Fat Coal Methane Adsorption Behavior under Variation Temperature and Pressure-Taking Shanxi Nanyu Mine Coal in China for Example

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Abstract: *Based on the Langmuir volume and Langmuir pressure of series isothermal adsorptions of fat coal of Shanxi Nanyu Mine in China, the four parametersof atemperature-pressure-absorbing equation (TPAE) have been regressed with 11% relative error. In the measured temperature (30~100℃) and pressure (0~30 MPa) range, TPAE can not only simplify Langmuir parameters, but also picture the quantitative relationship around the temperature-pressure-adsorption.*

Keywords: *temperature-pressure-absorbing equation; isothermal adsorptions;fat coal.*

1. INTRODUCTION

Coal is a porous medium and natural adsorbent. Coal bed gas is usually defined as a hydrocarbon gas, which is adsorbed mainly on the surface of coal matrix particles, free in coal pores or dissolved in coal seam water[1-4]. Compared with shallow coal seams, the geological influencing factors of gas content in deep coal seams have their own uniqueness, and gas-bearing reservoirs generally have high temperature and high temperature, Pressure, low porosity, low permeability, denseness, thin layer, and other characteristics. Adsorption of coal bed gas is not only an important parameter for gas reserves, but also a key indicator for designing the production process [5-8]. The adsorption amount of coal bed gas is a function of both temperature and pressure. Therefore, there are theoretically three kinds of adsorption: isothermal adsorption, isobaric adsorption and isosteric adsorption. In practical terms, the isothermal adsorption is most common experiments conducted in the research laboratories. The experimental data of isothermal adsorption is treated through Langmuir equations, and the results are presented in the Langmuir volume and Langmuir pressure. Mathematically, the Langmuir equationis only a binary equation. Therefore, its differential form is simple. To study the relationship between the temperature-pressure-adsorption amount, a three variables equation must need to be derivatized.This paper will illustrate how the series isothermal adsorptions of fat coal of Shanxi Nanyu Mine in China have been used to regress and to calculate the parameters of a temperature-pressure-absorbing equation (TPAE).

2. DATA AND TEMPERATURE-PRESSURE-ADSORPTION EQUATION

Fat Coal samples are mined from $5/Ps_1$ coal seam/layer of Shanxi Nanyu Mine in the Upper Permian Shanxi Formation of related coal mines at the eastern edge of the Ordos Basin, China. The data and parameters of fat coal samples are listed in Table 1. The Langmuir volume and Langmuir pressure of lean coal under different temperatures are listed in Table 2. The temperature range is 30~100℃ and pressure is 0~30 MPa.

TABLE 1: THE DATA AND PARAMETERS OF FAT COAL SAMPLE [1]

Parameter	Data
Coal seam/layer	$5/Ps_1$
M_{ad} (%)	0.81
A_d (%)	11.73
$R_{o,max}$(%)	1.18

TABLE 2: THE LANGMUIR VOLUME AND LANGMUIR PRESSURE OF FAT COAL [1]

Experimental temperature/℃	Langmuir volume/cm^3g^{-1}	Langmuir pressure/MPa
30	18.50	5.15
50	15.45	4.61
70	12.84	4.66
85	10.26	4.14
100	5.63	1.24

Using the temperature and pressure as independent variables and adsorption amount as dependent

variable, the temperature-pressure-absorbing equation can be expressed as

$$V = \frac{1}{\sqrt{MT}}\left[A + BP^{\beta}T^{1.5}\exp(\frac{\Delta}{T})\right] \quad (1)$$

In the form:

A is a constant of microporous geometric shape for a fixed porous medium, dimensionless.

B is the adsorption flow coefficient, which is related to the adsorption area, dimensionless.

M is a molecular weight, and the molecular weight of methane is 16.

P is pressure (MPa).

T is absolute temperature (K).

V is the adsorption amount (cm^3/g).

β is a parameter which measures the relative influence of adsorption pressure, dimensionless.

Δ is the energy difference between the lowest potential energy and the activation energy of an adsorbed molecule in the adsorbed mass flow, which mainly measures the relative influence of the adsorption temperature, K.

The details regarding the regression of TPAE from series Longmuir adsorption has been presented early [9]. The four parameters of TPAE regressed from Table 2 parameters of fat coal are listed in Table 3.

TABLE 3: THE TPAE PARAMETERS REGRETTED FROM ISOTHERMAL ADSORPTION MEASUREMENTS OF FAT COAL

Parameter	value
A	0.168
B	0.00026
Δ/K	1681
β	0.3757

3. RESULTS AND DISCUSSIONS

A. Verification

It is very necessary to verify the suitability of TPAE between the adsorption amount of TPAE and that of the Langmuir equation under an exact same temperature and pressure.

The relative error is defined as:

$$\delta_i = \frac{|V_{TP} - V_{LA}|}{V_{LA}} x100\% \quad (2)$$

The average relative error is defined as:

$$\bar{\delta} = \frac{1}{n}\sum_{i=1}^{n}\frac{|V_{TP} - V_{LA}|}{V_{LA}} x100\% \quad (3)$$

Here

n is the data numbers. There are 5 Langmuir's temperatures, and for each temperature, 16 pressure values are chosen, from 1 to 31 MPa with a fixed interval of 2.0 MPa. The n is equal to 80.

V_{TP} is the adsorption amount of TPAE at i conditions （temperature and pressure）.

V_{LA} is the adsorption amount of Langmuir at i conditions（temperature and pressure）.

The final average relative error of lean coal is 8.86%. It is reasonable to conclude that TPAE treats accurately a series isothermal adsorption.

Since the TPAE is a mathematical expression of temperature-pressure-adsorption, so it could be presented in a three-dimensional picture as shown in Figure 1. The adsorption amount of Langmuir at i conditions（temperature and pressure）can be added on the TPAE three-dimensional curve as the points. The 5 rows' points are corresponding 5 Langmuir's temperatures. It is beyond controversy to claim that TPAE treats accurately a series isothermal adsorption from another angle.

B. Simplification

Mathematically, the Langmuir equation only deals with a function between adsorption amounts and pressures under isothermal condition, therefore, it is not continued along the temperature. TPAE is trinary equation, it is continued along both temperature and pressure [10-14].

In the Table 2, there are total 10Langmuir parameters for 5 temperatures. In the measured temperature (30~100℃) and pressure (0~30 MPa)range, TPAE has only 4 parameters. Furthermore, Chinese government set up GB/T 19560-2008 "High Pressure Isothermal Adsorption Test Method for Coal" stipulates that when the maximum test equilibrium pressure is 8 MPa, the test pressure point is not less than 6, which is "unconventional temperature and pressure adsorption data". So far, there have been 2 types of unconventional thermobaric adsorption data. One is to measure only one pressure point at each temperature, called "unconventional variable temperature pressure swing adsorption data" [15]. The logic of designing an unconventional variable temperature pressure swing adsorption test is that, as the buried depth of the coal seam increases, the temperature and pressure will

increase simultaneously by a certain ground temperature/pressure gradient. The second type is to measure pressure swing adsorption in several isothermal conditions, but each temperature measurement point is less than the test pressure point specified by the national standard. This type of measured adsorption data is "unconventional series isothermal pressure swing adsorption data" [16, 17].Langmuir equation cannot be used to treat these two types of unconventional thermobaric adsorption data, but TPAE can.

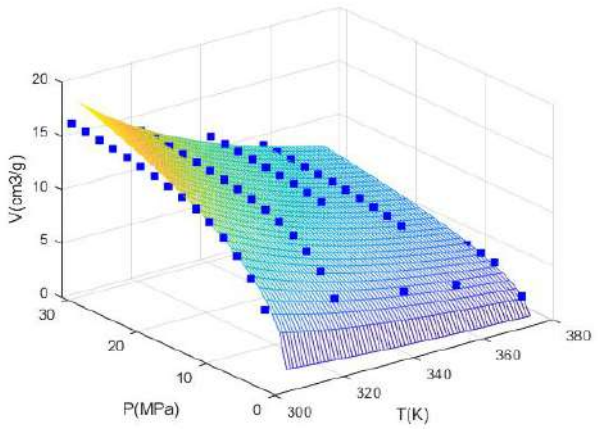

Figure 1: The measured adsorption values and TPAE surface of fat coal

4. CONCLUSIONS

The set of five temperatures' isothermal adsorption data of fat coal of Shanxi Nanyu Mine in China have been used to regress and to calculate the parameters of a temperature-pressure-absorbing equation (TPAE). This regression has transformed the Langmuir equation, which is a function between adsorption amounts and pressures under isothermal condition, into trinary (temperature-pressure-absorbing) equation.

Not only the average relative errors comparing with Langmuir value of the lean coal samples is11.09%, but also the TPAE curvature surface and adsorption points match very well. Both numerical and graphical evidence approved that TPAE is applicable to interpret the series isothermal adsorption data.

Furthermore, TPAE is applicable to interpret either "unconventional variable temperature pressure swing adsorption data", which express measuring only one pressure point at each temperature, or "unconventional series isothermal pressure swing adsorption data", which express measuring less than the test pressure point specified by the national standard.

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