Available online at www.sciencedirect.com
ScienceDirect
J China Univ Mining & Technol 18 (2008) 0521–0526
JOURNAL OF CHINA UNIVERSITY OF MINING & TECHNOLOGY
www.elsevier.com/locate/jcumt

Method for predicting economic peak yield for a single well of coalbed methane

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Abstract: The development of coalbed methane (CBM) in China poses great difficulties because of high investments, low production and high risks. So a study of the economic effect of a single well at its preliminary stage is helpful for commercial exploitation of CBM. Affected by wellbore flow pressure, initial reservoir pressure, relative permeability, Langmuir pressure and other factors, the trend of declining production of a single CBM well agrees, by and large, with a hyperbolic pattern of decline. Based on Arps's equation, nearly 200 wells production with different peak yields and initial rates of were simulated. Given the present cost of drilling, gas production and engineering on the ground, the gross investment for the development of a single coalbed methane well was estimated for the Fanzhuang block in central China. Considering the current industrial policies for CBM, we established an economic assessment model and analyzed economic peaks. The results show the economic benefits with or without government subsidies at different peak yields of a single CBM well. The results of the evaluation can be directly applied in the Fanzhuang block. The evaluation method, formulated in our study, can be used to other areas with similar conditions.
Key words: investment; hyperbolic decline; economic benefits; production peak

1 Introduction

Coalbed methane (CBM) is a natural gas resource accompanied by and concurrent with coal and is a kind of potential, clean energy resource with large reserves in China[1]. With the rapid development of the world economy, especially with the uninterrupted upgrading of industrialization in developing countries, the demand for energy resources will also keep increasing. The demand for conventional oil and gas resources often exceeds supply, directly leading to a continuous rise of oil prices. As a result, companies of different countries have a growing enthusiasm for exploration and development of such unconventional oil and gas resources as CBM. In China, for instance, the state has issued a policy to encourage the commercial development of CBM. However, the development of CBM wells is difficult and risky over a long payout period with many uncertainties and huge investments, but their output is low. Therefore, at the initial stages of development of CBM wells it is extremely important to determine whether the development of an individual CBM well and its ensuing production is economically efficient. To do this might be of some guidance to future production, in order to maximize economic returns for a certain level of investment.

2 CBM yield decline rule

An accurate prediction about CBM yield is the basis for economically evaluation of CBM projects and an important basis for making a development plan[2]. The United States have attempted to exploit CBM on the ground since 1953 and obtained an industrial gas flow in 1977. In the 1990s, its CBM output was increasing quickly. The CBM industry came late to China. It has gone roughly through three stages:

1) The in-mine extraction and release stage (1950–1979); 2) the stage of ground development tests and primary utilization (1980–2005) and 3) the initial industrialization stage of CBM (2006–). Therefore, there are no actual historical production data to conduct simulations or to study output rules of CBM wells, but we can use natural gas engineering theory, methods and international research results to conduct studies in this field.

The analysis of the TEAM production zone in the

Received 02 April 2008; accepted 15 June 2008
Project supported by the Creative Foundation for Young-Middle-Aged Researchers from CNPC 2006–2008
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United States indicates that once a gas well reaches its actual peak value, the gas yield begin to decline, continuously showing a typical but predictable trend of gradual decrease and changing along a drafted curve of its successive rates of decline until the well was completely scrapped[3]. Fig. 1 shows that the peak yield of Well OG-134 was obtained after about ten months of production. From then on, the peak yield was kept for another eight months which is the optimum period of gas yield, water drainage and gas desorption. After that, it began to decline. Therefore, the gas yield of this well did not decline during its production until 18 months after its start. We should pay attention to the fact that in all the years following production of this well, the rate of decrease remained unchanged. This case is identical to that of most other gas wells in the TEAM production zone.

So, we can predict the yield of CBM by studying how the yield curve declines.

2.1 Decline of CBM yield

Traditional decline analysis is based on Arps' equation[4]. It is an empirical relation that extrapolates a production forecast based on a curve fit of historical data. The general equation is given by

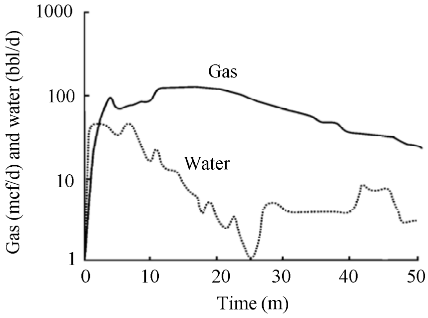

Fig. 1 Production curve of Well OG-134 in TEAM production zone (Richardson et al. 1991)

$$q = \frac{q_i}{(1 + D_i b t)^{\frac{1}{b}}} \tag{1}$$

where D_i is the initial rate of decline, b the decline exponent, q_i the initial gas flow rate and q the gas flow rate at time t.

There are three specialized forms of the equation: exponential decline, hyperbolic decline and harmonic decline, depending on different values of the decline exponent b (Table 1) in which D becomes the rate of decline at time t.

Table 1 Mathematical model of three types of production decline

Type of decrease	Exponential decline	Hyperbolic decline	Harmonic decline
Decline exponent	$b = 0$	$0 < b < 1$	b=1
Rate of decline	$D = D_i = \text{constant}$	$D = D_i(1 + bD_i t)^{-1}$	$D = D_i(1 + D_i t)^{-1}$
Output and time	$q = q_i e^{-Dt}$ $\log q = q_i - \frac{D}{2.303} t$	$q = q_i(1 + bD_i t)^{-1/b}$ $\left(\frac{1}{q}\right)^b = \left(\frac{1}{q_i}\right)^b + \frac{bD_i t}{q_i^b} t$	$q = q_i(1 + D_i t)^{-1}$ $\frac{1}{q} = \frac{1}{q_i} + \frac{D_i}{q_i} t$

2.2 Decline trend of CBM yield

The decline curve analysis to predict CBM reserves was first documented by Hanbywho used exponential declines to perform economic evaluations for CBM wells in the Warrior Basin of the United States[5].

Aminian et al have investigated the affect of key reservoir parameters on CBM decline using a numerical simulator[6]. They found that the wellbore flow pressure, relative permeability and Langmuir pressure had a significant effect on the shape of the decline curve. Changes in all these variables will affect the value of the decline exponent b (Eq.(1)).

Okuszko et al. have investigated reservoir and operating conditions affecting the value of b for gas wells, reviewed relevant literature and conducted simulations. The results indicate that gas declines correspond to b values between 0 and 1, satisfying the rule of hyperbolic decline. This simulation (Fig. 2) illustrates that the rate of decline is indeed not a constant and the observed curvature in the log-rate versus time plot indicates that the decline over the entire life of the well is not exponential.

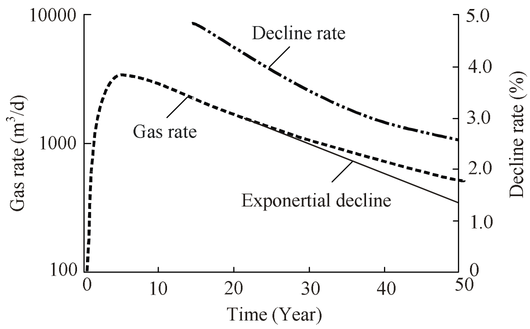

Fig. 2 Fifty-year simulation showing hyperbolic decline after 30 years (Okuszko et al. 2007)

From Fig. 2 we see that for the first 30 years the well shows an exponential decline (i.e., straight line of a semi log plot). After that (>30 years), it clearly shows a hyperbolic decline. If an exponential forecast had been used to estimate reserves for this well, the reserves would have been underestimated (Fig. 3).

Since the yield decline of CBM wells follows a hyperbolic decline, i.e., $0<b<1$, then the question