Calculating heterogeneity of Majnoon Field/Hartha Reservoir using Lorenz Coefficient method.

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Abstract: One of the principle concepts to understand any hydrocarbon field is the heterogeneity scale; This becomes particularly challenging in supergiant oil fields with medium to low lateral connectivity and carbonate reservoir rocks.

The main objectives of this study is to quantify the value of the heterogeneity for any well in question, and propagate it to the full reservoir. This is a quite useful specifically prior to conducting detailed water flooding or full field development studies and work, in order to be prepared for a proper design and exploitation requirements that fit with the level of heterogeneity of this formation.

The main tool used for these purposes is the application of the famous Lorenz coefficient method for calculating the degree of heterogeneity for any well. The starting point for this kind of complicated studies needs to start from the basics, in order to understand the big picture and be able to plan properly for the scope to be delivered, hence, utilizing analytical tools like the ones mentioned above becomes quite necessary, if not crucial, to the success of full field modelling and choosing an optimum water flood pattern and design.

This paper covers the methodology for quantifying and calculating the level of heterogeneity in a given reservoir (Majnoon Field/ Hartha Reservoir) using three out of four original wells of this reservoir, and how this value impacts and directly feeds into planning for water flooding projects and selection of an optimum flood pattern.

This methodology has been tested successfully in the stated super giant oil field, in which the reservoir in question is a carbonate rock formation. It is important to note that the chosen reservoir is giant areally with moderate thickness. An example of this is covered in the paper. It was concluded that utilizing a heterogeneity calculation method before conducting a detailed reservoir simulation study can save a lot of time and effort by providing guidance to the path which needs to be followed, and sheds light on the critical elements to be looked after. This has also helped to uncover many insights on the reservoir itself, hence allowing the engineer to plan...
for the necessary voidage replacement and water injection rates to sustain the reservoir pressure and pattern development.

The suggested method, in combination with geological and petrophysical information available, can be applied to majority of the reservoirs. This combination is paramount to ensure optimum time and planning is followed for each reservoir development study that involves water flooding.

1. Introduction

Heterogeneity is a very important factor in determining the recovery from petroleum reservoirs. Thus, heterogeneity calculations can be classified into static and dynamic techniques. Dykstra Parsons method provide the most excellent means to determine it.

Heterogeneity is the quality and situation of being heterogeneous. It was first defined in 1898 as the difference or diversity in kind from other kinds. Other definition consist of parts or things that are very different from each other. In petroleum studies it is referred to as the isotropy and anisotropy. Heterogeneity can be named as; complexity, deviation from norm, difference, discontinuity, randomness, and variability.

Many researchers noted that the differences between homogeneous and heterogeneous is relative, and it is based mainly on economic considerations. This shows how heterogeneity has a variable concept which can be changed and re-defined to describe any situation arises during production from a reservoir, and is mainly based on the researchers’ experiences and expectations. Other scientists state that heterogeneity is defined as the complexity and variability of the system property of interest in three-dimensional space.

These mentioned definitions clarify that heterogeneity does not refer to the overall system, or individual rock or reservoir unit, but instead it deals separately for each individual unit, properties, parameters and measurement types.

.2. Lorenz Coefficient

The original Lorenz technique was developed as a measure of the degree of inequality in the distribution of wealth across a population. In 1950 it was modified (the Lorenz Curve as used in petroleum engineering) by generating a plot of cumulative flow capacity against cumulative thickness, as functions of core measured porosity and permeability. Fitch et al. investigated the application of the Lorenz technique directly to porosity and permeability data.

Taking a known thickness of the reservoir and the well with most clear core data. Table 1 clarifies the method of calculations if the reservoir was divided into 10 layers only with porosity value of 0.33 and table 2 shows the area calculations, while Table.3 clarifies the calculation for the whole reservoir at each available property with porosity value of 0.18 (Because the calculations are for the permeability variation then the porosity must be of a fixed value).

Where:

κ: permeability (md), Φ: Porosity (%) and the probability was calculated by NORMSINV of excel; normal cumulative distribution.

the approximate area = (1st+ 2nd fracture of cum. κ h)/2*(1st– 2nd fracture cum. Φ*h) … etc.

h* gr = gross thickness- thickness of the rest of the layer (under that point)
**Table 1. Lorenz Coefficient calculations 1**

| Thickness (h) | \( \kappa \) | \( \Phi \) | \( \kappa*\Phi \) | cumulative \( \kappa*\Phi \) | Fracture of cum. \( \kappa*\Phi \) | Cum. \( \Phi*\kappa \) | Fracture of cum. \( \Phi*\kappa \) |
|---------------|----------------|-------------|------------------|--------------------------|-----------------------------|----------------|--------------------|
| 1.00          | 818.36         | 0.33        | 818.36           | 818.36                   | 0.39                        | 0.33           | 0.33               |
| 1.00          | 504.99         | 0.33        | 504.99           | 1323.34                  | 0.62                        | 0.33           | 0.66               |
| 1.00          | 311.61         | 0.33        | 311.61           | 1634.96                  | 0.77                        | 0.33           | 0.99               |
| 1.00          | 192.29         | 0.33        | 192.29           | 1827.24                  | 0.86                        | 0.33           | 1.32               |
| 1.00          | 118.66         | 0.33        | 118.66           | 1945.90                  | 0.92                        | 0.33           | 1.65               |
| 1.00          | 73.22          | 0.33        | 73.22            | 2019.12                  | 0.95                        | 0.33           | 1.98               |
| 1.00          | 45.18          | 0.33        | 45.18            | 2064.30                  | 0.97                        | 0.33           | 2.31               |
| 1.00          | 27.88          | 0.33        | 27.88            | 2092.18                  | 0.99                        | 0.33           | 2.64               |
| 1.00          | 17.20          | 0.33        | 17.20            | 2109.38                  | 0.99                        | 0.33           | 2.97               |
| 1.00          | 10.62          | 0.33        | 10.62            | 2120.00                  | 1.00                        | 0.33           | 3.30               |
| 10.00         | 212.00         | 0.33        | 2120.00          | 2120.00                  | 1.00                        | 3.30           | 1.00               |
| avg           | Avg            | Sum         | Max              |                           | sum                         | max            |                    |

**Table 2. Lorenz coefficient calculations 2**

| approx. area | Ln_k | h*gr | %h*gr | variation |
|--------------|------|------|-------|-----------|
| 0.019        | 6.71 | 0.000| 0.000 |           |
| 0.051        | 6.22 | 1.000| 0.100 | -1.28155  |
| 0.070        | 5.74 | 2.000| 0.200 | -0.84162  |
| 0.082        | 5.26 | 3.000| 0.300 | -0.5244   |
| 0.089        | 4.78 | 4.000| 0.400 | -0.25335  |
| 0.094        | 4.29 | 5.000| 0.500 | 0         |
| 0.096        | 3.81 | 6.000| 0.600 | 0.253347  |
| 0.098        | 3.33 | 7.000| 0.700 | 0.524401  |
| 0.099        | 2.85 | 8.000| 0.800 | 0.841621  |
| 0.100        | 2.36 | 9.000| 0.900 | 1.281552  |
| 0.80         |      |      |       |           |
| Sum          |      |      |       |           |
The approximated area was calculated from the figure obtained and the probability is calculated by Excel®.

From these calculations, the area under layer data and the area under the diagonal (always 0.5) was founded, then the Lorenz coefficient was calculated. Knowing that 0 value means a very homogenous reservoir and 1 value means a very heterogenous reservoir.

Based on the technical approach of calculating the Lorenz coefficient, figure-1 was deduced

![Lorenz Coefficient MJ-1](image)

**Figure 1.** Lorenz Coefficient MJ-1

And the results are as follows:

- Area under layer data = 0.871
- Area under the diagonal = 0.5
- Then the Lorenz coefficient = (0.871-0.5)/0.5 = 0.743 (very heterogenous)

3. Conclusions

1. Determining the heterogeneity of any reservoir is very important before any simulation process
2. Lorenz method is a straight forward and an easy to calculate heterogeneity efficiently and accurately
3. Hartha reservoir – Majnoon Field is a very heterogenous reservoir with a complicated nature.
4- Having a heterogenous reservoir leads to the necessity of making a very detailed simulation model in order to denote all the possible changes in the reservoir.

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