Influence of Preparation Process on Briquette and Form Coke Compressive Strength

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Abstract. This paper investigated preparation process of briquette by using starch and bentonite as composite binder. It also studied the impact of pulverized coal particle size, coking particle size, compacting pressures, moisture content on the strength of briquette and form coke. The result showed that coking coal particle size was the main influence factor. And the optimum conditions of molding process were as follows: low rank pulverized coal particle size was less than 0.63mm, coking coal particle size was less than 0.28mm, compacting pressure was 60 kN, molding moisture content was 12%. Under the optimal conditions, compressive strength of briquette and form coke was 3470 N/ball and 2910 N/ball, respectively.

1. Introduction
The characteristics of energy resources in China is rich in coal, oil poor, less gas, which determines the coal resource is the most important natural resources in China, which accounts for 70% of the proportion of the primary energy consumption in our country. While the low metamorphic coal resources accounted for 42.5% of the total coal reserves, therefore, the low metamorphic coal occupies the main position in our country rich in coal. Coal resources in Northern Shaanxi has proven reserves of coal accounted for 15 percent of China's proven reserves, while the low rank coal has some characteristics (low sulfur, low phosphorus, low ash, low moisture, high volatile, high heat, high activity), known as "green coal", and is of high quality coal chemical industry, coal for power generation and coal for gasification [1]. The treatment of low metamorphic coal is generally adopted by the low-temperature carbonization process. The process requires the feed size of 30~80 mm, and less than 30 mm of pulverized coal because of its small size, not easy to get gas, resulting in the largest coal tar can not be used for low temperature carbonization of coal powder processing current. Therefore, some researchers are devoted to the research of preparation process of briquette and coke making [2]. Yang et al. [3] studied the preparation of high strength coke. At present, the domestic coke production technology, there are hot and cold pressing method of molding process [4, 5].

Cold forming process before molding does not require pretreatment of raw coal. Li et al. [6] used the agglomerant cold-press molding technique to prepare the briquette. Cold compression molding is generally divided into two categories: no binder molding and binder molding. No binder shaped only
by high pressure make pulverized coal forming, this method is suitable for large plasticity, elasticity small lignite and peat [7]. When molding form "solid bridge", make its briquette strength is higher. Plus binder forming the main raw material is not bonded or weak caking coal. And add a small amount of binder after mixing, and mold at low temperature or room temperature [8, 9].

With the method of hot pressing forming technology used [10], the raw coal is required to preheating treatment before forming, namely through the low temperature carbonization, the coal molding in the softening temperature range, general coal feed pretreatment temperature between 400 °C–500 °C. If only one component, that 100% of the coal is heated forming in the softening condition, this kind of hot forming called non-binder hot forming method, but the single components of the coal hot forming is difficult to control; if coal is a two-component, so the main raw coal with bond, first by the low temperature carbonization, in soft state, must be able to make minor components of coal evenly with thermal coal, play a role in hot press molding binder.

In this paper, using the cold pressing forming process, the main research focus on effect of preparation process of coal particle size, coke particle size, the molding pressure, molding moisture and other factors, to obtain the optimal preparation process, so as to effectively utilize the low metamorphic coal and improve the economic benefits.

2. Experimental

2.1. Experimental materials

This research using a company in northern Shaanxi low cinder select size <60 mesh fraction. Industrial analysis and elemental analysis with low cinder and coking coal list in Table 1. Binder in experiment is binder composite: alkaline starch 5%, bentonite 3%. The pulverized coal is represented by 1, the coking coal is represented by 2 and the tar slag is represented by 3.

| Table 1. Industrial analysis and elemental analysis of the pulverized coal. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | M_{ad} | A_{ad} | V_{ad} | FC_{ad} | S_{c,ad} | H_{ad} | C_{ad} | N_{ad} |
| 1              | 4.16   | 2.98   | 33.86  | 59.00   | 0.26     | 4.86   | 75.32  | 0.98   |
| 2              | 0.60   | 9.50   | 17.68  | 72.22   | 1.18     | 4.18   | 80.48  | 1.24   |
| 3              | 4.2    | 6.79   | 43.59  | 45.42   |          |        |        |        |

2.2. Preparation of coke

A certain proportion of the composite binder, low metamorphic pulverized coal, tar slag, coking coal were mixed with a certain amount of water, stir well. Then loaded into a mold made on a tablet machine to use cold pressure forming; briquette will be naturally dried at room temperature for 48 h and placed in a drying oven for 2 h, drying temperature is 105 °C. Finally, through low temperature carbonization in a chamber furnace at 600 °C to get coke.

2.3. Coke strength test

Strength of Cold Compressive (SCC) measurement method in accordance with MT/T748-2007 carried out. The briquette and coke were put in the center stage of manual electric tablet machine, then slowly apply pressure until the briquette and coke broken. The applied pressure is strength of cold compressive. To obtain reliable data, each cold compressive strength taking average of 10 coke (briquette).

Drop Shatter (DS) measurement method in accordance with MT/T 925-2004 carried out, the coal sample were laid down from 2.0 m height from the ground, let it fall to 12 mm thick steel plate. Repeated drops three times then with 13 mm standard sieved, taking particle size greater than 13 mm quality coal accounted for as a percentage of the total mass of a single sample test value. Take the average value of five samples tested as coke (briquette) drop shatter.
Strength after Soaking Compressive (SSC) measurement method in accordance with MT/T749-1997 carried out. The coke (briquette) were removed after immersed in water at room temperature for 24 h, and then placed in the center of the tablet press force plane position, one-way uniform pressure, until the sample is broken up. Before samples were crushed to withstand the maximum pressure as a test of the sample. The average of five samples tested values as coke (briquette) strength after soaking compressive.

3. Results and Discussion

3.1. Effect of pulverized coal particle size

The low metamorphic pulverized coal particle is divided into five levels, namely: less than 0.28 mm, less than 0.63 mm, less than 1.25 mm, less than 2.5 mm, less than 5.0 mm. Binder is added as shaping and carbonization to obtain coke. The experimental results of briquette and coke strength of cold compressive are shown in Figure 1.

![Figure 1. Effect of pulverized coal and coke particle size on the strength of cold compressive.](image)

As can be seen from Figure 1, the pulverized coal particle size less than 0.63 mm, the briquette and coke strength of cold compressive is best. The general trend of the change is to increase, then decrease. This is due to the fact that the particle size is less than 0.63 mm to reduce the porosity of the pulverized coal-block and inter-block that has a bulk density. On the one hand, the uniform distribution of the pulverized coal bonding surface play a leverage, thereby increasing the adhesion of the pulverized coal particles. Another aspect of increasing the density of the block type can improve the drop shatter. But if pulverized coal particle size is too small, no large particles play the skeleton role in type blocks, so that the briquette and coke reduce mechanical engagement between forces, resulting in reduced strength. When the particle size is too large, the pulverized coal, the coal particles along with the degree of irregularity becomes large, so that the porosity between the particles increases, the surface of the uneven distribution of the binder particles, and the distribution rate per unit area is reduced, thereby reducing the adhesive force, causing briquette and coke strength of cold compressive decreases. Therefore, selecting low metamorphic pulverized coal particle size less than 0.63 mm.

3.2. Effect of coking coal particle size

The coking coal sieved into five different sizes, which were less than 0.28 mm, between 0.28 mm and 0.63 mm, between 0.63 mm and 1.25 mm, between 1.25 mm and 2.5 mm, between 2.5 mm and 5.0 mm. The above five kinds of coking coal particle size of 8%, respectively, added to the mix of incorporation to get briquette, the experimental results of briquette and coke strength of cold compressive are shown in Figure 2.
Figure 2. Effect of coking coal particle size on briquette and coke strength of cold compressive.

As can be seen from Figure 2, along with coking coal particle size becomes large, slow decline in briquette compressive strength, compressive strength decreased significantly in coke, briquette intensity range is much smaller than the range of variation of coke. And, we tested and analyzed the surface morphology of coke. The morphology of coke under an optical microscope are shown in Figure 3.
Figure 3. Coke surface topography which were prepared under different coking coal particle.

As can be seen in conjunction with Figure 3, the coke particles deposited in coke, coking particle size becomes larger with the larger of coking coal particle size. Coking coal having a medium volatile and middle plastic layer thickness, can produce a very high thermal stability when heated colloid. However, due to the expansion of pressure, coking coal and low cinder below 0.63 mm can not be completely fused during the mixed pyrolysis, promoting the precipitation of coke particles and resulting in coke cracks. With the increasing size of the coking coal, coke precipitation diameter also increased, making the coke surface cracks become larger. Coking coal particle size effect on the compressive strength is relatively small. Coking coal particle size increases from the test shows that is not conducive to a combination of low rank coking coal and pulverized coal, coke likely to cause cracks in. Therefore, the choice of coking size is less than 0.28 mm.

3.3. Effect of briquette pressure
Pulverized coal molding process, which will produce displacement and deformation under the pressure, as the pressure increases, the relative density of shaped blocks will show regular changes, which are usually divided into three stages (AB segment, BC segment and CD segment), shown in Figure 4. According to this variation, without considering the friction loss, the porosity of the shaped block with a molding pressure has following relationship [11].

$$\frac{d\phi}{\phi} = Kdp$$  \hspace{1cm} (1)

The formula: $\phi$— porosity of shaped blocks, %; $p$—molding pressure, MPa; $K$—pulverized coal repressive constant.
Figure 4. The relationship between relative density of compacts and pressure.

As can be seen from the above formula, the molding pressure is inversely proportional to the porosity of the shaped block. Molding pressure increases, the engagement of the material on the one hand between the particles is increased and the friction between the particles is increased to improve the briquette and coke strength; on the other hand allows adhesion molecules between coal particles and the binder increases, improving the efficiency of the role of the binder, prompting block strength. This gives a certain influence on the molding pressure to block strength.

Briquette preparation use different molding pressures. The experimental results of briquette and coke compressive strength are shown in Figure 5.

Figure 5. Effects of molding pressure on the strength of cold compressive of briquette and coke.

As can be seen from Figure 5, briquette and coke strength of cold compressive curves are increase with molding pressure increases, the strength of cold compressive decreases after the first increase, when the molding pressure reaches 60 kN, The maximum strength of cold compressive of briquette and coke. When the molding pressure at 30~60 kN, formula (1) to exactly match the phase of briquette and coke compressive strength and porosity changes and pressures on the relationship. As the pressure increases, the density of block is increased, and the coal particles are not crushed, so that briquette and coke compressive strength enhancement. When the molding pressure is greater than 60 kN, briquette and coke strength decrease with the molding pressure increases. This stage is mainly because during the molding process, the coal particles are subjected to the combined effect of cohesion repulsive force. When pulverized shaped, as the pressure increases, the cohesive force of the coal particles have suffered increased. After removing the pressure of block, the rebound effect between the coal particles,
so that the block-type elastic expansion, the volume increases. When the pressure exceeds a certain range, the rebound force is greater than the capacity of the block type, coal prone to cracking, thereby reducing the briquette and coke strength. While the molding pressure is too large, easy to make the shape of the applied liquid adhesive is extruded to reduce the utilization of a binder, will lead block strength decrease. Therefore, choosing the molding pressure is 60 kN.

3.4. Effect of moisture

In the material molding process, water plays an important role. Add a certain amount of water and stir the material together, can make a binder adhere better to the coal particles surface, reducing the friction between the particles, thus contributing to a more tightly packed particles. Water is simultaneously formed in the coal acts as a lubricant during the molding, which reduces the friction between the mold and the block shaped, block shaped to ensure a more uniform density distribution along the height direction. The content of water is too low or too high also reduces briquette and coke strength [12].

Briquette is prepared by adding different proportions of water. The experimental results of briquette and coke compressive strength are shown in Figure 6.

![Figure 6. The impact of moisture on the compressive strength of briquette and coke.](image)

As can be seen from Figure 6, forming water between 12 to 14 percent, briquette and coke strength are the best, with the increase of moisture forming, briquette and coke strength showed a decreasing trend after the first increase. When less water, the lubricating effect of water shortage during the molding process, due to the friction between the particles, the effective pressure of the molding material is reduced, and thus the intensity of the block shape is low. When more water, a thick layer of water attached to the surface of the particles, the particles will hinder inter-intensive coal, thereby reducing the mechanical strength of briquette and coke. Too much water will cause briquette which is more prone to cracking during the drying process. Therefore, most preferably 12% forms moisture.

3.5. Comparison of the various factors that affect the strength of briquette and coke

Comprehensive research data over a single factor, comparing the impact of various factors on briquette and coke strength, the results are shown in Table 2.

| Factors       | Pulverized coal particle size | Coking coal particle size | Molding pressure | Moisture |
|---------------|------------------------------|---------------------------|------------------|----------|
| Briquette     | 730                          | 810                       | 610              | 341      |
| Coke          | 620                          | 1490                      | 590              | 320      |
From Table 2, in the experimental range, Changes caused by changes in the coking coal particle size caused briquette and coke strength were 810 N·ball$^{-1}$ and 1490 N·ball$^{-1}$, whose values are maximum. It shows that the 4 factors of this study, the largest influence is the coking coal particle size, similarly, the minimum influence is moisture.

4. Conclusion
When starch and bentonite as composite binder uses to prepare briquette and coke, in which the process conditions, the variation in coking coal particle size effects on both compressive strength are the biggest changes, and have the best preparation of briquette and coke forming process conditions: low metamorphic pulverized coal particle size less than 0.63 mm, coking coal particle size less than 0.28 mm, forming pressure is 60 kN, forming 12% water, the compressive strength of briquette and coke produced under these conditions were 3470N·ball$^{-1}$, 2910N·ball$^{-1}$.

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