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Recent developments in drying and dewatering for low rank coals

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ABSTRACT

Globally, low rank coals are responsible for about half of the world's total coal deposits. However, these low rank coals present a high moisture content, which significantly impacts their utilization processes, including lower power plant efficiency, increased transportation costs, higher CO_2 emission, and spontaneous combustion during storage. In order to decrease the energy consumption of low rank coal during the utilization processes, drying and dewatering technologies must be well designed. This review presents recent development in drying and dewatering technologies for low rank coals. Evaporative drying technologies, such as rotary-drying, fluidized-bed drying, hot oil immersion drying, hot oil-immersion drying, as well as non-evaporative drying technologies such as hydrothermal dewatering, mechanical/thermal dewatering, solvent extraction, are summarized in detail. Future research to upgrade low rank-coals, which are deposited in arid geological environments, is also suggested.

Contents

1. Introduction

Increasing world populations and resulting economic issues have led to drastic increases in the demand for energy. Fossil fuels such as coal, oil and natural gas have thus far been the principal commodities – up to about 85% – in meeting the world's

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commercial energy needs [1,2]. Today, among all energy-rich materials, the use of coal has increased most rapidly generating 42% of the world's electricity [3]. Furthermore, in many countries, such as the United States, about half of electricity used is generated from coal [4]; in China the number is more than 70% [5]. Coal has retained its major role because of advantages-such as high density, low cost and ease of combustion [6]. However, the increase in global coal consumption has led to an alarming rise in emissions of CO_2, NO_x and SO_x into the environment [7]. According to reported data, more than 35% of the emitted CO_2 in the entire world is derived from coal [8]. Hence, for the sustainable development of the coal industry, there is no doubt of the necessity to develop energy conservation and emission reduction technologies.

Although the reserve of coal is abundant, about half of the world's coal deposits are low rank coals, which are relatively inexpensive, at just 20–30% of the price of high ranked coal [9]. Low rank coals (i.e., lignite, brown coal and sub-bituminous coals), are very abundant in Australia, Central Europe and Eastern Europe, the northern US, Germany, Japan and China [10]. The total world reserves of lignite are about four trillion tons, and in China, the reserves of lignite are about 190.3 billion tons (41.18% of the total coal reserve of China) [11]. Therefore, it is imperative that low rank coals be used cleanly and efficiently. However, the most obvious disadvantage of low rank coals – especially lignite and brown coal – is their high moisture content (25–70%), which significantly impacts utilization processes, including lowering power plant efficiency, increasing transportation costs, raising CO_2 emission, and spontaneous combustion during storage [9,12–14]. Generally, the moisture content of lignite, reduced to about 5–10%, can be used economically [15]. Reported results show that reducing moisture in coal from 40 to 25% can lower the average reduction in auxiliary power such as fans and milling by 3.8% [16]. The overall efficiency of raw lignite (with a water content of 35–55%), can be enhanced by 2–3% using a pre-drying process [17]. For brown coals (typically 55–70% as mined), 20–25% of the heat of coal combustion is wasted in removing water using conventional processes [18]. By optimizing the drying process, the efficiency of brown coal power plants could be increased by 4–6% [19]. At present, burning brown coals produces more carbon dioxide (about one-third more), than burning black coals [18]. When the moisture of the coal is reduced from 60 to 40%, the relative reduction of CO_2/MWh can reach 30% [20]. Thus, to decrease energy consumption, pollutants and greenhouse gas emissions of low rank coals during the utilization process, efficient and appropriate drying and dewatering technologies must be developed [21,22].

Successful research on mining, beneficiation, transportation and combustion of coal has been conducted in the past decades. Scott et al. [23], provided a general review of existing opencast coal mining methods in Australia. Dwari and Rao [24], presented a summary assessment of different technologies and their performances in the beneficiation process of coals. Mathews and Chaffee [25] offered a dedicated review of the history and advances in the structural representations of coal. Oh [26], studied carbon capture and storage potential in coal-fired plants in Malaysia. Dolan et al. [27], reviewed the development of sulfur removal from coal-derived syngas. With the development of energy saving in the coal industry, it is also necessary to summarize the advances in drying and dewatering technologies of low rank coals.

There are several methods for drying and dewatering low rank coals for upgrading. In the present study, the development of drying and dewatering technologies of low rank coals is examined, as well as their drying mechanisms and operating conditions. The influences of drying temperature, pressure and coal size are also described. Future challenges for upgrading low rank coals, deposited in arid geological environments by drying and dewatering technologies, are also presented and discussed.

2. Drying and dewatering technologies

2.1. Moisture states in coal

A number of oxygen – functional groups existing in low rank coals lead to a hydrophilicity and high water content [28,29]. Both physical and chemical changes may occur during the drying and dewatering process. To develop efficient drying and dewatering technologies for low rank coals, it is necessary to understand the fundamental characteristics of coal structure, particularly in relation to coal–water interactions [18]. In general, the water in low rank coals can be divided into freezing and non-freezing water; non-freezing water can be further divided into free water and bound water [30]. Non-freezing water is defined as water that is remains liquid at −3 °C, by using a proton nuclear magnetic resonance (NMR) technique [31], or water that does not freeze at the lowest temperature attained during the experiment using a differential scanning calorimetry (DSC) technique [18,32]. In addition, low rank coals contain many microporous structures. Water stored in these pores of different sizes forms different structured clusters [30]; water adsorbed in some micropores is difficult to remove using conventional methods [33]. The different types of water associated with coal can also be divided into five types (Fig. 1): interior adsorption water, surface adsorption water, capillary water, interparticle water and adhesion water [34,35]. Interior adsorption water is contained in micropores and microcapillaries within each coal particle and deposited during formation. Surface adsorption water is adjacent to coal molecules but only on the particle surface. Capillary water is contained in capillaries and small crevices found between different particles. Interparticle water is occurs between different particles, and the adhesion water is that which forms a layer of film around the surface of individual or agglomerated particles [34,36]. Some water can be readily removed using conventional methods such as vacuum filters and centrifuges; other water must be evaporated by heating the coal to a higher temperature. Low rank coals shrink after most of the water is removed which leads to upgrading the coal.

2.2. Classification of drying and dewatering technologies

To design a highly efficient drying and dewatering system, both the characteristics of the coal and the operating mechanisms of different drying and dewatering technologies must be considered. In the past century, various drying and dewatering technologies for upgrading low rank coals have been developed. Karthikeyan et al. [34], provided an overview of some typical dryers/methods for coal

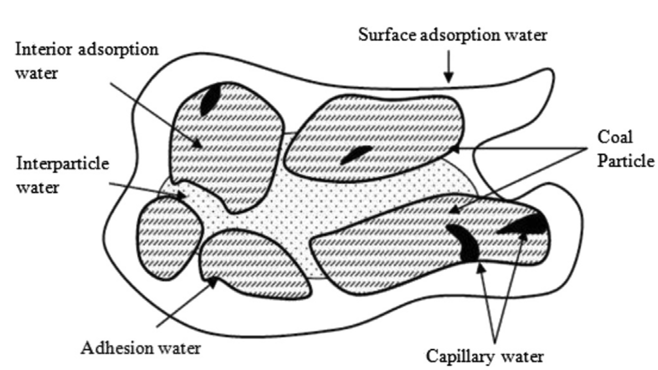

Fig. 1. Types of water associated with coal [35].