Lecture 8 summary:

Reservoir Management Modeling – Part 1

4. Reservoir Management Modeling

4.1. Modeling System

A comprehensive reservoir management modeling system can be thought of as four interacting subsystems:

1- Reservoir flow model: represents fluid flow within the reservoir.

2- Well bore model: represents flow from the sand face to the surface.

3- Surface model: represents surface facilities, such as separators.

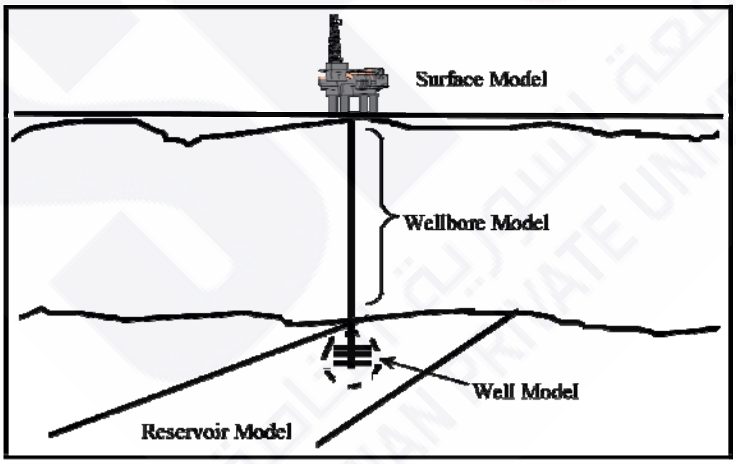

Figure 17. Reservoir Management Modeling System

Reservoir modeling: Simulators are based on conservation of mass, momentum, and energy. The set of algorithms is sufficiently complex that high speed computers are the only practical means of solving the mathematics associated with a reservoir simulation study.

Well bore Modeling: The well bore model usually consists of a multivariable table relating surface pressure to flow rate and gas-oil ratio

(GOR). The tables are often calculated using a separate program that performs a nodal analysis of wellbore flow.

The well bore well model may be coupled to reservoir model to more accurately account for fluid flow in pipes, figure 18.

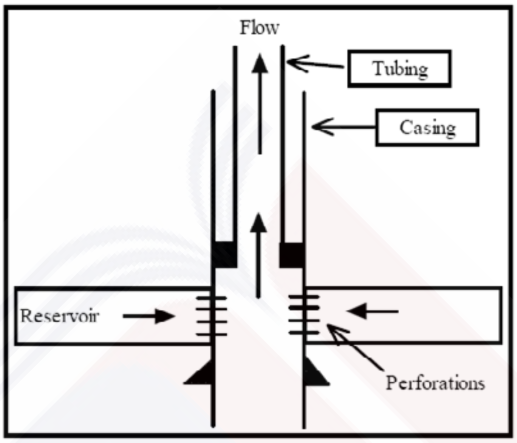

Figure 18. Well bore-Reservoir Coupling

Single Phase Flow in Pipes

Fluid flow in pipes can range from laminar to turbulent flow.

Reynolds number N_{Re} is often used to characterize fluid flow. Reynolds number expresses the ratio of momentum forces to viscous forces.

Fluid flow in circular pipes is laminar if $N_{Re} < 2000$, and it is turbulent at larger values.

The friction factor *f* depends on flow regime. For laminar flow, the friction factor is inversely proportional to Reynolds number . For turbulent flow, the friction factor depends on Reynolds number and pipe roughness.

Two Phase Flow in Pipes

Two-phase flow is characterized by the presence of flow regimes or flow patterns. The flow pattern represents the physical distribution of gas and liquid phases in the flow conduit.

Flow regimes for vertical flow are usually represented by four flow regimes: bubble flow, slug flow, churn flow, and annular flow.

Churn flow and annular flow are referred to as slug-annular transition and annular-mist flow respectively. Figure 19 illustrates the four flow regimes.

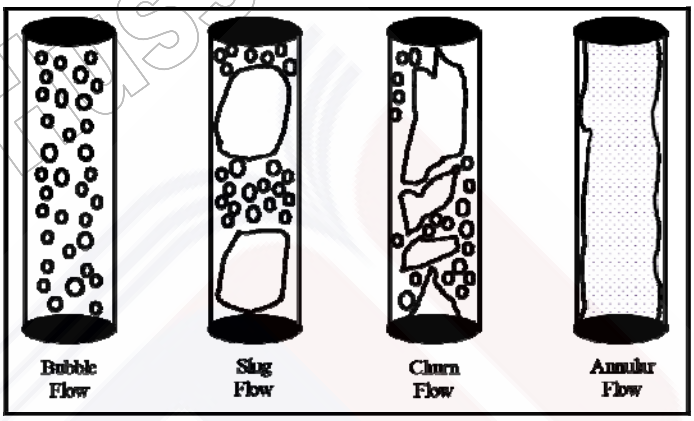

Figure 19. Flow regimes for vertical, two-phase flow

Well bore-Reservoir Coupling

Well bore models represent outflow from the sand face to the surface.

Reservoir fluid inflow represents fluid flow from the reservoir into the wellbore and may be modeled using either analytical methods or numerical methods.

Analytical methods rely on models of inflow performance relationships (IPR). An IPR is the functional relationship between reservoir production rate and bottomhole flowing pressure.

Darcy's Law is a simple example of an IPR for single phase liquid flow. The gas well backpressure equation is an example of an IPR for single phase gas flow. Vogel [1968] introduced an IPR for the oil rate from a two-phase reservoir. Vogel's IPR depended on absolute open flow potential, which is the flow rate that is obtained when the bottomhole flowing pressure is equal to atmospheric pressure.

Figure 20 illustrates the relationship between an IPR curve and a Tubing Performance Curve (TPC) or (vertical lift performance curves VLP).

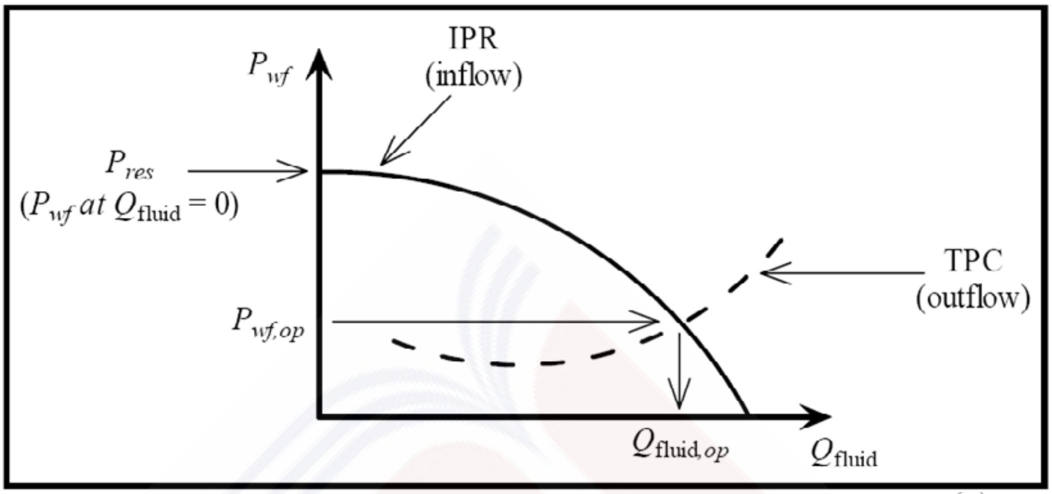

Figure 20. IPR versus TPC Plot

The IPR versus TPC plot is a plot of fluid flow rate Q_{fluid} versus bottomhole flowing pressure P_{wf}. Reservoir pressure P_{res} is the pressure at Q_{fluid} = 0. The intersection of the IPR and TPC curves identifies the flow rate and bottomhole flowing pressure that simultaneously satisfy inflow into the wellbore from the reservoir and outflow from the wellbore.

Another way to calculate inflow into a wellbore is reservoir simulation. Commercial reservoir simulators typically allow the user to specify tubing curves that relate surface pressure to bottomhole flowing pressure. Figure 21 illustrates a gridding scheme for a coupled wellbore-reservoir system.

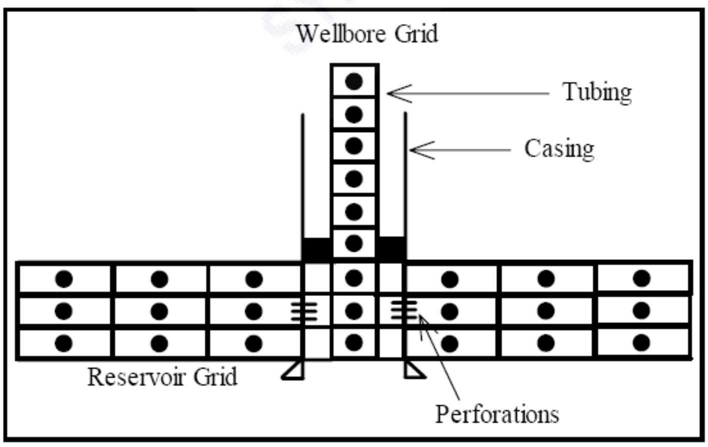

Figure 21. Schematic of a Coupled Wellbore-Reservoir Grid

Tubing curves in reservoir simulators allow to specify wellhead pressures and then calculate bottom hole flowing pressures. Modelers have found that more sophisticated wellbore models are needed to represent time-dependent (transient) effects in the wellbore. Modern wellbore models are using partial differential equations based on conservation of mass and energy that must be solved numerically in much the same way as flow equations in reservoir simulators.

Reservoir-Aquifer Model

A reservoir-aquifer system can be modeled in flow models using two different techniques: numerical aquifer model, or analytic aquifer model.

A - Numerical Aquifer Model

A reservoir-aquifer system can be modeled using small gridblocks to define the reservoir and increasingly larger gridblocks to define the aquifer.

This approach has the advantage of providing a numerically uniform analysis of the reservoir-aquifer system.

The numerical aquifer model represents aquifer influx by extending the finite difference grid covering the reservoir to include the aquifer (Figure 22).

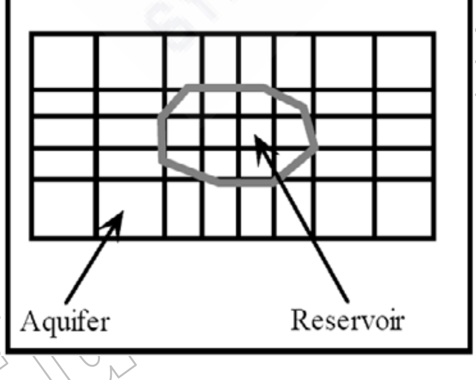

Figure 22. Flow Model Grid for Numerical Aquifer Model

B- Analytic Aquifer Model

Analytic aquifer models represent aquifer influx as a term in the fluid flow equations.

Van Everdinger and Hurst [1949] introduced one of the first analytic aquifer models. Their model could account for unsteady-state aquifer influx into the reservoir using dimensional time and pressure. Carter-Tracy [1960] and Fanchi [1985] modified the van Everdingen-Hurst model to simplify its implementation in reservoir simulators. Fetkovitch [1971] introduced a widely used analytic aquifer model that can represent steady-state and unsteady-state aquifer influx for a variety of aquifer sizes and strengths.

The steady-state aquifer model is available in simulator. It is based on the assumption that the aquifer influx rate is proportional to the pressure difference between the aquifer and the hydrocarbon reservoir.

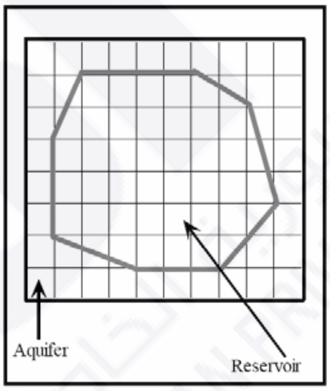

Figure 23. Flow Model Grid for Analytic Aquifer Model

Surface Facilities Model: surface facility models are simplified representations of real equipment.