the fault core more precisely into account.
This new model introduces the core part between the two layers in a simplified way where the flow between the two interfaces is assumed to occur only in the normal direction.
The hybrid finite volume scheme is again used to discretize the whole system of equations.
Numerical examples on faulted sedimentary basins show the ability of this new model to simulate new flow patterns within faults including the one
where two fluids flow independently from each other along both slippage surfaces.

References

[Fredman et al., 2007] : N. Fredman, J. Tveranger, S. Semshaug, A. Braathen, and E. Sverdrup, Sensitivity of fluid flow to fault core architecture and petrophysical properties of fault rocks in siliciclastic reservoirs: a synthetic fault
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