Contribution ID: **584**

Type: **Oral 20 Minutes**

A novel transient diffuse source algorithm for multiscale simulation in porous media

Tuesday, 15 May 2018 11:53 (15 minutes)

Fluid flow in porous media occurs on varied scales from pore to reservoir, where the fine scale heterogeneity may have a significant impact on large scale fluid flow. Resolving all pertinent scales in modeling and flow simulation is an arduous task limited by the availability of data and computational resources. Therefore, it is customary to use an upscaling procedure, in which the fine scale reservoir properties are represented on the coarse scale by some kind of averaging procedure. Existing local upscaling methods rely on steady state incompressible flow, which fail to capture transient multiscale effects. Particularly, they cannot preserve the dynamic connectivity while coarsening between multiple scales. This results in overly homogenized simulation models with systematically biased results. This same bias can be observed in multiscale flow simulation where large scale changes in pressure are resolved on the coarse scale, and multiphase fluid transport simulation is performed on the fine scale using a subgrid velocity field generated from the coarse problem. This precludes the need to upscale saturations and relative permeability which are highly non-linear and strongly dependent upon flow history. The current work combines the upscaling of pressure with multiscale multiphase simulation to generate high resolution velocity fields that capture the subgrid heterogeneity, fluid compressibility, and multiphase flow.

The upscaling step draws upon its similarity to pressure transient well testing concepts to set up local flow problems. Instead of a wellbore, each local problem is performed from a coarse cell face. This enables us to distinguish between well-connected and weakly connected pay while upscaling. This approach is similar to the multiscale mixed finite element literature where we have a basis function for a coarse face. After upscaling, superposition principle allows us to downscale the coarse flow, generating the fine scale velocity field. Finally, the transport problem is solved on the fine scale giving fluid saturations.

The proposed method is validated on the high contrast SPE10 synthetic model with over 8 orders magnitude variance in permeability, and demonstrated on a full field tight gas reservoir model.

References

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Primary authors: NUNNA, Krishna (Texas A&M University); Prof. KING, Michael (Texas A&M University)

Presenter: NUNNA, Krishna (Texas A&M University)

Session Classification: Parallel 4-G

Track Classification: MS 2.09: Fluid flows and transport processes in the porous media affected by heterogeneities [auto created title]