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Research on Technique for Reconstruction CBM Reservoir with Low Grade Coal in Hunchun Coalfield

Cao Li gang, Gao Yang, Hu Bo Lun*
Yanbianyao natural gas company, Shenyang 110013, China
*Corresponding Author: Email: mcq24111156@163. com

Summary

Hunchun Coalfield belongs to the low grade coal (brown coal). This coal seam is relatively complex and lies in depth of 400–650m. It has the characteristics of multiple thin coal seams. It amounts to 30–70 seams and its thickness is about 5–40m. In general, the thickness of each coal seam is 0.2–3.0m and the distribution of coal seam is in the range of 185–235m, of which only 45% can be mined and the other cannot. There are some technical and economic difficulties in the investment for the coal seams reconstruction. At present domestic and abroad, the development of coalbed methane (CBM) had no precedent and experience in reservoir reconstruction for such complex coal seams. We adopted the reservoir restructure using fracturing combination and the globe subdivided pressure technique. This process engineering is mainly to combine the characteristics of coal seams in Hunchun Coalfield and the production technology of petroleum and natural gas. We used optimal grouping of coal seam and the theory of pressure division by the globe to maximize the coal seam reconstruction. The research on key technologies for the reservoir reconstruction with multiple thin coal seams in Hunchun Coalfield and the production practice of the CBM testing wells showed that this technique has economic rationality and technological advancement.

Keywords: Coal bed methane (CBM); Multiple coal seams; Thin coal seam; Reservoir reconstruction; Research and application

1. Introduction

Hunchun Coalfield belongs to the low grade coal and the coal reserve in this area is about 10.2×10^8t [1]. The CBM reserve in No. 1 of Baliancheng–Banshi region is $19.2\times10^8 m^3$ (the gas content is $5.65m^3$/t on the average). In the area, the coal seam is deposited in sallow depth and it has the characteristics of multiple thin coal seams [2, 3].

Based on analysis of the characteristics of this reservoir, we reconstructed the coal seams. We used the fracturing combination of multiple thin coal seams and the globe subdivided pressure technique. This technique is advanced and rational in economy. In May 2010, Yanbian Yaotian Natural Gas Company drilled three parameter and production test wells in the western and southern area of Baliancheng minefield to show the very good effects of this technique in gas production [4].

2. Characteristics of the coal gas reservoir in Hunchun Coalfield

2.1 Coal seams

The coal–bearing formation consists of clastic, Hunchun series, Tertiary period, Cenozoic era, which is widely covered by the Quaternary strata; and underlain by volcanic effusive rocks of Yanshan period. The coal seams No.32, 34 and 36 were developed in the bottom conglomerate part. The lower coal–bearing section was developed through overall area and the developed seams are from No.18 to No.30. The middle coal–bearing section was developed in the southwestern direction and involves seams from No.11 to No.17. The top coal–bearing section was developed in the western direction and involves seams from No.1 to No.10. The coal–bearing formation in this area generally contains 30~70 coal seams, with a maximum of 110 coal seams. The coal–bearing ratio is about 3% and the recoverable and partially one coal seam are generally 3~8 seams. The lower coal–bearing section in the longitudinal direction had the best coal–bearing property and the order of developing property of coal seam in the whole area is No.23, 19, 20, 21, 22, 26 and 30. The accumulative thickness of each coal seam is generally 5~40m and the maximum thickness is 43.44m. The center of rich coal is located in the north of Banshi region No. 1, the west of the central western town and the adjacent area of Baliancheng. The maximum thickness of a single coal seam is 8.5m, generally 0.2–3.0m. in plane, the coal–bearing property and continuity in the western area is obviously better than one in the eastern area and the coal is brown and Long flame coal.

2.2 Characteristics of geological structure

Hunchun Coalfield is a large coal–bearing basin in Cenozoic era. Its overall strike is generally oriented in the northeast direction, forming a syncline structure. The fold and fault structures were relatively developed in the basin. Shuangxin–Machuan bulge in the north–south direction of the central part of the basin is divided the basin into two sags. The west is the YingAn–Banshi sag, which is the site of production mine. The northeast–eastern Hunchun anticline further divides the western sag into the northwestern YingAn syncline and northeastern Balian city–Banshi syncline. The normal fault with high angle is developed in the syncline. The syncline has a normal fault with an abrupt inclination. Baliancheng–Banshi syncline is the main area for CBM exploration and development.

2.3 Coal reservoir characteristics and gas content

According to the analysis of samples from the coal mine in Balian city, the permeability of coal seam in Hunchun Coalfield is relatively high as 0.1–5 mD. The pressure of coal reservoir belongs to the positive pressure and the pressure gradient generally ranges 1.01 to 1.05 MPa/100 m. These factors are favorable for CBM development by the surface drilling.

The low grade coal pores in this area are mainly composed of macropores and mesopores, which generally reflect the type of semi–closed pores and fine bottleneck pores, partially reflecting the semi–closed pore characteristics. The specific surface area is distributed at 5~6nm and 50~60nm. The adsorption capacity of low grade coal is generally lower than that of medium and high grade coals.

We sampled and tested by drilling of the coal seam in No. 1 of Banshi region. The gas content of coal seam was 0.83–4.11 m^3/t, with an average of 2.58m^3/t. The direct and indirect test results of CBM content in the underground of the coal mine in Baliancheng minefield were 6.20m^3/t and 8.18m^3/t on the average, respectively.

According to the true specific gravity and apparent specific gravity ratio of coal in Ying'an and No. 1 of Banshi region, the porosity of coal matrix is estimated to be high, the maximum value is 20.12%, the minimum 5.76%, and the average 12.48%.

Through underground observations of coal seams such as 23, 26, 28, and 35 in the Baliancheng coal mine, it is found that the joints and cracks of the coal seams are relatively developed, and the external cracks are dominant. Also, most of the crack surfaces are rough, generally no filling, and the amount of surface joint was about 15 pieces per 5cm, with about 20 pieces per 5cm in No. 1 of Banshi region (Fig.1).

Figure 1. Coal sample from coal seam No.19 in Baliancheng minefield

2.4 Resource abundance of CBM

From the viewpoint of features of developed coal seams, the coal seam in Baliancheng–Banshi region No. 1 has relatively good continuity and located in the coal–rich part of the basin. The individual and accumulated thicknesses of coal seam are relatively large. From the viewpoint of coal resources, although the resource amount of coal and CBM is not large in the whole region, but large in the local region. The coal reserves in the region are characterized by “western rich and eastern poor”. The CBM resources in No. 1 of Baliancheng–Banshi region is (1.2~1.5)×$10^8$$m^3$/$km^2$, which is characterized by small and rich.

3. Application of the process technology for coal reservoir reconstruction

3.1 Fracturing combination of multiple thin coal seams and principle of pressure division by the globe

The fracturing aims to connect the joint systems each other by injecting the water of high pressure into the coal reservoir. The water of high pressure with a high discharge amount is used in fracturing. The transported fracturing support maintains the fracture cracks and prevents the crack closing after the pressure relief to produce the channels for gas production.

The pressure division by the globe is generally used for large interval of the fracturing sections. In order to overcome the influence of the reservoir pressure gradient, the liquid flow is artificially distributed to efficiently fracture the coal seam in the fracturing section.

Also, the pressure division by the globe is generally used in oil and gas wells for primary fracturing of multi–layer oil and gas reservoirs. Due to the reservoir pressure gradient and the difference in backflow capacity between the seams, the fluid generally flows to the horizon with low pressure and strong liquidity. In order to control the flow direction of fracturing liquid, the unobstructed channel is closed by the globe throwing in time, while the relatively unobstructed channel is opened for maximizing the of the reservoir reconstruction (Fig. 2).

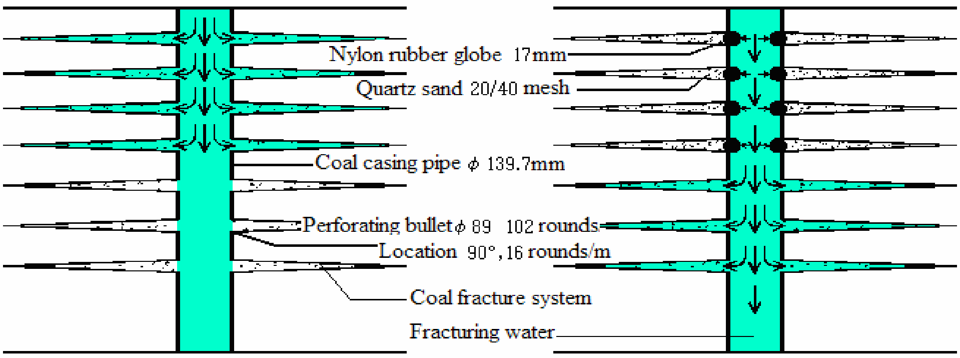
3.2 Optimization of technical parameters

The choice of main technical parameters in fracturing depends on the characteristic condition of coal reservoir, that is, the depth of range restructured by fracturing, the coal thickness, the developing state of fractures in the coal seam and hydro–geological conditions.

The main designed parameters are below.

(i). Pump discharge: 8m^3/min
(ii). Sand content: average more than 10%
(iii). Sanding method: using step sanding
(iv). Fracturing method: using casing fracturing
(v). Fracturing method with sublayer combination: using returning sand filling sublayer
(vi). Support selection: 20/40 mesh quartz sand
(vii). Mode of throwing a globe: timely
(viii). Configuration of fracturing fluid: use clean water +2% KLC + drainage promoter of 1‰.

In the design, the fracturing fluid configuration adopts clean water +2% KCL+1 ‰ drainage promoter, mainly considering the high ash content of the low grade coal seam. In order to suppress the water sensitivity expansion of the coal seam, KCL (potassium chloride) is added to prevent expansion and maintain the cracks. The addition of the drainage promoter can mainly reduce the backflow resistance of the fracturing fluid to a certain extent, and overcome the influence of the water tension on the resistance of the micro–channel.



a) The flowing direction before throwing the globe b) The flowing direction after throwing the globe

Figure 2. Principle diagram of globe subdivided pressure

3.3 Combination and division of fracturing section

The main principle is to divide the fracturing section into several subsections. In the sublayer combination, the coal thickness is generally lager than 3–8m and the section interval less than 30m. There is enough sand filling height for sublayer combinations, generally not less than 10m. The well No. BLCX–1005 is a typical example for the combination of fracturing sublayer.

In the well No. BLCX–1005, the total thickness of coal is 27.71m and the section for fracturing reconstruction is 385.50~539.00m. Depending on the coal seam structure, the fracturing section was combined into four intervals.

a) The first fracturing interval:

It is from 539.00 to 516.30m, the sublayer thickness 22.7m, the coal thickness 4.35m, the perforation thickness 6.80m, the sanding amount 20/40 mesh quartz sand 30m^3, the fracturing liquid 700m^3 (pre–liquid of 400m^3 and sand transporting liquid of 300m^3) (Fig.3).

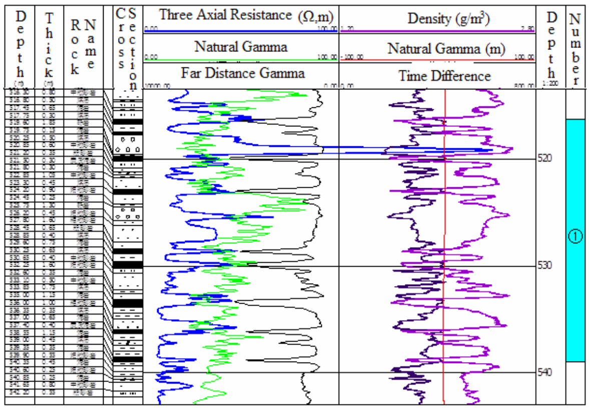


Figure 3. Analysis diagram in well No. BLCX–1005 (the first fracturing interval)

b) The second fracturing interval:

It is from 496.03 to 476.60m, the sublayer thickness 21.43m, the coal thickness 5.96m, the perforation thickness 8.93m, the sanding amount 20/40 mesh quartz sand 35m^3, the fracturing liquid 750m^3 (pre–liquid of 400m^3 and sand transporting liquid of 350m^3) (Fig.4).

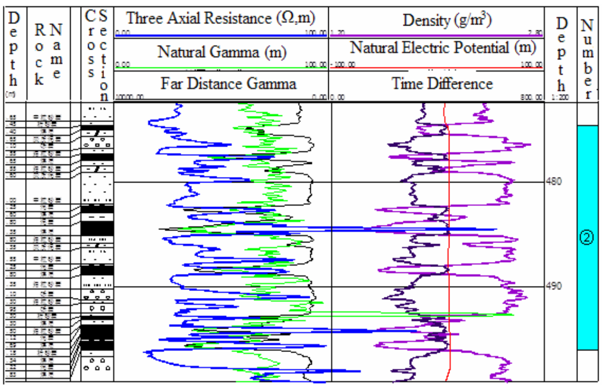


Figure 4. Analysis diagram in well No. BLCX–1005 (the second fracturing interval)

c) The third fracturing interval:

It is from 457.95 to 425.25m, the sublayer thickness 32.7m, the coal thickness 6.75m, the perforation thickness 9.45m, the sanding amount 20/40 mesh quartz sand 30m^3, the fracturing liquid 800m^3 (pre–liquid of 400m^3 and sand transporting liquid of 400m^3) (Fig.5).

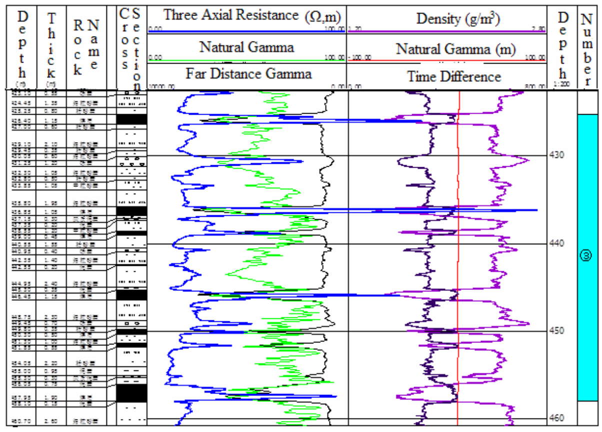


Figure 5. Analysis diagram in well No. BLCX–1005 (the third fracturing interval)

d) The fourth fracturing range:

It is from 403.15 to 385.50m, the sublayer thickness 17.65m, the coal thickness 2.50m, the perforation thickness 4.90m, the sanding amount 20/40 mesh quartz sand 25m^3, the fracturing liquid 650m^3 (pre–liquid of 400m^3 and sand transporting liquid of 250m^3) (Fig.6).

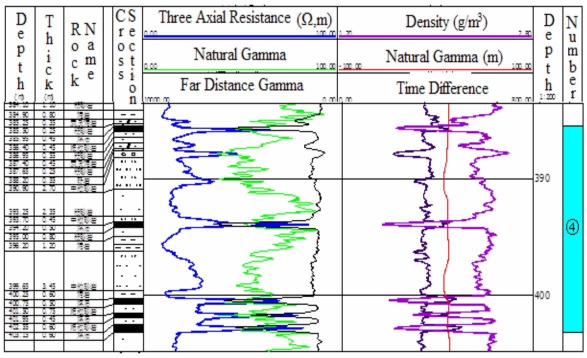


Figure 6. Analysis diagram in well No. BLCX–1005 (the forth fracturing interval)

3.4 Analysis of sublayer fracturing efficiency

3.4.1 Efficient utilization of coal reservoir with low grade and multiple thin coal seams

In view of the characteristics of coal reservoir with low grade and multiple thin seams in Hunchun Coalfield, the efficient utilization of coal seam productivity is an important problem to improve the gas productivity of one CBM well. Although the gas content in low grade coal is generally low as 2~8m^3/t, the thickness of coal seam is relatively large. Therefore, it is necessary to use the advantage of low grade coal to increase the gas productivity of single well. In addition to the sublayer globe fracturing combination, the well No. BLCX–1005 has taken engineering measures such as auxiliary perforation of non–fractured coal seam to effectively utilize the productivity of multi–coal seam reservoirs.

The actual coal thickness is 27.71m in the well No. BLCX–1005, while the thickness of the fractured coal seam is 19.56m, accounting for 70% of the total thickness of the coal seam, and the coal thickness (8.15m) of the other 30% is out of the fracturing range.

The reason is because of coal compressed by the sand filling.

In order to improve the contribution of productivity in this part, the non–fractured coal seams of thickness more than 0.5m were additionally perforated after the fracture was completed. The coal thick of 9.6m was additionally perforated to contribute the improvement of well productivity.

3.4.2 The overall analysis and productivity prediction of gas exhaust in a well

Based on the steady–continuous–slow principle in correspondence to the characteristic of large interval gas production in Hunchun Coalfield, we lowered the drainage speed of liquid as possible (generally 10~15m^3/d) and prevented the moving of coal seam by maintaining the general liquid level dropping in lower than 5m^3/d, for the purpose of protecting the flowing and storage channel of CBM.

Because of high storage pressure and gas containing saturation in the region, the fast speed of gas was observed.

For the purpose to study the pump depth–the liquid level varying law–the varying law of casing pressure–the varying law of productivity, we made the different working conditions for three wells to ensure the distinguished production of water and gas.

The gas well was safely operated and its production tendency good.

The data of drainage gas production in every well is followed.

a) Well No. BLC–03

The production was started from July 9, 2011 and ended in May 20, 2012.

The maximum pressure of casing is 1.5MPa, the drainage amount of liquid 4 800m, the depth of liquid level 205m and the total productivity of gas 35 000m. At present, the well is still under production and the predicted average production of one well is 1 000m^3/d.

b) Well No. BLCX–1004

The production was started from July 9, 2011 and ended in May 20, 2012.

The maximum pressure of casing is 1.5MPa, the drainage amount of liquid 3 600m^3, the depth of liquid level 240m, the total productivity of gas 263 310m^3, the instance flowing quantity 120m^3/h and the production of one day 768.00m^3/d. At present, the well is still under production and the predicted average production of one well is 1500m^3/d. It is operated by CNG method.

a) Well No. BLCX–1005

The production was started from July 9, 2011 and ended in May 20, 2012.

The maximum pressure of casing is 1.5MPa, the drainage amount of liquid 4 500m^3, the depth of liquid level 230m, the total productivity of gas 490 000m^3, the instant flowing quantity 200m^3/h and the production of one day 3 072m^3/d. At present, the well is still under production and the predicted average production of one well is 200m^3/d. It is operated by CNG method (Fig.7).

The analysis of drainage gas production of three wells showed that the production prediction of well was higher than the commercial standard for production of gas of 500m^3 in depth of 500m and it could be possible to develop the gas resource in Hunchun Coalfield in correspondence to the need of commerce and industry.

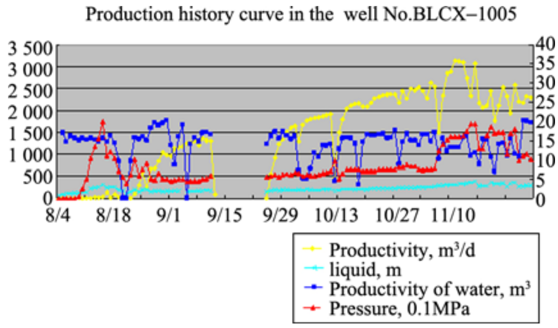


Figure 7. Production history curve in the well No. BLCX–1005

4. Conclusion

In view of the characteristics of low grade and multiple thin coal seams in Hunchun coalfield, we have reconstructed the coal seam reservoir in the CBM well using the sublayer fracturing technique with the globe throwing. Through the production practice of in wells No. BLC–03, No. BLCX–100 and No. BLCX–1005, it was proved that the engineering technique was rational and the evident effect of production improvement obtained.

Therefore, this technique can be introduced to the development of such similar coal seam.

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