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Integrated Wellbore/Reservoir Model Predicts Flow Transients in Liquid-Loaded Gas Wells

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Abstract
An integrated transient wellbore/reservoir model is described and applied to investigate the liquid loading in a gas well. The well produces from a storage reservoir with water coning from its aquifer.

The integrated model shows that the water cone causes the gas flow rate from each gas layer to decrease and the liquid holdup in the wellbore to increase. Depending on reservoir conditions, the well may enter into a mode of unsteady production during which the gas flow rate cycles over a period of several days. The reason for this unsteady flow is uncovered by the simulation.

Simulation results are compared with operational experience and full field reservoir simulations. The integrated model provides more realistic results compared to methods where the reservoir and the wellbore are modeled separately.

Introduction
Oil and gas production from the mature fields often encounters challenges as the reservoir depletes. Liquid loading in gas wells is one of them. Several techniques have been developed throughout the years to address the issue of gas well loading[1]. Though some of the techniques are well established, there is a growing demand for better simulation tools to optimize the operations.

For example, dynamic wellbore/reservoir integrated simulation is required when studying the transient liquid loading processes in gas wells. On the one hand, a reservoir model is needed to simulate the changes in well productivity and phase mobility as fluid saturations gradually change in the near wellbore area. On the other hand, a transient wellbore multiphase flow model is required to predict the onset of loading and the flow transients resulting from liquid accumulation.

Furthermore the mechanisms of the many liquid loading mitigation techniques (plunger-lift, compression, pumping, and gas-lift) are dynamic processes where the variables are constantly changing and interacting with each other. In that context, it is becoming evident that the complete system from the reservoir to the receiving facility must be considered as a whole rather than each component being studied separately.

There are also some other dynamic situations where interactions between reservoir and wellbore are important:

- Severe slugging in pipelines and wells can cause fluctuations in bottom-hole pressure that affect the flow from the reservoir. Depending on the characteristics of the near-wellbore region the variations in the inflow can feed forward and aggravate the unstable behavior of the system.
- At low flow rates there can be slow liquid build-up in the wellbore resulting in either the liquid being lifted out in a steady or unsteady flow pattern or the well dying.
- During well shut-in, the pressure will build up more slowly in the near-wellbore reservoir than in the wellbore resulting in a delayed shut-in pressure peak and holdup buildup. At start-up, the well may produce a large slug or not be able to start flowing.
- Under case of density-wave instability or casing heading in gas-lifted wells, the near-wellbore region will interact with the flow in the tubing and may contribute to dampen or amplify the oscillations.
- Gas and water coning in the near wellbore region cause the inflow to change with time, which affect the operation of the downstream equipment.

In all the above cases, a coupled model of the wellbore and near-wellbore reservoir is required to accurately simulate the dynamics, analyse the phenomena, and numerically test the remedial actions or control schemes. Some cases above are addressed in a separate publication[2] using the same integrated model introduced in this paper.

Although reservoir model integrated with steady-state wellbore model are common, similar complete dynamic modeling have been rare and their applications are rather limited. Sturm *et al.*[3] developed a dynamic reservoir/well model to simulate oil production from thin oil rims subject to gas and water coning. The model was used to develop gas and water coning control schemes. However their transient