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Well Representation in Reservoir Simulation Models Considering the Impact of Discrete Fracture Network Upscaling

Isabela Magalhães de Oliveira

Introduction

The Student Paper Contest (SPC) is a competition promoted by the Society of Petroleum Engineers (SPE) to give merit to students with technical excellence (Student Paper Contest, 2021). The 2021 SPC Brazil section occurred between 18 and 22 of October of 2021 in the online format in three divisions (undergraduate, Master's, and PhD). The competition is composed of the review of the project abstract, a presentation, and a question and answer session with a panel of judges. In this edition, some highlights of the dissertation of Isabela Magalhães de Oliveira are presented, who was the winner of the Master's division of the 2021 SPC Brazil.

The main objectives of the dissertation are (1) to evaluate the impact of DFN (discrete fracture networks) upscaling methods on new wells placed in the simulation model and (2) to develop a well-representation proposal of new wells in NFR (naturally fractured reservoirs) simulation models.

The main contribution of this work is an investigation of a well-representation approach for simulation models of NFRs, providing for real field cases, a better representation of injection and production forecast related to fault and fracture inclusion when utilizing DFN permeability-upscaling methods.

Methodology

Four main analyses are performed. The first three are focused on a Characteristic Flow Unit (CFU1) of a synthetic NFR and the fourth is focused on the field scale of the same reservoir. These analysis are described below:

1. For each fidelity scale (which are three: high fidelity model (HFM) with a cell dimension of 5x5x2m, medium-high fidelity model (MHFM) with a cell dimension of 25x25x4m, and a medium-fidelity model (MFM) with a cell dimension of 200x200x4m): observation of differences in static and dynamic well parameters when changing the DFN upscaling method (Oda, Oda corrected (ODAC), and Flow-based in three boundary conditions, Linear Pressure (LP), Constant Pressure (CP), and No Flow (NF));
2. For each DFN upscaling method: observation of differences in static and dynamic well parameters when changing the fidelity scales;
3. The test of well calibration methodologies in a coarse grid by considering the two previous steps conclusions;
4. The test of different DFN upscaling methods at a field scale to evaluate the impact on the field production forecast.

Results and discussion

Analysis (1) suggests a higher variation of the dynamic data as the scale increases, indicating more variability of flow rate and BHP in medium-fidelity models. The results for the producer well are illustrated in Figure 1, which shows the difference between the biggest and the smallest oil rate value obtained in each scale when the different DFN upscaling methods are applied.

Analysis (2) concludes that all methods are scale sensitive. Oda produces the most variability in BHP and oil rate, and NF yields the least dynamic data variation. However, LP and CP have the same results, suggesting that for the FB method, these would be the boundary conditions with the least variability. The results of analysis (2) are illustrated in Figure 2 for the producer well, showing the difference between the biggest and the smallest oil rate value obtained by each DFN upscaling method when applying the three fidelity scales.

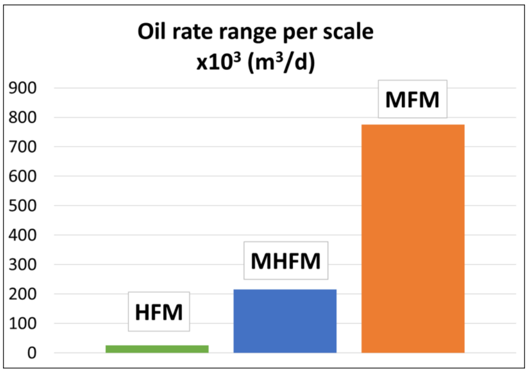

***Figure 1**: Range between the biggest and the smallest oil rate value when applying different DFN upscaling methods in each fidelity scale (values of the first 2 seconds of production).*

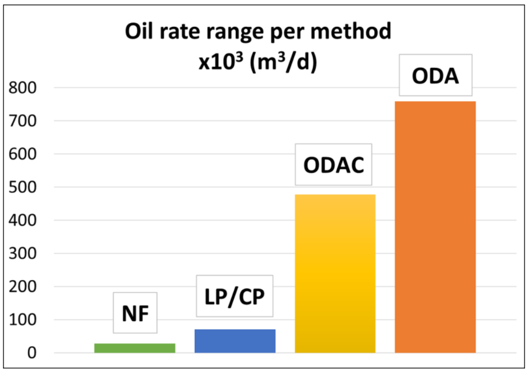

***Figure 2**: Range between the biggest and the smallest oil rate value when changing the fidelity scale in each DFN upscaling method (values of the first 2 seconds of production).*

The calibration tests, analysis (3), are performed in the CFU1 MFM ODA and the reference model is the CFU1 HFM LP according to the analysis of the previous results (model built with the least impacted scale and the least impacted DFN upscaling method). Three calibration methodologies are tested, and they focus on Well Index (WI) modifications, as WI connects the reservoir heterogeneities to the well model through the productivity and injectivity index (PI) (Ribeiro, 2010). For dual-continuum models, the well model considered in this work is in Equation (1) and the PI and WI are in Equation (2).

$$q_l = \left(\sum_{i=1}^{n} PI_i (P_{blocki} - BHP)\right)_{matrix} + \left(\sum_{i=1}^{n} PI_i (P_{blocki} - BHP)\right)_{fracture} \quad (1)$$

where q_l is the total phase flow rate considering n well grid blocks for each system (matrix and fracture), PI_i is the productivity or injectivity index, P_{blocki} is the well block pressure, and BHP is the bottom-hole pressure (CMG, 2019).

$$PI_{si} = WI_{si} * \frac{K_r}{\mu} = \left(\frac{2\pi \times K_{si} \times h_i \times wfrac}{ln\left(\frac{r_{e_i}}{r_w}\right) + skin}\right) * \frac{K_r}{\mu} \quad (2)$$

where PI_{si} is the productivity or injectivity index for the system s (matrix or fracture) for each well grid block i, WI_{si} is the well index, K_r is the fluid relative permeability, μ is the fluid viscosity, K_{si} is the well block absolute permeability, h_i is the grid block thickness, *wfrac* is the well fraction, r_w is the wellbore radius, and r_{ei} is the well block effective well radius (CMG, 2019).

Among the tested calibration methodologies, methodology 2 provides the best fit of dynamic data for producer and injector wells simultaneously (maximum of 2% of relative difference from the reference). This methodology refers to the replacement of the WI of the CFU1 MFM ODA by the reference model's WI in the fracture and matrix systems. Thus, methodology 2 is selected as the well representation proposal for new wells in medium-fidelity models.

In summary, the well representation proposal presented in this work can be divided into two main steps. First, there is the calculation of the fracture properties considering the heterogeneities close to the wellbore using the flow-based upscaling method with the linear or constant pressure boundary condition. Second, there is the incorporation of the WI calculated in this previous step in the well model of each MFM well for fracture and matrix systems.

The field-scale application, analysis (4), shows a significant difference of productivity among the DFN upscaling methods in the short-term production forecast, but this impact decreases as the production time increases. The results are summarized in Table 1 for the oil rate.

Conclusion

- The variations in well behavior caused by the DFN upscaling method can mask the reservoir characterization uncertainties and affect the reservoir development and management phase, demonstrating the importance to carry out a deep analysis of the fracture properties in the well block of new wells.

Table 1: *summary of the oil rate values at the end of each production term*

Production terms	Oil rate x10^3 (m^3/d)			
	LP/CP	NF	ODAC	ODA
First seconds	549	169	560	765
Short term (Until 6 months)	28	15	28	29
Medium term (6 months to 5 years)	6.0	6.0	5.6	5.5
Long term (5 to 32 years)	1.2	1.3	1.2	1.2

- The well representation proposal of this work suggests a productivity or injectivity index modification through a correction in the Well Index of each producer and injector well of the medium-fidelity model.
- This proposal can reduce the variability of the well flow rate and BHP when setting new wells during the development and the management phases of the reservoir and should reduce the significant impact of the DFN upscaling method in the short-term production forecast in a field-scale application.

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