Energy System Engineering Graduate Symposium

Uncertainty in Estimated Ultimate Recovery of Unconventional Reservoir

Yilda Kim
Instructor: Jordaan Sarah
Energy System Engineering Institute

Objective:
- Learn the history and different method of estimating EUR
- Decline curve
- Original Gas in Place (OGIP) well level, reservoir level
- Find the potential risk of using regular EUR method when applied to unconventional reservoirs like shale gas reservoir
- Understand the mechanism of the well production to better calculate the EUR in reality.
- Develop a decline curve equation to verify the best method

Background:
- Shale gas development is experiencing a boom recently
- Different from the conventional gas and oil, shale gas is existed in unconventional reservoir (continuous reservoir), which is hard to estimate the Original Gas in Place (OGIP) and monthly production
- OGIP and monthly production can heavily affect the profitability of the shale gas extraction
- Various EURs from different sources confuse the accurate estimation of shale gas production

Arps method

<table>
<thead>
<tr>
<th>Method</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>Arps method</td>
<td>It is a semi-empirical method, and it is accurate when used in conventional reservoirs. It is a difficult method to define, particularly when boundary-dominated flow is established.</td>
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<tr>
<td>type curve</td>
<td>Pseudo time and pseudo pressure can provide a method to determine the decline curve in a complex gas reservoir. It is a convenient method used in practice.</td>
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<td>Quadratic cumulative</td>
<td>Although it is easy to use, it is not suitable for the flow in the early stage.</td>
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<td>Power law</td>
<td>It cannot reflect the depletion process, because it turns out to be late.</td>
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<td>Continuous EUR approach</td>
<td>It is based on the power law method and hyperbolic type curve. Actually, this method is used when the reservoir is not in boundary-dominated flow.</td>
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Result: 1. Uncertainty in EUR by These Methods:

- Barnett Horizontal well production:
  - From the actual production data, we can estimate that average well production in 30 years should be around 1 bcf/well
  - Calculate the EUR:
    - We can define the Di and b according to the equation that 1/D=bc+b/1/D, and then get the a, so we can use the hyperbolic equation to calculate the EUR.
    - In practice, the difficulty is that b is hard to calculate through the equation, because D is so irregular, we define b according to the type of the reservoir, which is more common in reality.
  - Strategies: Separated decline curve
    - The difficulty is to define the Di and b, so we define the b according to the reservoir type. Then we will extrapolate the decline curve and find the hyperbolic equation.
    - Dividing the decline curve into 3 parts (transient flow, hyperbolic decline and hyperbolic with a low b or exponential decline), and it can be a method to improve accuracy. Boundary-dominated time should be defined.

Procedure:
1. Reorganize the data because the data we get is not convenient for extrapolation.
2. Use this mean initial monthly production to extrapolate the decline curve directly. At the same time, calculate the EUR.
3. Compare the 2 EURs to compare the result to see which is more close to the actual data.
4. Check if there is a big error if we just regard it as a hyperbolic type curve directly.

Result:
- Traditional method to define D and b can sometimes invalid in reality.
- Some data shows that actual data can match the decline curve only with a high b, which illustrates that boundary dominated flow is not achieved.
- Using these hyperbolic method to extrapolate the decline curve can some times result in a larger EUR. Therefore, it shows that EUR affected by long transient flow period should be paid attention.
- A very common hyperbolic equation is hard to get, because the well varies a lot, but potential risks should be understood to guide real activity.
- Usually, during the late period of the well, the b can become smaller or even close to 0.
- For the similar wells, generalized equation can be used. After verification of hundreds of wells, the mean calculated EUR by only several months data are close to 1 bcf/well, which can illustrate the method we introduce.