Application of a Probabilistic Method to the Forecast of Production Rate Using a Decline Curve Analysis of Shale Gas Play

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ABSTRACT
Sustained high oil prices and improved production technologies have recently led to the development of shale gas. To predict estimated ultimate recovery (EUR) for a part of shale gas production well, both Arps’ hyperbolic decline and Stretched Exponential Production Decline (SEPD) are used for carrying out decline curve analysis (DCA). To minimize the uncertainty in predicting the production of shale gas having a significant variation in the initial production behavior, Monte Carlo simulation is used to single-well analysis. Monte Carlo simulation is also used in combination with decline envelope for multiple-well analysis. The probabilistic results of both methods are analyzed.

KEY WORDS: shale gas; estimated ultimate recovery; decline curve analysis; Monte Carlo simulation; decline envelope.

NOMENCLATURE

- $b$ = decline exponent
- $D_i$ = initial decline rate, %/month
- $G_P$ = cumulative production, MMcf
- $L$ = a certain period of production time, month
- $n$ = exponent parameter for SEPD model, dimensionless
- $N_P$ = estimated ultimate recovery, MMcf
- $q_i$ = initial production rate, MMcf/month
- $q_t$ = production rate, MMcf/month
- $t$ = production time, month
- $\tau$ = characteristic time parameter for SEPD model, month
- $\Gamma(a,z) = $ incomplete gamma function

INTRODUCTION
The development of conventional resources is toward technically challenging areas such as deep sea and the arctic region. This has led to a gradual increase in development cost. There has therefore been an increase of interest in unconventional resources that are economically developable and it has been estimated that shale gas has the largest reserve among these (EIA, 2013). The commercial development of shale gas reservoirs is also most actively pursued because new technologies such as horizontal drilling and hydraulic fracturing enabled unconventional resources economically viable. It is being exploited in North America with the aid of appropriate infrastructure. In the development of shale gas reservoirs, the prediction of the producible gas reserve and its evaluation is essential. Decline curve analysis (DCA), which is utilized for the evaluation of both unconventional and conventional resources, is used when detailed information about the reservoir, production well, or field is not available for rapid analysis (Yang and Lim, 2013).

DCA is used to determine the decline trend based on production history and can be utilized in planning future production. Among the Arps (1945) equations used for DCA, hyperbolic decline is most commonly used and is based on the postulation that the decline exponent that determines the shape of the decline curve has a value between 0 and 1. Because it indicates that transient flow occurs and that the decline exponent exceeds 1 during the shale gas production period, various DCAs that are applicable to unconventional resources such as shale gas have been recently studied. Among these, SEPD (Valko and Lee, 2010) can be used to predict the shale gas production rate taking into consideration the variation in the flow behavior with time.

Moreover, shale gas formations have low permeability and production can be carried out through cracks generated by hydraulic fracturing. Because the decline rate during the initial production period is high, but very low latter on, there are significant variations from the initial production behavior. Therefore, predicting production rate using deterministic DCA is very difficult due to the uncertainty in the production behavior.

In this study, a single-well production rate is predicted by Monte Carlo