The Optimization of the Coalbed Methane Assessment Indexes in the High Abundance Coalbed Methane Enrichment Area in the Case of the Southern Part of the Qinshui Basin, China*

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Abstract

To seek the blocks for the coalbed methane (CBM) development and acquire the gas wells with the higher productivity are the final goals of the assessment on the high abundance CBM enrichment area. Based on the CBM geological conditions, reservoir conditions and CBM well productivity situations, to approach various factors impacting the CBM well productivity, and finally, the limit values of the assessment indexes on the high abundance CBM enrichment area are: the enrichment areas are located mostly in the groundwater stagnant area with the syncline structure and simpler hydrogeological conditions; the seam buried depth is shallower, permeability >1md; gas-bearing saturation degree >70%; reservoir pressure gradient >0.5MPa/100m; and daily gas production of single CBM well >2000m³/d.

Keywords: High abundance coalbed methane; Enrichment area, Assessment index; Qinshui Basin

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1. Introduction

The CBM distribution is controlled by many complicated factors, and in the different areas and under the different geological conditions the enrichment degree and distribution features have the obvious differences. There are many discussions on the basic geological conditions or the main control factors impacting the CBM enrichment [1-5]. As the main part restricting the CBM development, the high abundance CBM enrichment area plays the most important role for increasing the CBM reserve and production. At present, there has not the clearly defined scope on the high abundance CBM enrichment area, various researchers have different understandings on it, and its assessment indexes and values also are different. However, concerning to the high abundance CBM enrichment area the final goals are identical: To seek the blocks for the CBM development and acquire the blocks with the higher productivity.

In this paper, starting with the productivity analysis of the CBM well, through the analysis on the main control factors impacting the CBM well productivity, rationally select the assessment parameters on the high abundance CBM enrichment area; then, taking the CBM geological background, productivity data of the CBM wells and reservoir test data of the southern part of the Qinshui Basin as the basis, to discuss the correlation relationship of the CBM well productivity and its assessment parameters, to determine thereby the limit values of various assessment indexes on the high abundance CBM enrichment area, and then to provide the basis for constructing the more scientific and rational assessment index system.

2. Select the assessment parameters on enrichment area

The assessment index system is an organic whole constituting by several single assessment indexes (factors), and it shall reflect the objectives and requirements for the optimization of the high abundance CBM enrichment area. Commonly it is considered that the selection of the CBM favorable area shall possess the factors in the aspects of “geological condition, reservoir condition and resource condition”; however, concerning to the selection of the assessment parameters on the high abundance CBM enrichment area, except above factors in three aspects, it must consider the current CBM well productivity situations.

2.1. Geological conditions

The predecessors researches indicated that the periphery of the Qinshui Basin all is the uplifted area, and the elevation of the coal seam outcrop area is universally higher than that in the basin interior; in the updip position of the annular slope zone, in the lateral direction the groundwater plugs the Permo-Carboniferous coal-bearing strata, and in the down dip direction and in the basin hinterland it forms the confined water enclosed area, then, it has the possibility to result in that the whole annular slope zone contains the gas, and forms the large-type CBM reservoir plugged by the confined water. The hydrogeological condition is located in the confined area, and the gas content in seam is high. In the position where the axial parts of two folds are superimposed, especially in the axial part of the anticline, the permeability of the coal reservoir is higher, and it is favorable for the CBM development.

2.2. Reservoir conditions

The features of the coal reservoir can reflect the simple situations of the CBM occurrence, diffusion, migration and CBM development in later period at some degree. Its main parameters are the coal
reservoir permeability, seam adsorption capacity, reservoir pressure and gradient, seam buried depth, 
Langmuir volume, Langmuir pressure and gas-bearing saturation degree, etc.

2.2.1 Seam buried depth

Various researches indicated that the seam buried depth is one of main factors impacting the seam permeability. With the increase of the buried depth, the larger the static pressure born by the seam, the greater the effective stress, and it results in the reduction of the seam permeability. However, the permeability is a key parameter impacting the CBM productivity. Analysing the examples of the successful CBM development at home and abroad, it can be seen that the depth limit on the CBM development is not strictly restricted, wholly, the CBM in shallow part is more favorable for recovery than that in deep part.

2.2.2 Seam reservoir permeability

The permeability is one of key parameters impacting the CBM recoverable capacity, it directly impacts the recovery rate and the recoverable resource quantity of the CBM well, and it also is the key parameter impacting the CBM productivity. There are many factors impacting the seam permeability, and it could be roughly divided into two kinds: quantitative and qualitative [6]. Of which, the coal rank, coal lithotype, coal-petrological composition and coal matrix structure and so on belong to the qualitative factors, and they impact the coal reservoir permeability mainly by the development property and open degree of the fractures (cleats). In the factors which could be quantitative, they mainly include the parameters such as the seam buried depth, in-situ stress and so on. Thus, it can be seen that the seam permeability is a comprehensive factor, to select it as the parameter for assessing the high abundance CBM enrichment area, it can even more reflect the features of the CBM enrichment area such as the reservoir and productivity and so on.

2.2.3 Reservoir pressure gradient

The reservoir pressure gradient is a key index reflecting whether the coal reservoir pressure is situated in the under-pressure, normal or over-pressure states, and it has the important impact on the CBM recovery. Moreover the reservoir pressure is the energy source for fluid flow in coal seam. The CBM production is realized through draining the water from the seam, reducing the seam reservoir pressure and then desorping the CBM. The CBM production process also is the process that the reservoir pressure is reduced continuously and the energy is deplected successively. Therefore, the higher the reservoir pressure, the larger the reduced space of the CBM recovery pressure, the effective the water draining and pressure reducing operations, and the greater the gas-producing capacity of the gas well.

2.2.4 Gas-saturation degree

The gas-saturation degree reflects the filling situation of gas in the pore-fracture system of coal, and it reflects that in the CBM well drainage process the pressure needs to reduce how much MPa to let the CBM throw off the coal matrix binding and is produced. As if the initial gas-saturation degree of the coal seam is higher, then in the pore-fracture system of the coal the excess surface free energy is relatively lower, the variation of the outer conditions such as the pressure reducing, the adsorbed gas is very easy to throw off the coal matrix binding and becomes the free gas conducting the diffusion. In fact, the gas-saturation degree is the ratio of the measured gas content and theoretical gas content. The measured gas
content is the gas content acquired from the coal core desorption (desorbed gas, residual gas and loss gas). The theoretical gas content is the gas content corresponded to the original formation pressure on the isothermal adsorption curve. The researches had indicated that some CBM high-production and enriched areas all are the high saturation degree; the gas reservoir with the moderate saturation degree has not only the poor stable production effect but also the low production [7]. Moreover, the gas-saturation degree can reflect the dual properties of the gas content and adsorption capacity.

2.3. Resource conditions

In one area, the resource quantity is determined by the gas content, seam thickness and resource abundance, etc, and is the material basis for the CBM with the recoverable property. The CBM resource quantity and abundance are the important factors determining the CBM well productivity, the high gas content in seam and the larger resource quantity are the keys ensuring the stable and continuous gas production of the gas well; while the resource abundance is one of the control factors ensuring the gas source supply for the wellbore and the high production of the gas well.

2.4. CBM productivity situations

Although the CBM producing situation is restricted by various factors, the engineering construction in later period, such as the fracturing, draining and so on have the great impact on it. However, under the current technical conditions, the gas producing situation of the CBM wells reflects the distribution of the CBM productivity feature in the Qinnan area to a definite degree. According to the Code for coalbed methane resources/reserves (DZ/T0216-2002), the gas well with the average daily CBM production of more 3000m³/d is the high-producing well. In the southern part of the Qinshui Basin the CBM exploration and development practices proved that based on the data analysis of 74 CBM wells which are practically drained at present, the average daily gas production of 35 wells is more 2000m³/d (Fig.1), moreover the gas producing is stable, and the gas supply is sufficient. Therefore, it is feasible that taking the gas production of 2000m³/d as the limit value for assessing the high abundance CBM enrichment area.

Fig. 1. Production distribution histogram of partial CBM wells in the Qinnan area

3. Value-taking standard for enrichment area assessment parameters
There are many factors impacting the CBM productivity. In the Qinshui Basin the target seam is stable, the thickness variation is lesser, and they are not the key factors impacting the gas well productivity. The main factors resulting in the difference of the gas well productivity are: CBM resource abundance, seam permeability, reservoir pressure gradient, seam buried depth, development and distribution situations of structures and hydrogeological conditions. Here, it takes the average daily CBM production of more 2000m³/d as the basis to discuss the limit values for the assessment parameters of the high abundance CBM enrichment area.

3.1. Permeability

The coal reservoir permeability plays the decided role on the CBM well production. Based on the statistics on permeability data in the Qinnan area (Panzhuang, Shizhuang, Fanzhuang and Zhengzhuang), in more 50% of data points the coal reservoir permeability is larger than 1.0md (Fig.2). Based on the relationship between the coal reservoir permeability and the gas well production, both appear as the semi-logarithmic normal distribution (Fig.3), and between both it has the inevitable geological relation. According to the relevant data, the CBM high production area is located in the area with the moderate coal reservoir permeability (0.5md~1.0md), and the permeability too low or too high all are unfavorable for the high producing of the CBM well [8]. The statistic relationship data of the CBM well production situation and the coal reservoir permeability indicated that in the high gas production well the coal reservoir permeability is ranging in 0.5~5.0md commonly (Fig.3), for example, TL-003, TL-006 and Jin-test No.1 well group and so on. In the well with the highest gas production the permeability is about 1.0md; if the permeability is lower than 0.5md or larger than 10md, the gas production of the CBM well is lower commonly, for example, TL-008, LT011 and G2-G-4 wells and so on [9].

Fig. 2. Coal reservoir permeability distribution histogram in different blocks in Qinan area
Fig. 3. The relation map of gas production and permeability (reference[9], revised)

3.2. Gas-bearing saturation degree

The gas-bearing saturation degree reflects at some degree the saturated degree of the pore-fracture system filled by the gas. This index has the very important signifercence for judging the CBM well productivity, and it can reflect comprehensively the dual properties of the gas content and adsorption capacity. According to the statistic relationship between the limited gas well production and gas-bearing saturation degree, in the low-production well of <500 m3/d, the gas-bearing saturation degree of coal reservoir is mostly ranging in 28% ~ 67%, and in the gas well with the higher gas production (the daily gas production is more 2000 m3/d), the gas-bearing saturation degree is ranging in 72% ~ 145% (Fig.4). Therefore, the gas-bearing saturation degree attaining to more 70% should be the important index for the CBM well acquiring the higher productivity in the Qinnan area.

Fig. 4. The relation map between the gas content and gas-bearing saturation degree

3.3. Coal seam buried depth
The coal seam buried depth impacts directly on the geostress strength suffered by the coal reservoir, while the geostress determines again the development and openness of the fractures in coal reservoir. Therefore, the seam buried depth has a definite of impact on the CBM well productivity. Based on the statistic analysis on the CBM drainage wells with the average daily gas production of more 2000 m$^3$/d, the seam buried depth of these wells in ranges mostly from 260 to 400 m (Fig.5).

3.4. CBM resource abundance

As one of the control factors ensuring the high producing of gas well, the CBM resource abundance plays the important role for assessing the high abundance CBM enrichment area. Based on the superimposed analysis of the resource abundance and CBM production in the Qinnan area, it can be seen that in the Qinnan area the resource abundance of No.3 seam is higher, 0.8 ~ 2.0×10$^8$m$^3$/km$^2$, and from north to south, the CBM resource abundance appears as the reduction trend. For the block with the average daily CBM production of 2000m$^3$/d, the CBM resource abundance is more 0.8×10$^8$m$^3$/km$^2$ (Fig.6).

![Fig. 5. The relation map between the CBM well production (>2000m$^3$/d) and buried depth](image)

3.5. Reservoir pressure gradient

The reservoir pressure gradient is a key index reflecting whether the coal reservoir pressure is situated in the under-pressure, normal or over-pressure states, and it has the important impact on the CBM recovery. Based on the statistic analysis on the reservoir pressure gradient of No.3 seam in the Qinnan area, it can be seen that in the Qinnan area, the reservoir pressure gradient of No.3 seam appears as the variation trend of high in west and low in east, the reservoir pressure gradient in Zhengzhuang is the highest, attaining to 1.0MPa/100m, the reservoir pressure gradient in Panzhuang is about 0.6MPa/100m, and that in Shizhuang and Fanzhuang is about 0.5MPa/100m (Fig.6). Based on the superimposed analysis of the reservoir pressure gradient of No.3 seam and the CBM production in Qinnan area, it can be seen that for the block with the average daily CBM production of 2000 m$^3$/d, the reservoir pressure gradient is more 0.6MPa/100m.
4. Conclusion and discussion

According to the analysis on the space features of various parameters of the high abundance CBM enrichment area in the Qinnan area, the assessment indexes of the high abundance CBM enrichment area in the Qinnan area shall be the indexes in 8 aspects: structure and water dynamic condition, coal seam buried depth, permeability, gas-saturation degree, reservoir pressure gradient, CBM resource abundance and single well daily gas production. Based on the correlation analysis of various parameters and CBM well productivity of the CBM enrichment area, the limit values of the assessment indexes of the high abundance CBM enrichment area in the Qinnan area are: the enrichment areas are located mostly in the groundwater stagnant area with the syncline structure and simpler hydrogeological conditions; the seam buried depth is shallower, permeability >1md; gas-bearing saturation degree >70%; reservoir pressure gradient >0.5MPa/100m; and daily gas production of single CBM well >2000m³/d.

![Fig. 6. The relation map among the gas production and isolines of CBM resource abundance and reservoir pressure gradient](image)

References


