Application of Multi-group Seam Thickness Prediction in CJT Coal Mine

Shan Rui
Xi’an Research Institute, China Coal Technology & Engineering Group Corp., Xi’an 710077, China

e-mail: sanxin1984@163.com

Abstract: Accurate prediction of coal thickness is of great significance to guide coal mine safety production. Taking the coal thickness prediction of the CJT coalfield in Shaanxi province as an example, this paper selects the conventional wave impedance inversion technology and seismic multi-attribute technology to comprehensively predict the thickness of the target coal seam, and the correlation coefficient of the prediction trend of the coal seam thickness is as high as 98%. The prediction results show that wave impedance inversion combined with multi-attribute quantitative prediction of coal seam thickness is an effective method for complex geological conditions in the study area.

1. Introduction
It is an important factor affecting the safe and efficient production of coal resources to ascertain the thickness change in advance and in detail, which will affect the design of the first mining surface, the selection of supports, and the mining deployment, etc. The study of the thickness change is of great significance to guide the safe production of coal mines [1]. The first method is to analyze the variation rule of seismic attribute and coal seam thickness, and to quantitatively predict coal thickness by establishing the linear or nonlinear relationship between coal thickness and seismic attribute [2], Geostatistics and artificial neural network are the main methods, and seismic multi-attribute analysis technique is more and more widely used to quantitatively predict coal seam thickness [3-5]. Meanwhile, Peng S.P., Cui R.F. and other experts used inversion to obtain high-precision coal thickness information. The main inversion methods are seismic constrained sparse pulse inversion and logging constrained inversion [6-8]. The above methods can predict the change trend of coal seam thickness well.

Taking a coal field in the Jurassic period of northern Shaanxi province as an object, this paper predicts the variation trend of coal seam thickness by conventional interpretation of multi-group seismic data, combined with logging constraint inversion and seismic multi-attribute analysis.

2. Adaptability analysis of coal thickness prediction method
The forward modeling study found the response relationship between coal seam thickness and seismic attributes. Fang H.R. used the model forward modeling to generate the data set, and obtained the post-stack migration profile through data processing. Through the comparative analysis of different migration profiles and their instantaneous attribute profiles and waveform difference attribute profiles, it is concluded that the recognition limit of the thickness of coal seam with buried depth of 400m in the post-stack profile is λ/8 (λ is the seismic wavelet length), The recognition limit on the
instantaneous amplitude attribute profile is, $\lambda/8$, the recognition limit on the instantaneous phase attribute profile is less than, $\lambda/8$, and the recognition limit on the waveform difference attribute profile is $\lambda/4$, obviously, the higher the main frequency and the shorter the wavelength of the seismic data are, the higher the resolution is.

Zhu F.X. and Li G. studied the relationship between the characteristic parameters of seismic kinematics and dynamics and the thickness of coal seam through model forward modeling [8-10]. For coal thickness less than $\lambda/4$, the variation of coal seam thickness is correlated with the amplitude, phase and frequency of reflected wave. The prediction of coal seam thickness by geological attribute is applicable to the area where the thickness of coal seam is less than the adjusted thickness. When the thickness of the coal seam is larger than $\lambda/4$, the reflection waves of the roof and floor of the coal seam are separated to form a certain time difference, and the wave impedance inversion can be combined with the coal seam velocity to calculate the actual thickness of the coal seam.

2.1. Prediction of coal seam thickness by seismic inversion
Seismic wave impedance inversion is one of the important means of lithologic seismic exploration and has become a comprehensive technique of seismic processing and interpretation. Conventional seismic data reflects the formation reflection interface, logging data reflects the lithologic information, seismic inversion can be regular interface type convert the seismic section of rock type of log, facilitate compared with drilling and logging data connection, the inversion results can be used to more carefully study the spatial variation and distribution of all kinds of stratigraphic characteristics, thus become the key technology of coal thickness prediction research. In this area, the spatial morphology and thickness variation of thicker coal seams are analyzed by means of well logging constraint inversion.

2.2. Prediction of coal seam thickness by seismic multi-attribute
In the stratum, the spatial change of rock property and fluid property will cause the change of seismic reflection waveform, amplitude, frequency, energy, phase and a series of seismic properties. In order to reduce the multi-solution of seismic attributes, a variety of attribute parameters can be extracted, different attributes can be analyzed and predicted comprehensively by using a variety of mathematical statistical methods, and the thickness of thin coal seam can be quantitatively predicted. The method of joint interpretation of coal seam thickness is more perfect [6-9].

In order to predict the thickness of coal seam by seismic multi-attribute fusion, a variety of attributes of the target horizon are extracted first, and the effective combination of attributes is optimized through relevant technical analysis. Then, the prediction model of coal seam thickness and property is established by using the borehole coal seam thickness and its seismic property value. Finally, the variation trend of coal seam thickness is obtained by calculation.

3. Application of seismic inversion and multi-attribute analysis in multi-group coal seams

3.1. Survey profile
The study area is northern shaanxi Jurassic coalfield. The strata are generally a monocline with NE trend, less than 1° dip angle, and the overall morphology is gentle. There are more than ten layers of coal seams in the area, among which A2, A3, A4, A5 are the main coal seams, all of which are yanan formation of Jurassic. A2 coal seam thickness is 10.8-12.7m, with an average of 3.78m; A3 coal seam is 1.93-2.54m, with an average of 2.36m. A2 of extra-thick coal seam and thin layer A3 coal seam are the research objects.

3.2. Fine calibration of coal seam
The study area interprets and demarcates seismic data by synthetic seismic records (Figure. 2), The reflection wave of T2, from A2 coal seam is shown as two strong phases, with obvious characteristics
of wave group. The reflection wave of T3 from A3 coal seam is about 30ms away from the reflection wave of A2 coal seam, with obvious characteristics of wave group. The target layer of the data volume is continuous, the signal-to-noise ratio is high, and the waveform is especially stable (Figure 3). On this basis, the seismic reflection wave characteristic of coal seam is used to carry out fine tracing of reflected wave of coal seam.

According to the forward modeling analysis, the main frequency of seismic data in the target layer is 50Hz, the coal seam velocity is 2000m/s, \( \lambda/4 \) the thickness is 10m. When the thickness of the coal seam is less than 10m, the thickness change of the coal seam is related to the seismic property, which is suitable for the prediction method of the thickness of the multi-attribute coal seam. After the tuning thickness is exceeded, wave impedance inversion is selected to predict the thickness of the coal seam. The thickness of A2 coal seam in the study area is 10.8~12.7m, and the attribute is not highly correlated with the coal thickness, but it has good conditions for inversion after no time. Wave impedance inversion can better solve the thickness change of thick coal seam.

3.3. Inversion predicts coal seam thickness
The accuracy of the inversion depends on the known log and the established low frequency model. The accurate time-depth relationship between well logging and seismic data was established by single well seismic synthesis records (Figure 2), and the low-frequency model was established by using seismic interpretation of stratification, fault and seismic data. In the inversion process, the inversion spatial variation function was calculated by using well logs to guide model interpolation. Taking the low-frequency geological model as the input constraint, an appropriate interpolation algorithm was
selected to perform the interpolation, and the inversion results were obtained (Figure 3).

![Figure 3 impedance data volume (vertical view)](image)

The thickness of A2 coal seam varies little, but the wave impedance value can be basically recognized by studying the reflection wave characteristics of the coal seam and well seismic calibration. The inversion results correspond well with each well, and the inversion profile clearly depicts the spatial distribution characteristics of coal seam. The numerical range of wave impedance of the coal seam is divided by the analysis of sensitive parameters, then impedance extraction and time thickness superposition are carried out on the inversion data body, and then the plane thickness distribution diagram of A2 coal seam is obtained by multiplying the velocity value of the coal seam obtained by the statistical analysis of the log curve (Figure 4).

![Figure 4 Prediction of A2 coal seam thickness in the study area](image)

3.4. Quality analysis of multi-attribute coal thickness prediction results

The thickness of A3 coal seam in the study area is 1.93-2.54m. Along the A3 layer as the center, six types of seismic attributes, including amplitude attribute, frequency attribute, phase attribute and spectrum statistic attribute, were extracted by using 10ms time window. The sample data of 24 Wells in the study area were selected to extract the thickness value of coal seam and the seismic attribute value of well point. And the seven selected seismic attribute combinations are independent from each
other and effective for the thickness of coal seam (Table 1). Through multiple regression calculation, the thickness distribution map of coal seam is obtained (Figure. 5), and the intersection map of coal seam thickness and borehole coal thickness is predicted to show that the correlation coefficient is up to 98%.

Table 1 satatics of coal thickness and seismic attribute related coefficiection

| Number | Attribute                      | Training Error | Validation Error |
|--------|--------------------------------|----------------|------------------|
| 1      | Dominant Frequency             | 0.17           | 0.20             |
| 2      | Average Frequency              | 0.14           | 0.17             |
| 3      | Instantaneous Frequency        | 0.12           | 0.15             |
| 4      | Second Derivative              | 0.10           | 0.16             |
| 5      | Instantaneous Phase            | 0.09           | 0.13             |
| 6      | Second Derivate Instantaneous Amplitude | 0.06       | 0.10             |

![Figure.5 prediction of A3 coal seam thickness in the study area](image)

4. conclusion

Impedance inversion and multi-attribute analysis and prediction techniques are used to predict the thickness of different coal seam target layers, and good results are obtained.

Reference

[1] Wang B, Liu SH.D, Huang L.Y. (2012) Integrated Forecasting Analysis of Coal Seam Thickness. Coal Technology, 31: 94-96.
[2] Cheng Y. (2019) Geological statistical coal thickness prediction method and application analysis. China mining magazine, 28:245-249.
[3] Zhao Y.X, Li X.W, Yuan CH.Y, etc. (2019) Application of neural network technology optimized by multiple seismic attributes to prediction of C81 sandstone reservoirs in coal seam area in L block of ordos basin. Marine Geology Frontiers, 35:65-72.
[4] Du B.L. (2018) Application of seismic multi attribute BP neural network in predication of coal seam thickness. Chinese Journal of Engineering Geophysics, 15:246-251.
[5] Peng S.P, Zou G.G., Li Q.L. (2008) Application of well logging constrained seismic inversion in coal thickness prediction. Journal of China university of mining and technology,37:729-733.
[6] Cui R.F. (2007) Application of wave impedance inversion technique in seismic exploration of coalfield. Shandong coal society: 2007:4. Et

[7] Zuo W.H. (2018) The prediction of coal seam and upper sandstone thickness using well logging constrained 2D seismic inversion technique. Chinese Journal of Engineering Geophysics, 15:181-188.

[8] Liu Y.T. (2019) Fine study of multi-group coal in xi leng sheng li coal mine based on fusion of seismic inversion and attribute optimization. Xuzhou: China University of mining and technology.

[9] Zhu F.X, Liu T.F. (2002) Study and application effect of coal thickness interpretation method in Jurassic coalfield in northern shaanxi. China coalfield geology, 14: 60-64.

[10] Li G. (2012) Method of predicting coal seam thickness by seismic attribute and its application. Xi'an: xi'an research institute of coal science research institute.