DECLINE CUMULATIVE PRODUCTION ANALYSIS (DCPA) – ALGORITHM, FOR GEOTHERMAL FIELD

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Abstract

Forecasting of geothermal production decline is one of the main tasks in reservoir engineering, in order to manage the reservoir and maintain the sustainability of the resource utilization. Studies on the analysis of production decline in geothermal fields have been widely implemented, one of which is the DCPA conducted by H.A. Davila J. (Davila, 2017), and applied in Kamojang geothermal field - West Java Indonesia. DCPA ‘Davila’ in Kamojang (steam dominated) geothermal field, appears to be more accurate than previous studies. This study is to support the DCPA by creating a computer program (algorithm and numeric calculation written in Fortran90/95 programming languages (Imam, 2009) (Tanjia, 2005)), thus it can expected to speed up the data matching process or the analysis process.

Keywords: Steady state, Decline cumulative production analysis, Steam dominated, Liquid dominated, Geothermal field, Algorithm, Fortran

Introduction

In order to improve the economicsof a field (hydrocarbons or geothermal), it is necessary to implement the reservoir management; part ofthat is an optimum reinjection design. The beginningof an optimum reinjection design is a declinecumulativeproductionanalysis (DCPA). The applicationof DCPA can be used to predict a cumulativeproductiondecline in a well.

Departed from DCPA’s Davila whoreported that therewas a good match between DCPA and production rate measurements at the KMJ-11 well. The well is completed in the waterdominated reservoir and mostly produce 100% steam (S. Sudarman, et.al., 1995). This studyaimed at making the DCPA algorithmmusing programing language. It is expected that this study will be continued at a later stage of making DCPA software. Fig. 1 shows the flow rate forecasting with the DCPA’s Davila method (red line) plot very close with the production rate data (red cycle), the stochastic and exponential are represented by green and brownlines respectively diverging from the data KMJ-11.

Decline Cumulative Production Analysis (DCPA)

Analysis to predict the decline of production by using Decline Cumulative Production Analysis (DCPA) method has been done by several researcher; oneofthem is Davila (2017).

Linear correlation between natural logarithmic of decline cumulative production against cumulative production, and decline cumulative production against production time charts resulting data initial rate and timedecline exponent to perform the production rate - time equation. The equation, to calculate the production rate in order forecast the production rate of well.
Mathematical Model
A formula to forecast the geothermal production has been developed based on the linear relationship of decline cumulative production versus cumulative production and decline cumulative production versus production time charts (Afken, 2005) (Boas, 2006) (Kreyszig, 2011). The analysis is taken under steady state condition (Davila, 2017).

Derivation of cumulative production (Q) is,

\[ \frac{dQ}{dt} = q \]  \hspace{1cm} (1)

q is the production rate.

The decline cumulative production (Q_D) is,

\[ Q_D = \frac{m}{q} = \frac{Q}{q} \]  \hspace{1cm} (2)

The linear relationship of Q_D and Q is,

\[ \ln \left( \frac{Q}{Q_D} \right) = a_0 + a_1 \ln(Q) \]  \hspace{1cm} (3)

so

\[ q = e^{a_0} Q^{a_1+1} \]  \hspace{1cm} (4)

The linear relationship of Q_D and t (time) is,

\[ \ln \left( \frac{Q}{Q_D} \right) = b_0 + b_1 \ln(t) \]  \hspace{1cm} (5)

so

\[ q = e^{b_0} Q_{D} t^{b_1} \]  \hspace{1cm} (6)

Eq. (4) same to eq. (5) we get,

\[ Q = e^{a_0} \left( \frac{b_0 - a_1}{a_2} \right)^{b_1} \]  \hspace{1cm} (7)
Substitution eq. (7) to eq. (6) we get,

\[ q = \exp \left( \frac{b_q a_1 + b_q}{a_1} \right) t^\left( \frac{b_q}{a_1} \right) \]  
\[ q = q_i t^\tau \]  

Eq. (9) is the production rate-time equation, where

\[ q_i = \exp \left( \frac{b_q a_1 + b_q}{a_1} \right) \]  

is initial rate,

and

\[ \tau = \frac{b_q a_1 + b_q}{a_1} \]

is time decline exponent.

The flow rate is

\[ q_p = \frac{Q}{q_i} = \tau t \]

and the natural logarithm is,

\[ \ln(q_p) = \tau \ln(t) \]

\( \tau \) is the slope in flow rate versus time.

The algorithms, sequences or steps to calculate \( q_i \), \( \tau \), and \( q \) and to plot production rate versus time as follow,

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Fortran90/95
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start

read q and t data

calculate Q, ln(Q), q/Q, ln(q/Q) and ln(t)

write ln(Q), ln(q/Q) and ln(t) data

finish
**Procedure (steps of the study):**
The data used for DCPA is Kamojang field (steam dominated type of reservoir), i.e. production rate of KMJ-11 well (Sri, 2011) is:
Tabel 1. Production Rate KMJ-11 Year 1996

<table>
<thead>
<tr>
<th>Month</th>
<th>ton/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>77,234</td>
</tr>
<tr>
<td>February</td>
<td>75,313</td>
</tr>
<tr>
<td>March</td>
<td>74,296</td>
</tr>
<tr>
<td>April</td>
<td>72,600</td>
</tr>
<tr>
<td>May</td>
<td>72,133</td>
</tr>
<tr>
<td>Jun</td>
<td>71,135</td>
</tr>
<tr>
<td>July</td>
<td>70,351</td>
</tr>
<tr>
<td>August</td>
<td>70,262</td>
</tr>
<tr>
<td>September</td>
<td>69,610</td>
</tr>
<tr>
<td>October</td>
<td>69,263</td>
</tr>
</tbody>
</table>

From the natural logarithm of Q_D and Q chart (Figure 3) we can determine the $a_0$ and $a_1$ constants, and from the natural logarithm of Q_D and t chart (Figure 4) we can determine the $b_0$ and $b_1$ constants.

\[
y = -1.0507x + 4.574
\]

\[
R^2 = 0.99996
\]

Figure 3: Natural logarithm of decline cumulative production (Q_D) and cumulative production (Q).
Substitution $a_0$, $a_1$, $b_0$, and $b_1$ to Eqn. (10) and (11), to calculate initial rate ($Q_i$) and decline exponent ($\gamma$), and then we get the production rate – time equation:

$$q = Q_i t^{-\gamma} \text{ ton/hour.}$$

**The Result**

The DCPA algorithm has been written and executed. Plotting the calculated production rate versus time has been done. Figure 5 shows the decline production curve obtained with the DCPA (blue line) plot very close the production rate data KMJ-11 well (yellow square).

Based on the matching curve between the production rate data (January to October 1996) and the DCPA (calculated), the flow rate forecasting of KMJ 11 can be made.
Conclusion
The DCPA algorithm has been made in this research, with the possibility to use as a toll for production forecasting for the dominated steam as well as the liquid dominated of geothermal wells.
It is expected that the following research can be continued by using the recent data measurement of KMJ 11, and other wells in Kamojang Geothermal Field; before continuing in applying the DPCA in Liquid Dominated wells.

Reference


Mary L. Boas, 2006, Mathematical Method in the Physical Sciences, John Willey & Sons, inc., USA.
