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# STUDY ON ADSORPTION AND DESORPTION CHARACTERISTICS OF NORMAL COAL AND DEFORMED COAL WITH DIFFERENT STRATIFICATION AT THE SAME LOCATION

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**Abstract:** A series isothermal adsorption data of normal coal and deformed coal from China have been transformed into the temperature-pressure-absorbing equation. At 42.0 °C temperatures and 9.0 MPa pressure, the adsorption amount of normal coal is 44.708 $cm^3/g$ with -0.6719 $KJ \cdot mol^{-1} \cdot cm^{-3} \cdot g$ unit isosteric adsorption enthalpy, and the adsorption amount of deformed coal is 43.41 $cm^3/g$ with -0.5202 $KJ \cdot mol^{-1} \cdot cm^{-3} \cdot g$ unit isosteric adsorption enthalpy. The normal coal should be absorbed first, then the deformed coal. The deformed coal should be desorbed first, then the normal coal.

**Keywords:** temperature-pressure-absorbing equation, unit isosteric adsorption enthalpy, unit isosteric desorption enthalpy.

## I. INTRODUCTION

Coal and gas outburst is a geological disaster caused by the instantaneous release of a large amount of gas and coal due to the pressure gradient of coal seam gas is greater than the tensile strength of the coal body.

Scholars have put forward four theoretical hypotheses [1, 2] of ground pressure dominance, gas dominance, chemical essence, and comprehensive action to explain many phenomena accompanied by outstanding phenomena, such as temperature change, cooling of coal walls, structural soft coal, high gas content and pressure, and high desorption speed.

In related studies, the relationship between temperature change and protrusion [3, 4] and Comparison of adsorption energy between deformed coal and normal coal [5-7] are more fully experimented and studied. But there is not a paper related to the adsorption and desorption thermal dynamic characteristics of normal coal and deformed coal at the same coal mine location, at the exact same temperature and pressure.

## II. SAMPLES AND ISOTHERMAL ADSORPTION DATA TRANSFORMATION

### A. Samples

Samples of normal coal and deformed coal are collected at the same coal mine location from the #3 seam of the Daning Coal Mine in the southern Qinshui Basin of China.

The coal seam belongs to anthracite coal with high degree of metamorphism [8].

### B. Isothermal adsorption

The isothermal experimental temperatures were 303 K and 313 K. The isothermal adsorption data are listed in Table 1.

 

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TABLE 1: THE ISOTHERMAL ADSORPTION DATA OF NORMAL COAL AND DEFORMED COAL [8]

| coal | 303K | | 313K | | firmness |
|---|---|---|---|---|---|
| | a | b | a | b | coefficient |
| normal coal | 51.899 | 1.378 | 49.143 | 1.201 | 2.000 |
| deformed coal | 50.770 | 1.101 | 48.506 | 0.979 | 0.330 |

Where:
a is the Langmuir volume, $cm^3/g$.
b is the reciprocal of the Langmuir pressure, $MPa^{-1}$.

### C. Temperature-Pressure-Adsorption Equation [9]

Using the temperature and pressure as independent variables and adsorption amount as dependent variable, the temperature-pressure-absorbing equation can be expressed as

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

Where:

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.
V is the adsorption amount ($cm^3/g$).
b 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 1 parameters of normal coal and deformed coal are listed in Table 2.

TABLE 2: THE TPAE PARAMETERS REGRETTED FROM ISOTHERMAL ADSORPTION MEASUREMENTS OF NORMAL COAL AND DEFORMED COAL

| Parameter | Normal coal | Deformed coal |
|---|---|---|
| A | 0.168 | 0.168 |
| B | 0.01469 | 0.01717 |
| D/K | 1120 | 939 |
| b | 0.1894 | 0.2221 |

## III. ADSORPTION THERMALDYNAMIC AT THE SAME LOCATION

There are several sequence steps involving the calculation of adsorption thermodynamic at the same location.

### A. Determining the temperature and pressure

The change of temperature and pressure in the formation is related to depth and has a certain change law. Under normal circumstances, the temperature of the normal temperate zone of the surface is 15~20 °C, and the temperature increases by 3 °C for every 100m increase in the burial depth of the formation; From the surface, for every 100m increase in buried depth, the reservoir pressure increases by 1MPa.

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According to this law, the corresponding temperature and pressure of different deep coal reservoirs can be deduced. Since the higher isothermal adsorption temperature is 313K, the burial depth of both normal coal and deformed coal of the Daning Coal Mine was assuming 900 meters. Therefore, the temperature is 315K and the pressure is 9.0MPa.

### B. Determining the adsorption amount for normal coal and deformed coal

By substituting the data in Table 1 and the temperature and pressure into Equation 1, it is easy to get that the adsorption amount is 44.708 $cm^3/g$ for normal coal, and the adsorption amount is 43.41 $cm^3/g$ for deformed coal.

### C. Calculating isosteric adsorption enthalpy

According to Equation 1, the temperature values under different pressures can be calculated for normal coal adsorption of 44.708 $cm^3/g$. The temperature values under different pressures can be calculated for deformed coal adsorption of 43.41 $cm^3/g$.
The indefinite integral expression of the Clausius-Clapeyron equation [10] of adsorption is

$$lnP = \frac{\Delta_g^l H_m}{R}\frac{1}{T} + C \quad (2)$$

Where, $\Delta_g^l H_m$ is the enthalpy of molar change, which is equal in magnitude to the heat of molar adsorption, which is the isosteric adsorption enthalpy with one mole adsorption amount as the comparison base.

The subscript "m" represents the mole. The subscript "g" indicates the initial state is gas; Superscripts "l" indicates the final state is liquid. From Equation 2, the lnP vs 1/T should be a straight line, and the slop of this straight line is related to the adsorption enthalpy. Table 3 lists the lnP and 1/T values for the normal coal and deformed coal.

TABLE 3: lnP AND 1/T VALUES FOR NORMAL COAL AND DEFORMED COAL

| 1/T | lnP | |
|---|---|---|
| | normal coal | deformed coal |
| 0.0033 | 1.7251 | 1.8405 |
| 0.00325 | 1.9272 | 1.9933 |
| 0.00319 | 2.1215 | 2.1401 |
| 0.00314 | 2.3084 | 2.2811 |
| 0.0031 | 2.4882 | 2.4167 |
| 0.00305 | 2.6612 | 2.5471 |
| 0.003 | 2.8279 | 2.6725 |
| 0.00296 | 2.9884 | 2.7932 |
| 0.00292 | 3.1432 | 2.9094 |
| 0.00287 | 3.2923 | 3.0214 |
| 0.00283 | 3.4362 | 3.1292 |
| 0.00279 | 3.5750 | 3.2332 |
| 0.00275 | 3.7090 | 3.3334 |
| 0.00272 | 3.8384 | 3.4300 |
| 0.00268 | 3.9633 | 3.5233 |

Where, the normal coal adsorption amount is 44.708 $cm^3/g$, the deformed coal adsorption amount is 43.41 $cm^3/g$.

The lnP vs 1/T plot of the normal coal and deformed coal is shown in Figure 1.

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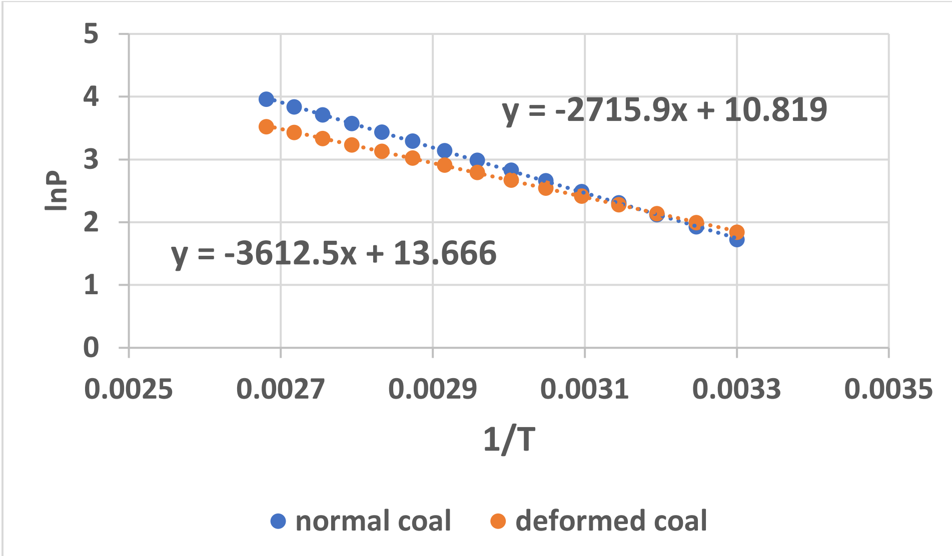


**Figure 1: The lnP vs 1/T plot of the normal coal and deformed coal**

The slops of lnP vs 1/T plot of both normal coal and deformed coal in Figure 1 are negative. Based on the indefinite integral expression of the Clausius-Clapeyron equation of adsorption, Equation 2, the following three inequality must be correct:

$$lnP > 0 \qquad (3)$$

$$\frac{1}{RT} > 0 \qquad (4)$$

$$\Delta_g^l H_m < 0 \qquad (5)$$

Inequality 5 indicates the adsorption process is an exothermic process.

**D. Calculation of the unit isosteric adsorption enthalpy**

The enthalpy of adsorption is proportional to the quantity of the substance and is an extensive quantity. To compare the adsorption priority of normal coal and deformed coal at the same location, their unit isosteric adsorption enthalpy (UIAE) should be calculated. The unit isosteric adsorption enthalpy can be calculated by following these two steps:

1. Multiply the slope in Figure 1 by the gas constant R=0.008314KJ/ (mol· K) to get a product.
2. Divide the product by the adsorption amount (the normal coal adsorption amount is 44.708 $cm^3/g$, the deformed coal adsorption amount is 43.41 $cm^3/g$) to obtain the Unit Isosteric Adsorption Enthalpy $KJ\cdot mol^{-1}\cdot cm^{-3}\cdot g$.

The results are listed in Table 4.

TABLE 4: UIAE OF NORMAL COAL AND DEFORMED COAL AT 315 KAND 9.0 MPa

| normal coal | deformed coal |
|---|---|
| -0.6719 | -0.5202 |

Based on the thermodynamic principle, exothermic processes can happen spontaneously. From the perspective of energy, normal coal can release more energy at the same location so normal coal should have the highest priority to carry out adsorption. At the same location, the normal coal will be absorbed first, then the deformed coal.

**E. Calculation of the unit isosteric desorption enthalpy**

The reverse process of an exothermic is an endothermic process.Endothermic processes can’t happen spontaneously, desorption can be conducted with outside energy. The unit isosteric desorption enthalpy (UIDE) of normal coal and deformed coal are listed in Table 5.

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TABLE 5: UIDE OF NORMAL COAL AND DEFORMED COAL AT 315 KAND 9.0 MPa

| normal coal | deformed coal |
|---|---|
| 0.6719 | 0.5202 |

From the perspective of energy, deformed coal needs less energy at the same location so deformed coal should have the highest priority to carry out desorption. At the same location, the deformed coal will be absorbed first, then the normal coal.

## IV. CONCLUSIONS

A series isothermal adsorption data of normal coal and deformed coal are collected at the same coal mine location from the #3 seam of the Daning Coal Mine in the southern Qinshui Basin of China have been transformed into the temperature-pressure-absorbing equation.

At 42.0 °C temperatures and 9.0 MPa pressure, the adsorption amount of normal coal is 44.708 $cm^3/g$ with -0.6719 $KJ\cdot mol^{-1}\cdot cm^{-3}\cdot g$ unit isosteric adsorption enthalpy, and the adsorption amount of deformed coal is 43.41 $cm^3/g$ with -0.5202 $KJ\cdot mol^{-1}\cdot cm^{-3}\cdot g$ unit isosteric adsorption enthalpy. From the perspective of energy, normal coal can release more energy at the same location so will be absorbed first, then the deformed coal.

At 42.0 °C temperatures and 9.0 MPa pressure, the adsorption amount of normal coal is 44.708 $cm^3/g$ with 0.6719 $KJ\cdot mol^{-1}\cdot cm^{-3}\cdot g$ unit isosteric desorption enthalpy, and the adsorption amount of deformed coal is 43.41 $cm^3/g$ with 0.5202 $KJ\cdot mol^{-1}\cdot cm^{-3}\cdot g$ unit isosteric desorption enthalpy. From the perspective of energy, deformed coal needs less energy at the same location so it will be desorbed first, then the normal coal.

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## BIOGRAPHY

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