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Study on lignite dewatering by vibration mechanical thermal expression process

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ABSTRACT

A new dewatering process — vibration mechanical thermal expression (VMTE) process developed from mechanical thermal expression (MTE) process was studied in this paper. The enhancement of moisture content reduction of Zhaotong lignite by vibration in VMTE process under different temperatures and pressure was determined. Compared to MTE process, the dewatering efficiency was enhanced by 10% by VMTE process with a vibration force of 5 kN in tested range. The moisture content decreased from 1 to 0.19 (g/g) (db) under the most severe processing conditions. The investigation was carried out to identify how variations in vibration force affect the dewatering during the VMTE process. The vibration was proved to enhance the volume reduction of lignite samples which is closely related to the decrease of moisture content by accelerating particle compaction and the change of coal structure. The increase of vibration force in a special range resulted in more severe reduction of moisture content than that out of the range. The reduction of moisture content caused by the vibration force increase in the range from 1 kN to 4 kN was 3.6 times that in the range from 0 to 1 kN. A limitation of dewatering caused by the increase of vibration force was expected to exist.

1. Introduction

In China there were large deposits of lignite that were or could be used for power generation. Therefore, the efficient utilization of lignite was significant for coal-based energy systems in China. However, lignite were generally charactered with high moisture content which was sometimes greater than 60% (wet basis) on a mass fraction basis which exerted strong influences on their utilization processes, such as combustion, gasification and liquefaction [1,2]. But lignite did have certain advantages over black coal, such as low mining cost, high reactivity, high amount of volatiles, and low pollution-forming impurities including sulfur, nitrogen, and heavy metals [1,3,4]. Effective dewatering technologies were needed for the preparation of lignite prior to utilization.

Mechanical thermal expression (MTE) was a process developed for the energy efficient dewatering from high moisture content lignite. A significant amount of researches on many different aspects of the MTE process had been carried out by researchers in CRC for Clean Power from Lignite and Monash University in Australia and Dortmund University in Germany [5–13]. During the MTE process, lignite was typically heated to between 100 and 250 °C and the water was removed without evaporation by the application of mechanical pressure up to 12 MPa. Lignite was compacted and the pore volume where water existed in was reduced due to the combined application of thermal and mechanical energy. Importantly, it had been illustrated that a significant reduction in water content can be obtained by MTE process for Australian, Greek, German and Indonesian lignite and biomaterials [6,14,15]. But the costs of time were always more than 100 s in the experimental tests which would be a barrier between lab study and industry utilization. The mechanism study of MTE process also pointed out that the time needed for "constant-rate process" (also called "primary consolidation"), which dewatering mainly occurred in, is proportional to the square of the initial height of the coal filling [16,17]. If the MTE process was enlarged to industry scale the cost of time would be out of acceptable. So, it would be significant to find out a way to improve the dewatering efficiency of MTE process.

Researches in particle compaction showed that vibration could accelerate the compaction process [18,19]. The vibration forced particle relative motions by reducing the friction between particles which resulted in the improvement of compaction compared with static compaction [19]. The density achieved in vibration compaction was higher than that in static compaction under the same conditions. The vibration was expected to accelerate the dewatering in MTE process because the MTE process was also a compaction process. In this paper, lignite dewatering by vibration mechanical thermal expression (VMTE) process improved from MTE was tested.

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Table 1
Characteristics of raw coal sample.

Analysis	Units	Value
Total moisture	% arb	50.06
	g/g db	1.00
Ash	% db	20.08
Volatile matter	% daf	60.27
Fixed carbon	% daf	39.73
C	% daf	66.58
H	% daf	3.98
N	% daf	1.83
S	% daf	1.92
O_{diff}	% daf	25.69
True density	g/cm^3	1.23

2. Experimental

2.1. Coal sample description

The raw coal used in this study was obtained from Zhaotong, Yunnan, China. The characteristic of this raw coal sample was given in Table 1. The raw coal used in the test had a particle size of less than 1 mm.

2.2. VMTE experiments

The equipment used in VMTE experiments was developed from MTE rig reported by Hulston and Chaffee [6]. The experimental equipment was constructed with a vibration platform and a temperature controlled pressure dewatering rig. The vibration force was provided by two vibrating motors located on the vibration platform. These two vibration motors were run at the same speed but in opposite directions to eliminate the vibration force in horizontal direction. There was a stainless steel sample chamber (40 mm in diameter, 80 mm in height) fitted with filter membrane and a water collection chamber. Samples were compressed by a compression device, which applied a known force to sample chamber. The applied pressure was measured by a piezometer in the compression device. The samples were heated by a temperature controlled electrical heating mantle surrounded the sample chamber. The water removed from the samples through a filter membrane located at the bottom of the sample chamber. VMTE tests were carried out at a variety of vibration forces, temperatures and pressures, ranging between 0 and 5 kN, 50 and 250 °C and 3.4 and 12.7 MPa, respectively.

Experiments were begun by placing 30 g of raw coal into the sample chamber. The piston was inserted into the sample chamber and a pressure slightly higher than 2.0 MPa applied to expel any residual air trapped in the sample chamber and prevent water evaporation during heating. The pressure increased to the desired value at a rate of 10 MPa/min after the temperature reached the desired value. After the pressure reached the desired value, the vibration was performed for 10 s. After completion of the experiment, the MTE products were collected for subsequent tests (Fig. 1).

2.3. Moisture content determination

The moisture content was determined based on a method according to the GB/T 211-2007 standard which was similar to the Australian Standard AS 2434.1 [20]. Samples were dried under flowing nitrogen at 105–110 °C until no further mass decrease of samples. Oven dried samples were subsequently used for further tests.

2.4. True density determination

The true densities of the samples were determined by helium pycnometry using an Ultra PYC 1200e pycnometer (Quantachrome, USA) on dried samples. Prior to measurements, samples were purged under vacuum environment to ensure complete removal of air.

2.5. Total volume and pore volume determination

The pore volume V_{pore} of V-MTE products was determined by the difference between the total volume and the volume occupied by the coal [6], such that

$$V_{pore} = \frac{\pi}{4}D^2H - \frac{m_{coal}}{\rho_{He}} \quad (1)$$

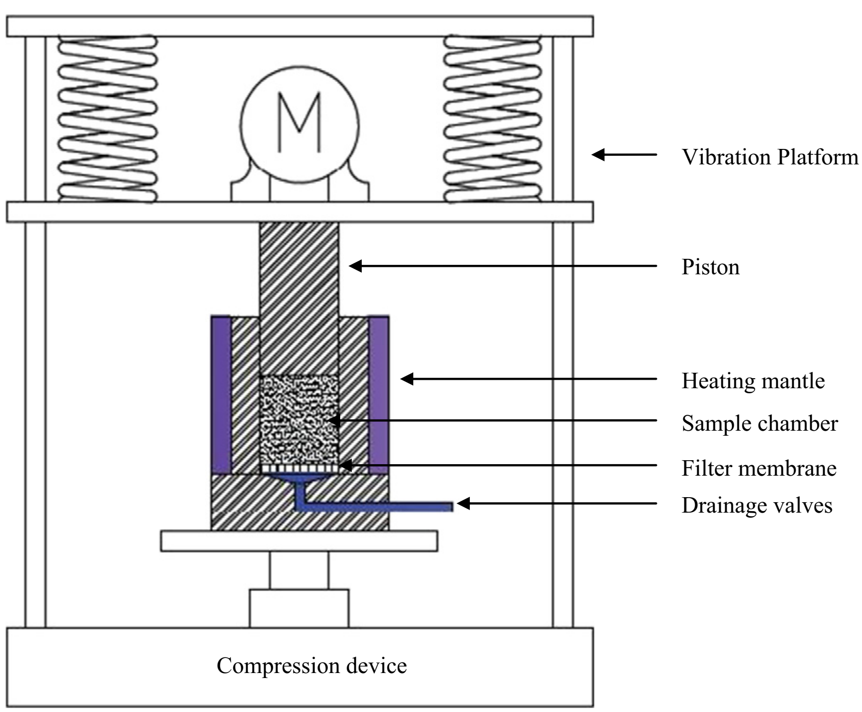

Fig. 1. Schematic diagram of VMTE rig.