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Prediction of Young Modulus of coal using artificial neural networks in Qinshui Basin, China

GUO Xiaoqian^{1,2}, LIU Dameng^{1,2} and YAO Yanbin^{1,2}

¹ School of Energy Resources, China University of Geosciences, Beijing 100083, China;

² Coal Reservoir Laboratory of National CBM Engineering Center, China University of Geosciences, Beijing 100083, China;

1 Introduction

Mechanical properties of coal are most important parameters in controlling fluid storage and flow before and after coal extraction [1-2]. Reservoir simulation design and wellbore stability analysis are influenced by elastic and strength character of coal rocks [3]. Young's modulus, and shear modulus are used when deformations in underground mines need to be computed. Thus accurate assessment of elastic properties of coal rocks is extremely important for ground mining.

Traditional methods such as uniaxial compressive strength, triaxial compressive strength, point load, Schmidt hammer, scratch and indentation tests, were conducted to obtain the compressive strength and elastic modulus. The procedure for measuring these parameters has been standardized by both the American Society for Testing and Materials (ASTM) and the International Society for Rock Mechanics (ISRM). However, these experiments are complicated and time consuming [4-5]. Another disadvantage of test samples is that it will not be in the in situ conditions anymore. It's very difficult and nearly impossible to simulate the ground stress and fluid condition in lab. And due to variations in rock composition, lab results may not be fully representative of the entire reservoirs.

Geophysical well logs can be used to deliver a continuous data of in situ properties of rocks. Among these logs, full wave sonic logs can be used to calculate dynamic Young Modulus (E_{dyn}). However, due to the complicated and expensive operation procedures, full wave sonic logs are seldom used. In order to overcome these difficulties, lots of relationships have been developed to estimate the E_{dyn} , but majority of them are based on a special rock type [2,6].

In this study, neural network technique was introduced

for prediction of E_{dyn} in Zhengzhuang District of Qinshui Basin in China. Density logs (DL), gamma ray (GR) and shear wave logs (AC) are the frequently used well logs for the target zone. Network between E_{dyn} and the three logs will be established.

2 Material and method

2.1 Log data

Data from well S30 were used in this study. Before introducing any well logs into study two reasons should be considered for quality control. The first one is the depth mismatch and gamma ray log can be regarded as the baseline. The other one is noise in the formation, which means any data represents -999.75 should be removed [7]. In this study, four well logs were corrected by hand or automatically by recorder, density logs, gamma ray, shear sonic logs and compression sonic logs. Fig. 1 shows the interval transit time in well S30. And we also have density, gamma ray from the raw well logs.

2.2 Estimation of Young module

Estimation of Young moduli is often calculated through acoustic logging using the following relationship [1, 8]:

$$E = \frac{\rho}{\Delta t_s^2} \left(\frac{3\Delta t_s^2 - 4\Delta t_p^2}{\Delta t} \right) \times 10^9 \quad (1)$$

Where ρ represent the density, cm^3/g ; Δt_s and Δt_p represents the compression and interval transit time, us/m . E_{dyn} of well S30 was acquired from Eq.(1) as baseline. Then ANN will be used to predict the E_{dyn} from the three logs.

3 Neural network models

ANN has been widely applied to form models of

* Corresponding author. E-mail: guoxcugb@gmail.com

complicated problems in the last two decades. The whole system is consist of parallel processing components and can be trained to perform a particular function by adjusting the values of connections between elements [9,10].

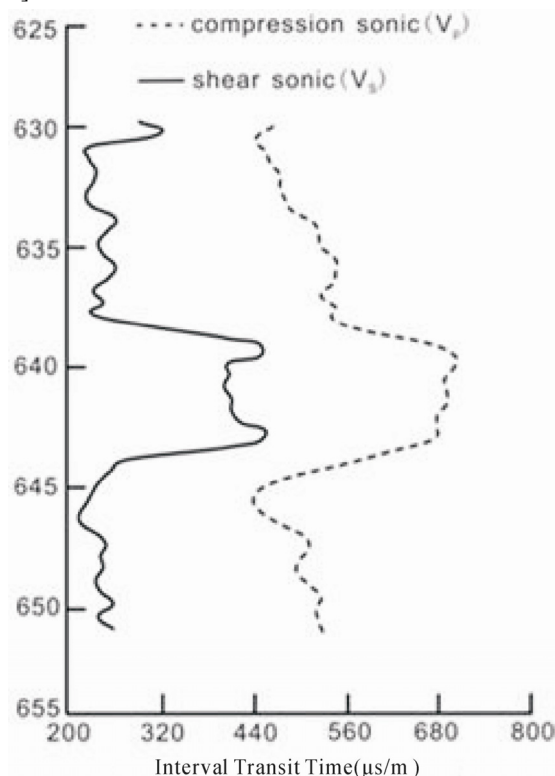


Fig.1 Interval transit time in well S30

In the present study, back-propagation is chosen as the network type. The input data are transmitted through the networks, layers by layers and a set of data are obtained. The connections of the network were set. Fig.2 shows the architecture of the three layered network to calculate the Young's module from gamma ray, density and shear wave logs.

In the optimization of the network, log data from GR, DL, AC and Young Modulus from well S30 were used. Each of the logs had 108 data points. After several trials, for the output data, E_{dyn} , the optimal number of neurons of the first and second hidden layer using trial and error method is obtained 20 and 25 perceptrons, respectively. Mean square error (MSE) was chosen as predictor to provide the best model and the acceptable correlation coefficient is 0.8745 between predicted and operational E_{dyn} . Fig.3 indicates the predicted E_{dyn} using ANN network and follows calculated results from logs appropriately, which obviously mean that the train data found a good match with the calculated data.

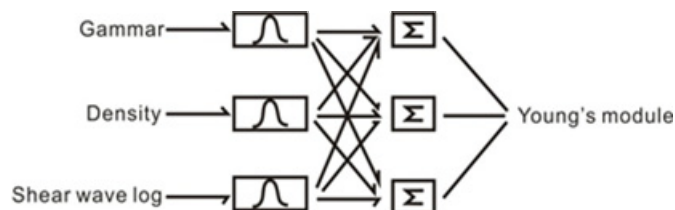


Fig.2 Architecture of the three layered network to calculate the Young's module

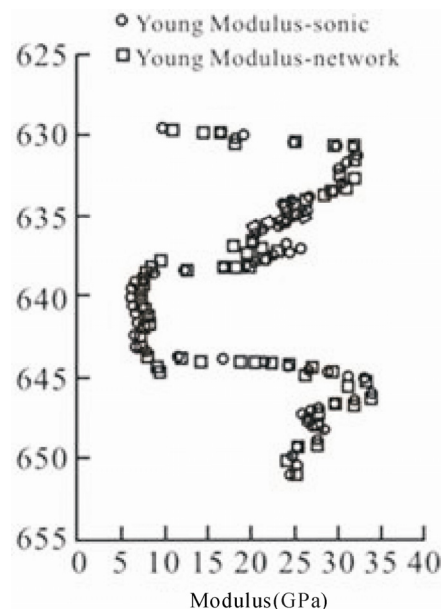


Fig.3 Values calculated from sonic log and the predicted values based on GR, DL and AC in S30.

4 Conclusions

This study demonstrates the applicability of artificial neural network to predict the Young's Modulus. A well trained ANN network by a lot of data was employed in one of the CBM wells in north of Qinshui Basin, China. The consistency between model and log data was good, so it can be concluded that the ANNs with the structured presented here can be used for the prediction of Young's Modulus. Besides, the network can also be used in other fields.

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