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Study of Pore Fractal Structure and Combustion Performance on Efficient Compound Coal†

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This paper is using coal, coal slurry and coal gangue of Huaibei mining area as efficient complex coal blending samples, carrying on the study that the pore fractal structure has effect on supercritical fluidized bed combustion, which shows that the amount of coal gangue has great effect on compound coal quality; fractal dimension of compound coal along with a single coal ratio change presents a monotone change and when the fractal dimension from 2.429 gradually increases to 2.518, the ignition temperature from 586 ºC falls to 457 ºC, easy ignition burning; when the amount of coal gangue of compound coal from 10 % falls to 30 %, the ash melting point rises from 1370 ºC to 1450 ºC, the slag-bonding intensity decreases when they are burning.

Key Words: Efficient compound coal, Hole structure, Fractal dimension, The combustion characteristics.

INTRODUCTION

Coal is one clean coal technology of supercritical fluid bed boiler combustion, which not only make boiler operation stable, but also can increase the combustion efficiency, reduces the coal consumption and reduces atmospheric pollution of coal dust[1,2].

The pellet of coal is a material which has the hole spheroid and the hole structure is the main part of physical structure of coal[3]. Many researchers are concentrating the attention on the study that pore structure in the combustion process change rule. This article uses nitrogen adsorption instruments, uses coal, coal slurry, coal gangue and efficient compound coal of Huaibei mining area as samples and makes a system study that the pore fractal structure has effect on supercritical fluidized bed combustion.

EXPERIMENTAL

Preparation of experimental coal samples: Coal, coal slurry and coal gangue of Huaibei mining area though grinding and sieving are made into coal samples. In order to express mixed coal sample more convenient, using the symbol A as the coal, the symbol B as the coal slurry, the symbol C as the coal gangue, the followed number represents the proportion of them. For example, the proportion of 6:2:2 preparations the coal, marking as A6B2C2.

Experimental method: It is mainly used by blast coal oven, muffle furnace, carbon and hydrogen analyzer, automatic calorimetric apparatus to analysis the quality of coal. To test the pore structure of coal, we mainly used SSA-4200-type instrument and nitrogen as adsorbed gas to analysis both single point, multi-point BET hole, BJH mesopore, pore distribution, pore size, pore volume and area, average pore size and other data analysis. The surface area ranges from 0.01 m^2/g to no upper limit and the range of hole diameter is 0.35-400 nm. The set-point pressure of the BET in experiment is 0.05-0.2 Kpa.

RESULTS AND DISCUSSION

Coal quality results and discussion: From Tables 1 and 2' C_{ad}, it is observed that the coal quality about coal and coal slurry is close, but the difference results of coal quality in coal gangue is large compare with another two kinds of coal. With the content of gangue coal increased, the content of moisture and ash are also constantly increasing, but fixed carbon and volatile are declining. From the results of the calorific value, the numerical of coal is highest and coal slurry is lower than coal, but gangue coal don't have numerical. From other groups of compound coal, with the content of gangue coal increased, the calorific value is accordingly reducing, which explains that gangue coal has great influence in compound coal.

Adsorption Deng Wen Xian and pore structure analysis: It can be seen from above adsorption loop shape of coal samples that Huaibei coal and blending coal type is II isotherm. It reflects that the coal have complex pore structure,

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TABLE-1
INDUSTRIAL ANALYSIS OF COAL SAMPLES

Coal samples	V_{ad} (%)	A_{ad} (%)	M_{ad} (%)	FC_{ad} (%)
A	15.94	42.22	1.16	40.68
B	15.24	50.68	1.45	32.63
C	9.66	84.77	1.65	3.92
A8B1C1	14.81	47.49	1.18	36.52
A6B3C1	14.82	49.18	1.17	34.83
A6B2C2	14.50	52.71	1.25	31.54
A5B3C2	14.01	53.48	1.30	31.21
A4B3C3	13.71	57.69	1.30	27.29
A4B2C4	13.16	61.26	1.33	24.25

TABLE-2
ELEMENTAL ANALYSIS AND CALORIFIC VALUE OF COAL SAMPLES

Coal samples	C_{ad} (%)	H_{ad} (%)	St_{ad} (%)	O_{ad} (%)	N_{ad} (%)	Calorific value (cal/g)
A	48.82	2.70	0.41	1.12	1.37	4204
B	40.79	2.49	0.34	2.69	1.32	3586
C	5.88	2.85	0.07	2.61	1.34	-
A8B1C1	45.65	2.53	0.41	2.28	1.34	3889
A6B2C2	43.54	2.57	0.41	2.55	1.32	3802
A6B1C3	41.84	2.61	0.37	2.61	1.32	3347
A5B3C2	40.75	2.64	0.32	2.58	1.33	3363
A4B3C3	37.93	2.63	0.27	2.60	1.33	2730
A4B2C4	33.71	2.71	0.27	2.63	1.34	2308

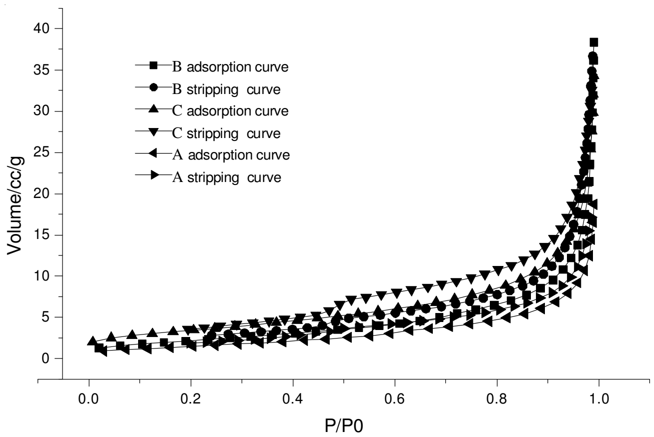

Fig. 1. Three kinds of single coal adsorption/taking off Deng Wen Xian

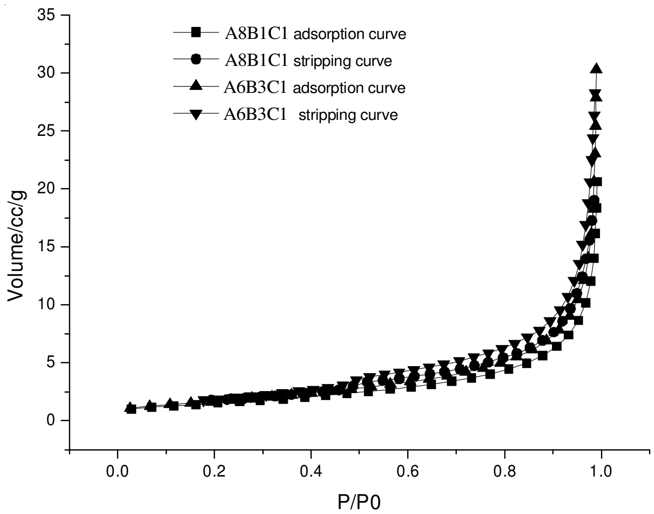

Fig. 2. 10 % Amount of coal gangue adsorption/taking off Deng Wen Xian

the pore distribution is complete and continuous. The difference on isotherm shape means different pore size distribution of coal. It can be seen from the figure, the adsorption of transition from single molecule layer to multi-molecular layer of the stage in the curve of the first half, so it rising slowly and the

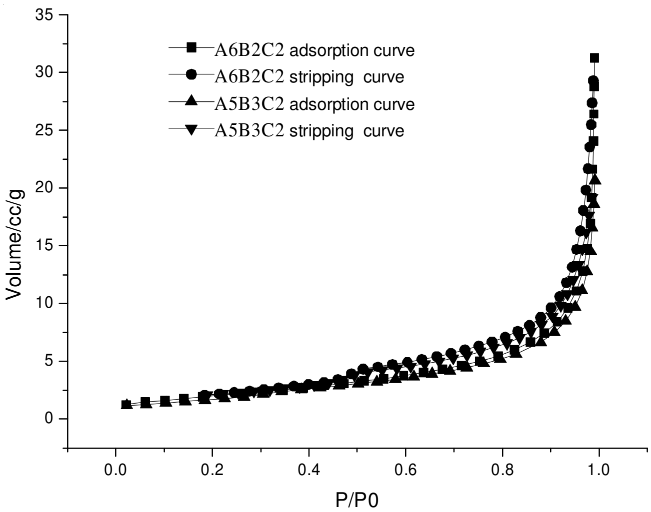

Fig. 3. 10 % Amount of coal gangue adsorption/ taking off Deng Wen Xian

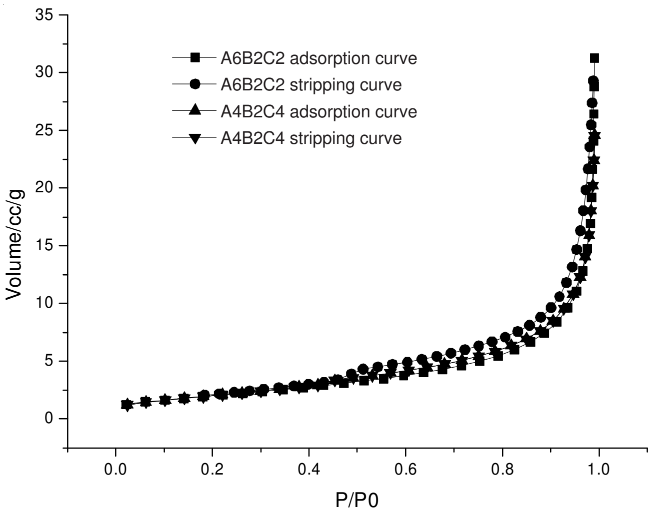

Fig. 4. 20 % Amount of coal slurry adsorption/taking off Deng Wen Xian

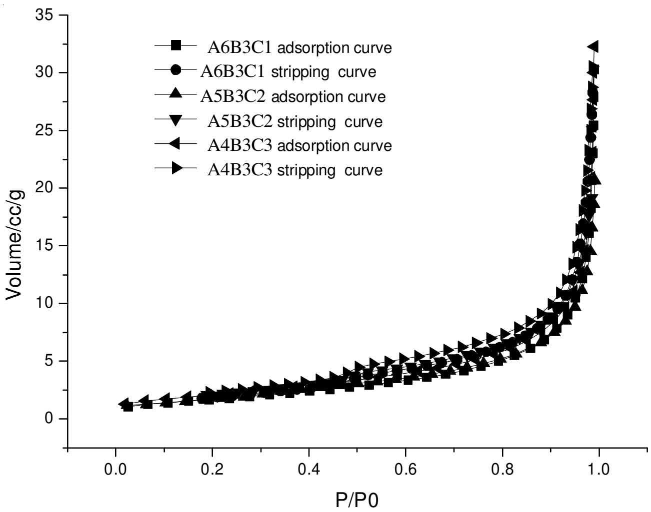

Fig. 5. 20 % Amount of coal slurry adsorption/taking off Deng Wen Xian

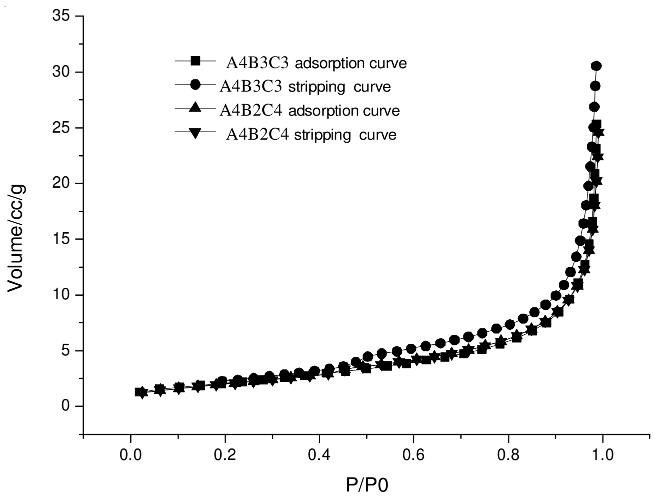

Fig. 6. 40 % Amount of coal adsorption/taking off Deng Wen Xian

shape is convex. In the latter half, the curve go up sharply, which indicates that the adsorption increases sharply in some large hole of coal caused by capillary condensation.

From the shape of absorption return line,the compound coal ratio has great impact to the shape of absorption return line. It can be seen from the figure that the absorption return line of slime and gangue are larger in the same pressure ratio. When the pressure is low,the adsorption return line of slime coal and sludge return can be closed. When the pressure ratio is 0.4, the adsorption return line of compound coal almost closed. These differences indicate that the physical mixing of coal has some changes in the structure of hole.

The reasons why there are differences of the adsorption return line are that the coal pore structure and pore size are difference. Moreover, the little hole under low temperature causes "closed" phenomenon, which can also cause deviation. Because the adsorption return line of coal is close to isotherm II, Type II isotherm in similar pressure happens capillary and hole condensing phenomenon, thus affecting adsorption loop line shape.

From coal adsorption/desorption isotherms and pore volume distribution, it is concluded that the hole of internal coal which is from coal, slurry coal, gangue coal and the

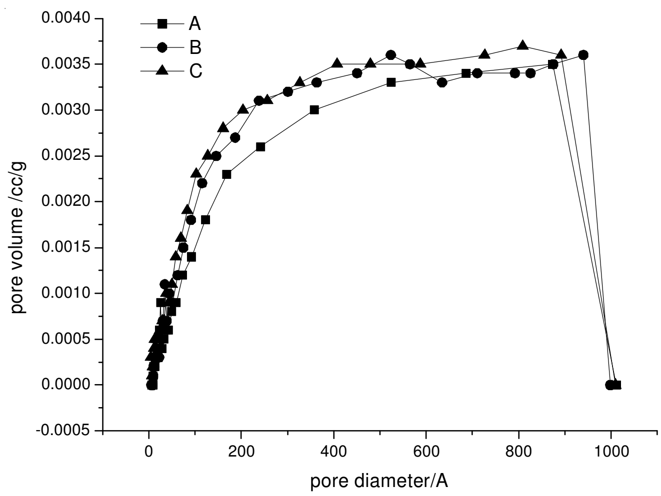

Fig. 7. Three kinds of single coal hole volume distribution

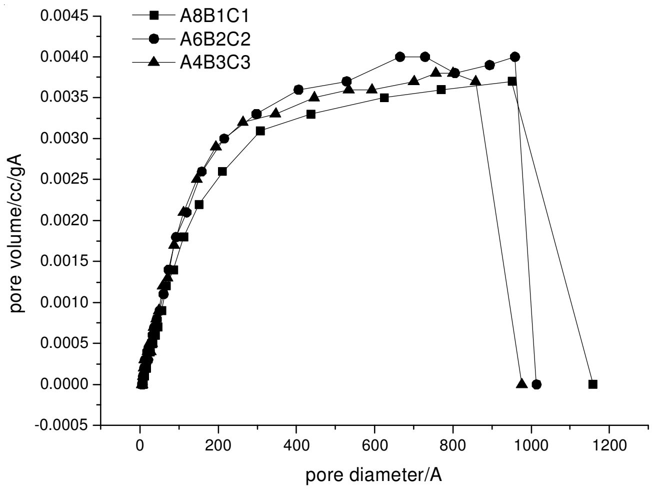

Fig. 8. Compound coal hole volume distribution

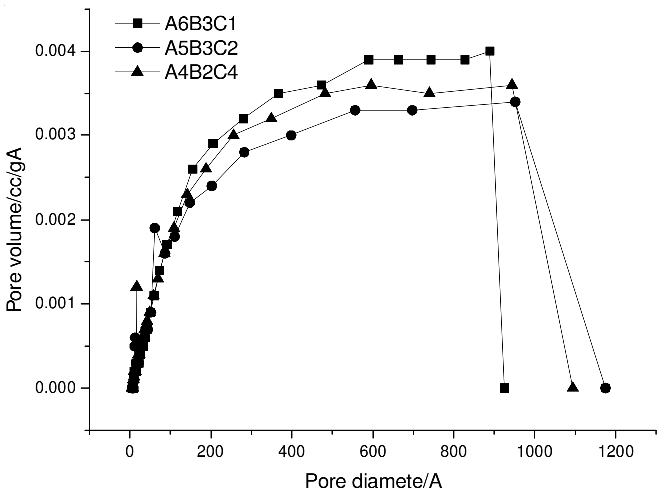

Fig. 9. Compound coal hole volume distribution

efficient compound coal of Huaibei mining area is most mesopore and big hole. And the structure of coal pore is most cylindrical and needle hole.

Surface of the coal granule fractal dimension: Using fractal geometry theory can set the Huaibei mining area geometry of the irregular shape as a sub-body, according to the method of fractal geometry to solve the sub-quantitative spatial distribution of physical parameters-fractal dimension, it be able to effectively portray the geometry of the shape. Avnir and Jaroniec[4] reported that the gas molecules primarily occur in the holes in the monolayer adsorption in the adsorption experiments, when the adsorbed gas relative pressure $P/P_0 <$ 0.37 range. The adsorption fully reflects the solid surface structure. For holes, the solid surface fractal dimension obtained from the Avnir and Jaroniec[4] formula, θ is relative adsorption; K is the adsorption constant; r = 3-D, D is the gas adsorption on the surface fractal dimension. By the Avnir formula, according to the assay of the coal sample data for graphics, we can get the slope which can be found in the fractal dimension D (Table-3).

Table-3 shows that the fractal dimension fitting correlation coefficients are greater than 0.98, which is fitting more efficient. The fractal dimension are between 2-3, indicating that the coal, slurry coal, gangue coal and the efficient compound coal of

Huaibei mining area gas adsorption[5] characteristics is in line with Avnir fractal distribution. More surface fractal dimension, indicating that it has lots of holes and the surface structure of coal is more complex. It can be seen from Fig. 10 that in the three coal composing blending, with the mass fraction of gangue from 0 to 100 %, blending of the fractal dimension decreases from the 2.532 to 2.404. These results indicate that the pore fractal dimension with single coal that the fractal dimension is smaller increases the proportion in the Huaibei coal physical mixing process, the fractal dimension of blending reduces accordingly.

TABLE-3
COAL SURFACE FRACTAL DIMENSION

Coal samples	Fractal dimension D	Related coefficient R
A	2.532	0.9940
B	2.467	0.9867
C	2.401	0.9952
A8B1C1	2.508	0.9986
A6B3C1	2.501	0.9856
A6B2C2	2.495	0.9982
A5B3C2	2.487	0.9815
A4B3C3	2.475	0.9923
A4B2C4	2.429	0.9867

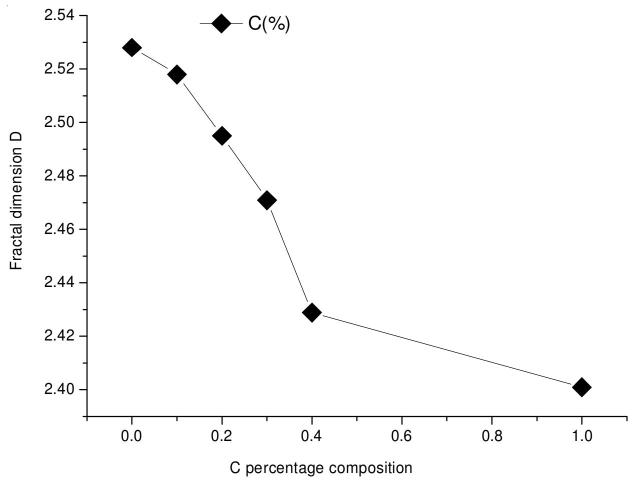

Fig. 10. Fractal dimension change rule with the content of gangue coal changing

Coal granule structure on coal fire and slag-bonding[6] characteristics influence: Using muffle furnace to measure the ignition temperature and coal ash fusion temperature[7], the fractal dimension[8] of the ignition characteristics and gangue content of the ash fusion temperature results is presented in Figs. 11 and 12.

Fig. 11 (Table-3) showed that when the fractal dimension gradually increased from 2.518 to 2.429, its ignition temperature gradually reduced from 457 to 586. These results show that the fractal dimension of blending is more bigger and it will be more easier firing. Table-3 (Fig. 12) showed that in single coal, coal ash softening temperature which is the melting point is lower, in the combustion process it prones to moderate slag-bonding and ash fusion temperature gangue coal is bigger than 1500 ºC, in the combustion process, it only occurs moderate slag-bonding or no slag-bonding. Fixed the content in slime' blending, when the content of gangue coal

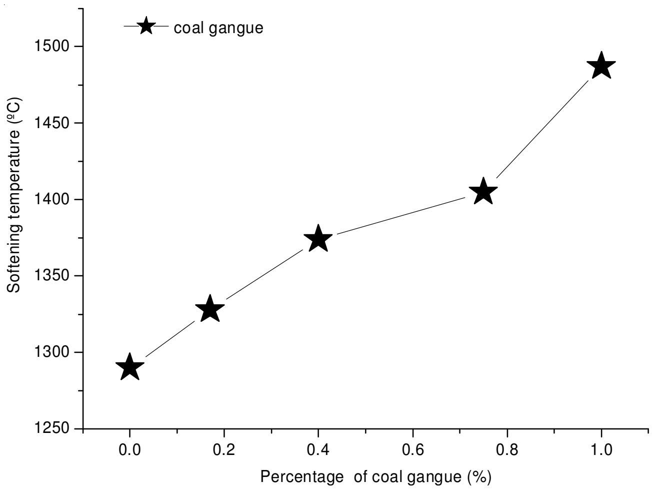

Fig. 12. Fractal dimension of compound coal to the influence of the characteristic combustion

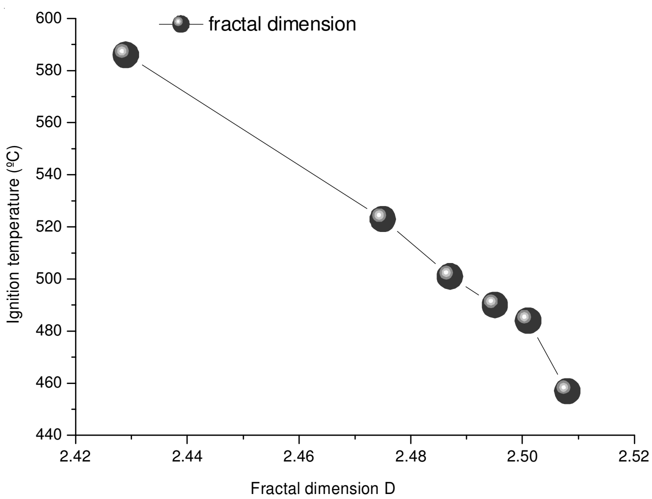

Fig. 13. Relationship of gangue coal content and softening temperature T_2

increased, the ash fusion temperature of coal blending is gradually increased, the slag-bonding degree gradually becames waning.

Conclusion

(1) From texting coal, slurry coal, gangue coal and the efficient compound coal of Huaibei mining area, it shows that the content of gangue coal has great impact on the properties of compound coal. This is mainly because gangue coal contains mineral composition and special hole structure.

(2) From isotherms adsorption of coal samples and pore volume distribution, it is observed that isotherms adsorption and desorption curves of coal samples have adsorption loops with different closed degrees, but all belong to the range of type II isotherm. Hole of compound coal is mainly the middle hole and the large hole, the pore structure of coal is mostly multi-cylindrical and needle holes, thus constituting complex pore structure.

(3) Avnir Fractal model accurately describe the hole surface structure of coal, slurry coal, gangue coal and the efficient compound coal of Huaibei mining area. With the proportion of coal gangue of smaller fractal dimension increasing, its fractal dimension decreases.

(4) The specific surface area of coal, slurry coal, gangue coal and the efficient compound coal of Huaibei mining area with variation of the fractal dimension and the ignition temperature with variation of the fractal dimension is consistent. Therefore, fractal dimension show the good and bad of combustion characteristic. When the fractal dimension of the Huaibei compound coal increases, the ignition temperature drops, the ignition characteristics will become better.

(5) When the content of coal gangue increases from 10 to 30 %, the ash fusion temperature of coal, slurry coal, gangue coal and the efficient compound coal of Huaibei mining area is up, the slag-bonding degree has a weakening trend.

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