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We present results from a new Navier-Stokes model for multiphase flow in porous media implemented in Ansys Fluent 16.2 [1]. The model includes the Darcy-Forchheimer source terms in the momentum equations and proper account for relative permeability and capillary pressure in the porous media. This approach is widely used for single phase flow, but not for multiphase flow in porous media. This might be due to the complexity of introducing relative permeability and capillary pressure in the CFD solver. The introduction of relative permeability and capillary pressure may cause numerical instabilities as the saturation of a grid cell approaches the residual saturation, i.e. the relative permeability goes towards zero. This means that the viscous resistance in the Darcy-Forchheimer equation approaches infinity. Furthermore, by coupling the Navier-Stokes equation and Darcy-Forchheimer equation it is possible to model both the non-porous and porous media using the same formulation.

We are testing the Ansys Fluent 16.2 for two-phase flow in porous media using analytical data as reference. For a radial inflow to a vertical well in a homogeneous reservoir, we compare with the analytical solution for the volumetric flow rate into the well

q_\alpha = 2*pi*K_abs*k_r\alpha*h*(P_ref-P_well) / (mu_\alpha*(ln(r_reservoir / r_well) + S))

where K_abs is the absolute permeability, k_r\alpha is the phase relative permeability, P_ref is the reservoir pressure, P_well is the well pressure, mu_\alpha is the phase viscosity, r_reservoir is the reservoir radius, r_well is the well radius and S is a skin factor for near-well damage. The relative permeability is modeled for the oil and water system with the Corey correlation [2]

k_rw=k_rw,max*s_wn^n_w and k_ro=k_ro,max*(1 – s_wn)^n_o

where s_wn=(s_w-s_wi)/(1-s_wi-s_or) is the normalized saturation, and where s_w is the water saturation, s_wi is the residual water saturation, s_or is the residual oil saturation, k_rw,max is the water relative permeability at residual oil saturation, k_ro,max is the oil relative permeability at residual water saturation, n_w is the Corey exponent for the water system, and n_o is the Corey exponent for the oil system.

The comparison between the CFD and analytical solution is shown in Figure 2 and validates the implementation of the relative permeability. Further validation tests on core plugs and with reservoir simulators will be presented at the conference.

References

[1] ANSYS Fluent, 16.2, User's Guide, ANSYS Inc.
[2] Corey, A. T., 1954, The interrelation between gas and oil relative permeability, Prod. Monthly 19 (1): 38-41

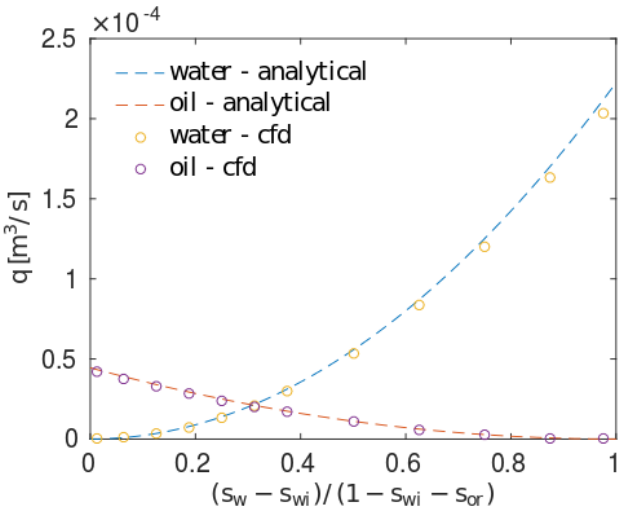

Figure 1: comparison of numerical and analytical multiphase inflow to a vertical well.