Free-Space Well Connection Method for Efficient Coupling of Wells and Grid Cells of Arbitrary Geometry

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Summary

In reservoir simulation studies, one of the crucial factors affecting the accuracy and hence reliability of the results is the representation of well connections in the numerical reservoir grid. Although there have been numerous attempts to redefine the relationship between wellbore pressure, grid cell pressure and the corresponding fluid flowrate, the original Peaceman formulae are still the most prevalent simulation software option by far. The simplicity of their implementation overshadows their limited applicability to symmetric 2D scenarios of purely cylindrical radial flow, also built into the "3D projected Peaceman" formula.

One of the attempts to improve the inflow model was the Multi-Point Well Connection (MPWC) method (SPE 173302) which solves the local flow problem using the Boundary Element Method (BEM). In terms of its boundary conditions, pressures of the next-neighbour cells surrounding the well-connection cell appear in the final coupling formula, which makes the method difficult to implement and computationally less efficient.

A new method has been formulated to overcome the drawbacks of MPWC and still utilise the benefits of BEM. The proposed Free-Space Well Connection (FSWC) method converts the next-neighbour cells into infinitesimal layers of equivalent transmissibilities and applies free-space boundary conditions to their outer surfaces. All cell faces are adaptively refined into a required number of boundary elements and their pressures and fluxes are expressed by means of free-space Green's functions representing well perforation sources/sinks. The method is applicable to cells and perforations of arbitrary geometry, including perforations outside the cell of interest, and to general cases of heterogeneous anisotropic rock permeability. Balancing all boundary pressures and fluxes yields the resulting well-connection transmissibility (or well index) and inter-cell transmissibility multipliers that emulate the flow asymmetry outside the well-connection cell.

Accuracy of the FSWC method has been verified against various analytical and numerical models. Even for the ideal case of a fully penetrating vertical well in the centre of a square reservoir, the FSWC-computed well index is closer to the analytical solution than that of Peaceman. Despite its broad applicability, superior accuracy and robustness, the method is fast and requires just a few CPU seconds to reach the desired precision. This is demonstrated by various examples with realistic well trajectories from full-field reservoir simulation runs.