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EXPERIMENTAL RESEARCH OF THE LIGNITE DRYING PROCESS IN PACKED BED

Milić Erić[1a], Zoran Marković[1b], Aleksandar Milićević[1c], Rastko Jovanović[1d], Danka Kostadinović[1e], Ivan Lazović[1f] and Milica Jovčevski[2a]

[1]Vinca Institute of Nuclear Sciences - National Institute of the Republic of Serbia - University of Belgrade, Mike Petrovića Alasa 12-14, 11351 Vinča – Belgrade, Serbia
[2]Faculty of Mechanical Engineering, University of Niš, Niš, Serbia
[1a]milic@vinca.rs, 0000-0001-6850-3112
[1b]zoda_mark@vinca.rs, 0000-0003-0553-3263
[1c]amilicevic@vinca.rs, 0000-0003-4615-8789
[1d]virrast@vinca.rs, 0000-0003-0265-2304
[1e]dankak@vinca.rs, 0000-0003-2890-4979
[1f]ivan.lazovic@vinca.rs, 0000-0002-3877-5157
[2a] milica.jovic@masfak.ni.ac.rs, 0000-0002-5699-5831

Abstract
One of the biggest challenges is the development of low-carbon technologies for coal utilization. Clean coal technologies are a group of measures aimed at reducing carbon dioxide emissions by increasing the energy efficiency of coal-fired power plants. Experimental studies were carried out on the convective drying of lignite. The drying process was investigated under the packed bed conditions. The effects of sample size, temperature and coal grain size on the drying rate were investigated. Temperature was recognized as the most influential parameter.

***Keywords**: convective drying, lignite, moisture, packed bed*

1. INTRODUCTION

The methods for reducing the moisture content of low-rank coals may be divided into two main groups: conventional evaporative drying (direct or indirect dryers, packed bed or fluidised bed dryers, rotary kilns, etc.) and non-evaporative dewatering methods (mechanical-thermal expression, hydrothermal dewatering, etc.).

In the combustion of coals with high moisture content the thermal efficiency is reduced and increased CO_2 emissions that contribute to the greenhouse effect. This is because in conventional coal-fired power plants a part of the fuel's heat is consumed in the boiler during combustion and mill drying to evaporate coal moisture. The coal moisture leaves the power plant as steam together with the flue gas, so that this heat cannot be used in the plant process and is lost.

Kolubara lignite is the mostly used coal in the Republic of Serbia. It belongs to low quality coals with moisture content in the range of 45% to 52% [1] . As a first step in researching the process of convective drying in the Vinca Institute of Nuclear Sciences, Laboratory for Thermal Engineering and Energy, a number of experiments were performed in the in the packed bed drying process.

Conventional convective evaporative drying involves complex transport phenomena consisting of three successive processes. The first is the movement of moisture in solids, which occurs from the moist interior to the gas-solid interface (internal pores, particle surface, etc.). This process is slower for larger solids and/or materials with low moisture content. The second process is evaporation, which is favoured by heat (energy) that is either supplied from the outside or extracted from the solid and used to convert liquid into vapour. The last process is the movement of the vapour into the surrounding gas by diffusion and convection. The slowest of these processes determines the

overall drying rate, etc.). Predicting the kinetics of falling desiccation by theory alone is very difficult. Therefore, precise experiments on a small scale are required instead. Concepts such as the "characteristic drying curve" ([2-3] or the "drying coefficient" ([4-5]) can be used to predict the drying rates under different conditions.

2. EXPERIMENTAL RESEARCH

Convective drying experimental research in packed bed of Kolubara lignite had the following objectives: determination of the Kolubara lignite drying kinetics curve, analysis of the drying agent influence, determination of the influence of temperature of the drying agent and material particle size and validation of the mathematical model. The Sherwood Tornado M501 fluidised bed dryer with a 5 litre sample tube, Figure 1 was used to carry out experiments to dry Kolubara lignite samples in a packed bed [1].

The decrease in moisture content of the Kolubara lignite samples was determined by measuring the air mass flow balance at the dryer inlet and the dryer outlet. The following measured parameters were used for the calculations described above: volume flow rate at the inlet, temperature and relative humidity of the air at the inlet and outlet of the dryer. The minimum fluidisation velocities upstream of the sample were determined for all grain sizes and air temperatures. The magnitude of the air velocity upstream of the sample was approximately 0.6 m/s to 0.7 m/s.

The air is fed into the dryer by means of a centrifugal blower and then passed through an electric heater (electric power 2 kW). The blower is operated and controlled by a thyristor circuit which allows the motor speed to be regulated over a wide range of operating conditions. The dryer is fitted with feedback to ensure that the blower motor is kept at the same programmed speed regardless of the effects of the power supply and heating. The projected operating flow rate is in the range of 0 to 2 m^3/min, while the maximum blower load can be achieved at 2.5 m^3/min.

The air temperature downstream of the heating element is measured by a thermocouple connected to a control unit that activates and deactivates the heating element based on a specific air temperature at the inlet upstream of the sample. The air temperature upstream of the sample can be set within a range of 20 to 200 °C. It should be noted that at higher air flows with air temperatures upstream of the sample above the value of 150 °C, there were difficulties in keeping the air temperature upstream of the sample constant. This could affect the measured values and influence the accuracy of the results obtained.

Figure 1. Sherwood Tornado M501 dryer and other instruments for experimental research

The experimental apparatus was upgraded with the orifice plate with suction tube is installed at the device inlet and complies with the standards SRPS EN ISO 5167-1 and SRPS EN ISO 5167-2 "Measurement of fluid flow by means of pressure differential devices inserted in circular cross-

section conduits running full", Part 1: "General Principles and Requirements" and and Part 2: "Orifice plates" and additional equipment for measuring the air flow.

The measurements of the differential pressure and the static air pressure at the orifice plate were carried out with two AlnorAXD 560 digital micromanometers. The air temperature was measured using a type K thermocouple and a Testo 925 digital thermometer, while the relative humidity was measured in front of the measurement opening using a Testo175-H2 hygrometer. A DB3 PCE Instruments digital barometer was used to measure the barometric pressure.

The most widely used domestic lignite from Kolubara, which has a relatively low calorific value (6200 – 9300 kJ/kg) and an extremely high moisture content (47.2 – 51.4%), was selected to carry out experiments on drying coal in a packed bed [6].

3. RESULTS

The average diameter of the lignite particles is determined using the openings of the sieves used to sieve the coal. The initial mass of the sample was 200 g, and each additional increase in mass was 50 % of the initial mass. The initial temperature of the dried air was 30 ºC, and each additional increase in temperature was 30 ºC. Figures 2-4 show the comparative results of drying in the packed bed for two different sample masses, two particle sizes and two temperatures[1].

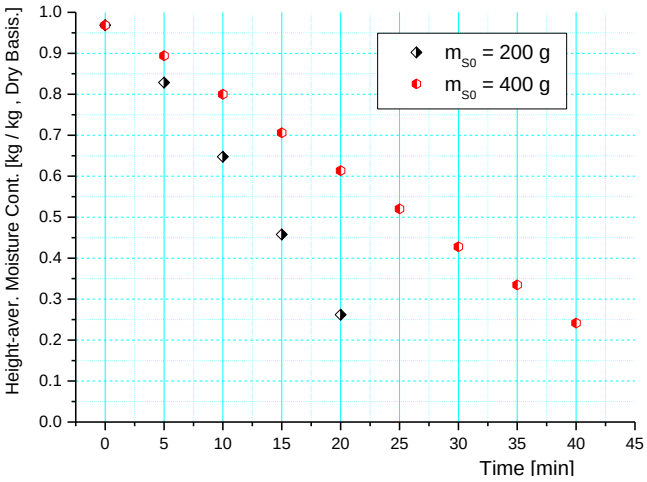

Figure 2: Results of the drying kinetics of lignite in the packed bed for two different sample masses with the same particle size and an air temperature of 90 ºC in the front of the dryer heater

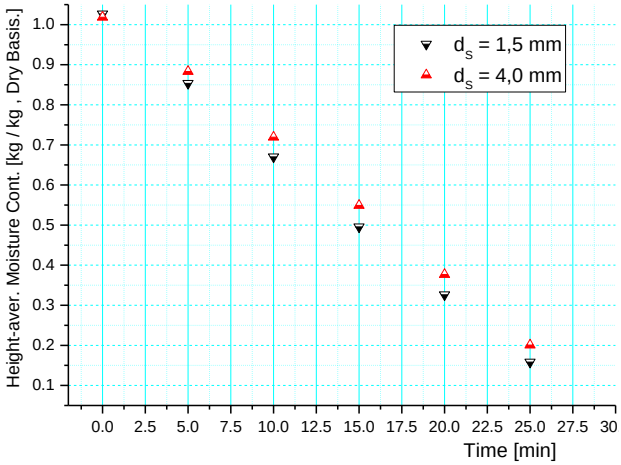

Figure 3: Results of the drying kinetics of lignite in the packed bed for two different particle sizes with the same sample mass of 200 g and an air temperature of 90 ºC in front of the dryer heater

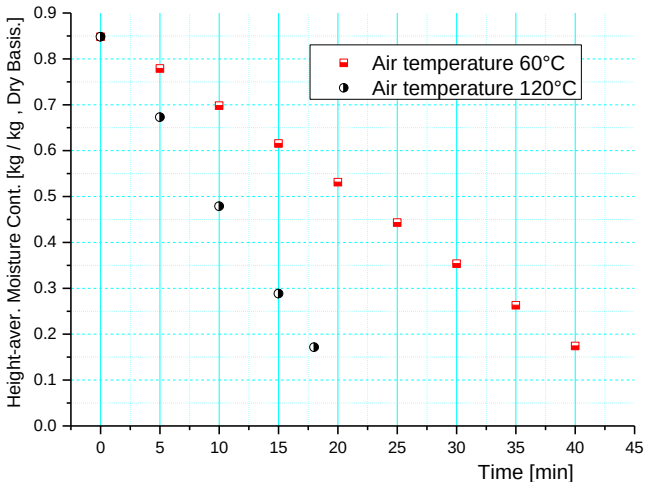

Figure 4: Results of the drying kinetics of lignite in the packed bed for two different air temperatures in front of the dryer heater with the same sample mass of 200 g and 4 mm particles

4. CONCLUSIONS

A series of experiments were conducted on convective drying in the packed bed of the Kolubara lignite samples. The experimental investigations of the drying process in the packed bed were carried out for several different coal sample masses and different coal particle sizes at different air temperatures from 30 to 120 ºC, which were measured in front of the sample and the dryer heater. The test results obtained show that the drying time increases proportionally with the increasing mass of the sample. The size of the lignite particles has no significant influence on the drying rate of the sample. Figure 3 shows that the differences in the amount of moisture removed are very small for two particle sizes where the ratio of the mean diameter of the particles is 2.7 times. As the temperature increased, the drying rate of the sample increased, while the drying time decreased. Temperature is the most influential of the three parameters analysed.

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