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Experimental Investigations on Drying Behaviour of Bulgarian Brown Coal in a Steam Fluidized Bed

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Since January 1998, RWE Energie AG has been operating a steam fluidized bed test dryer. It is installed at the site of the power plant Niederaussem in the Rhenish Brown Coal Mining Area between Cologne and Aachen. Main targets of the project are:

- the investigation of main parameters for optimizing the drying process as there are steam pressure, fluidization velocity and particle size,
- to identify the expenditure for the connection of the drying and the combustion process as there is e. g. the neccessity of milling of the coal, either the raw or the dried coal.

The plant operates with intermediate superheated steam of about 300 °C and 30 bar. (Figure 1). The steam is expanded and cooled (by thermal oil) to the drying parameters. It is fed into the dryer via an open nozzle bottom for fluidization of the coal, currently in a stationary mode.

An amount of about 20 kg of milled raw coal (0 – 6 mm particle size) is stored on top of a screw feeder with a maximum feed rate of 16 kg/h of raw coal. The feeding device is directly connected to the dryer at the same pressure. The coal is fed continuously to the top of the fluidized bed.

The fluidized bed is heated by an internal heat exchanger with a contact surface of about 0.75 m^2. For heating, the hot oil from the intermediate superheated steam cooler is used.

The dry coal is discharged through the open nozzle bottom via a screw conveyor to the dry coal vessel. As an indication for the fluidization state of the bed, the pressure drop is measured between the top of the bed and the steam inlet. For indicating the height of the fluidized bed, the pressure drop in the section above the heat exchanger is monitored.

In the frame of the JOULE III program which is financed by the European Commission, tests with brown coals of different european countries will be performed. Participants in the project are:

- the University of Stuttgart, Germany, as the coordinator,
- PPC (Greece), Fortum Heat and Power Oy (Finland), RWE Energie AG (Germany) as industrial partners,
- Imperial College (United Kingdom), National Technical University of Athens (Greece), Technical University of Timisoara (Romania), Technical University of Wroclaw (Poland) and Technical University of Sofia (Bulgaria) as university partners.

Actually, a test series with Bulgarian brown coal from Maritza East has been completed. On the background of first results with other coals, we focused on the variation of the particle size. By sieving with mesh sizes of 1.6 and 6.3mm, we prepared two fractions with significant different particle sizes (Figure 2):

- fraction A from 0 to 1.6 mm (0.5 mm average),
- fraction B from 1.6 to 6.3 mm (1.7 mm average).

With both fractions we performed variations of the following parameters:

- steam velocity (0.07 to 1.7 m/s),
- raw coal feed rate (4 to 16 kg/h),
- raw moisture (18 to 43 wt%), and
- pressure (1.3 and 5 bar, for fraction B).

Besides these drying tests with the fluidized bed dryer, we did some lab scale tests to investigate the shrinking behaviour of the coal resulting in different pore sizes which are important for the combustion later on.

As expected, there can be observed a significant increase of heat transfer when reducing the particle size (Figure 3). The values are about 200 to 230W/m²K for fraction B and 300 to 350W/m²K for fraction A.

As assumed, no influence could be observed by variation of the raw moisture of the coal (Figure 4). This confirmes our energy balances used for the evaluation of the heat transfer coefficient.

In the case of increasing the raw coal feed rate, an unexpected influence on the heat tranafer coefficient was measured, mostly significant for fraction A (Figure 5). This can be explained by compression of the bed by increasing the feed rate resulting in a lower voidage, a higher particle surface and a higher amount of particles per volume, a higher amount of particle contacts between particles and heat exchanger and between different particles, and last in a higher heat transfer coefficient. We will look on that in our future programs with other coals.

As mentioned before, we did some tests under pressure of 5bar with fraction B. In theory, a significant effect is expected for large particles (>1mm). Based on the thesis of Martin and Dietz, for fraction B a heat transfer coefficient at 5bar is expected 50% higher than for atmospheric conditions (1.3bar). Comparing these theses of Martin and of Dietz with the measured values (Figure 6), an increase of about 20% can be observed when comparing the maximum values of heat transfer for atmospheric and pressurized conditions.

All these results shown above are leading to our opinion that, for the used paricle sizes which are typical for fluidized bed drying, the particle convective heat transfer mechanism is the main component of the overall heat transfer.

To get an idea of the coal behaviour during drying also concerning the following combustion, we measured the pore size distribution by BET method on coal samples, prepared differently.

It is well known that coal is shrinking during drying as it can be seen for both fractions (Figure 7). The relative bulk volume indicating the particle size is depending on the coal moisture.

When comparing pore sizes for the oven dried coal and the fluidized bed dried coal, we see a significantly higher inner surface for the oven dried coal (Figure 8). To indicate the pore sizes of raw coal we prepared the coal by freeze drying. Because ice is expanding it would lead to a very high inner surface by cracking the solid structure before sublimation under vacuum. We have to look for a better preparation method.

Looking on light microscopic photos (Figure 9), it can not be seen the above mentioned difference of the structure between oven dried and freeze dried coal. But it can be confirmed a significant difference between these two coals and the coal from the fluidized bed.
Other preparation methods are actually in progress, either to get better values for raw coal and for comparison with coal dried in beater mills as used in conventional power stations up to now.

As a conclusion the following statements can be posted for drying of brown coal in a steam fluidized bed:

- for the usual coal size, the particle convective mechanism is the leading one for heat transfer,
- therefore, development of pressurized fluidized bed drying is not of basic interest for RWE Energie AG, as it only enhances the secondary gas convective heat transfer mechanism,
- the question of the sequence and the total expenditure for crushing and milling is still open.

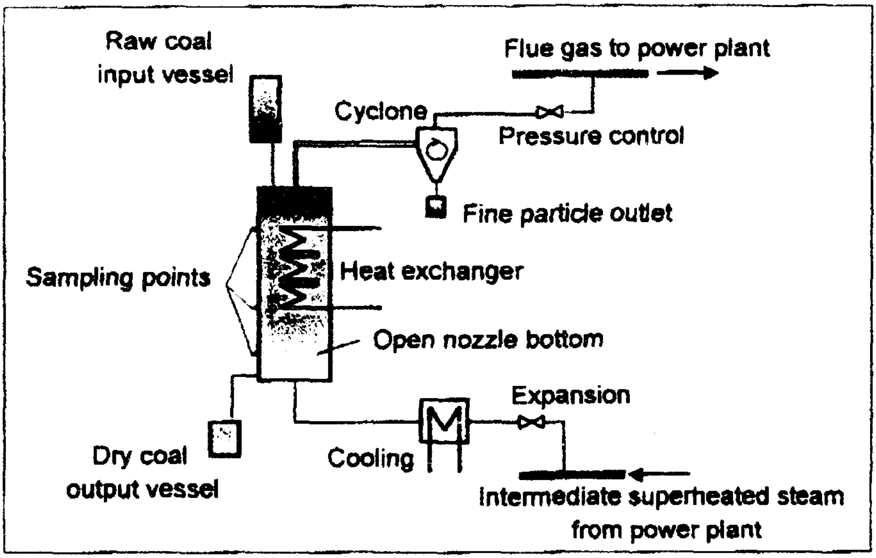


Figure 1: Flow scheme of the test dryer

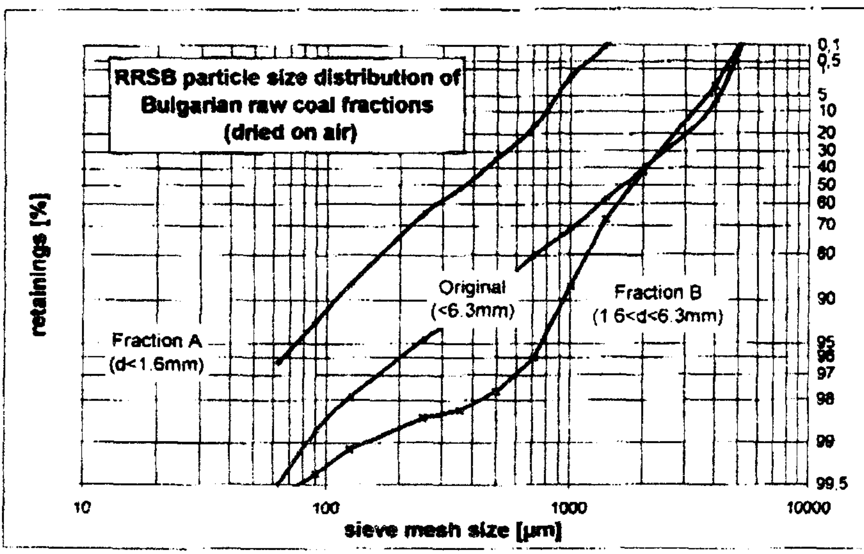


Figure 2: Particle size distributions of fractions A and B

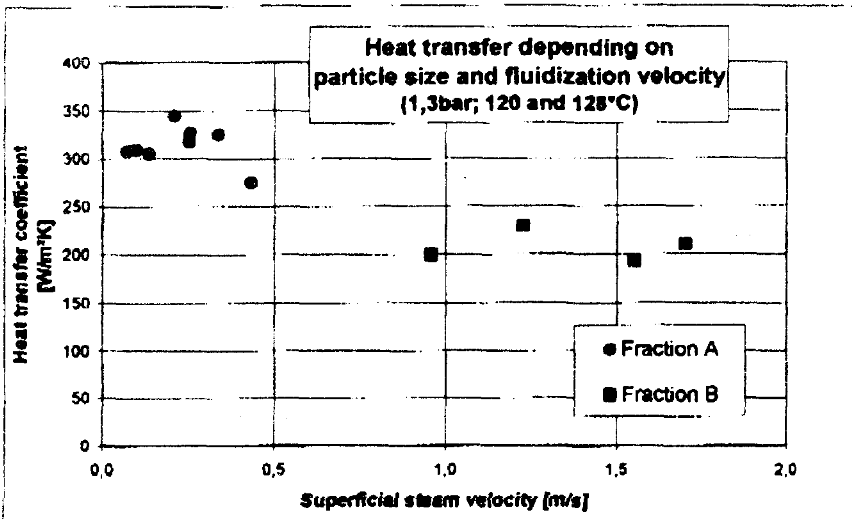


Figure 3: Heat transfer coefficients depending on particle size

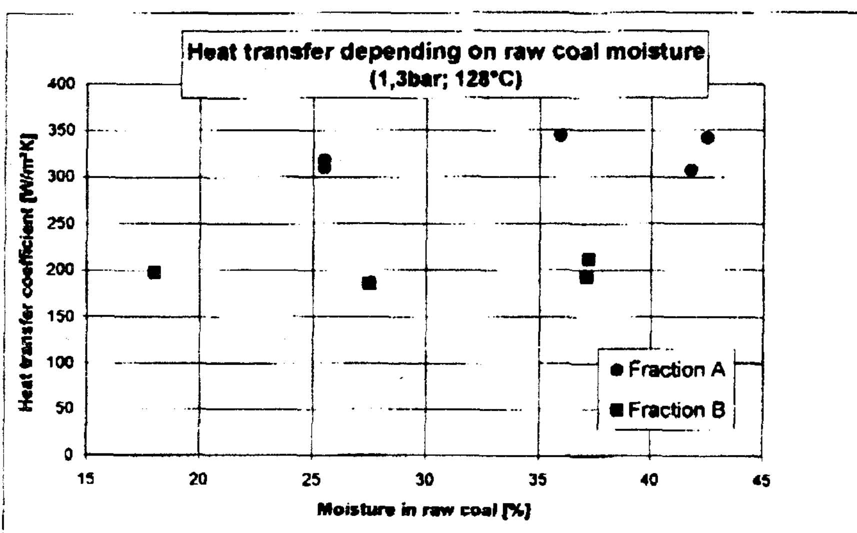


Figure 4: Heat transfer coefficient depending on raw coal moisture

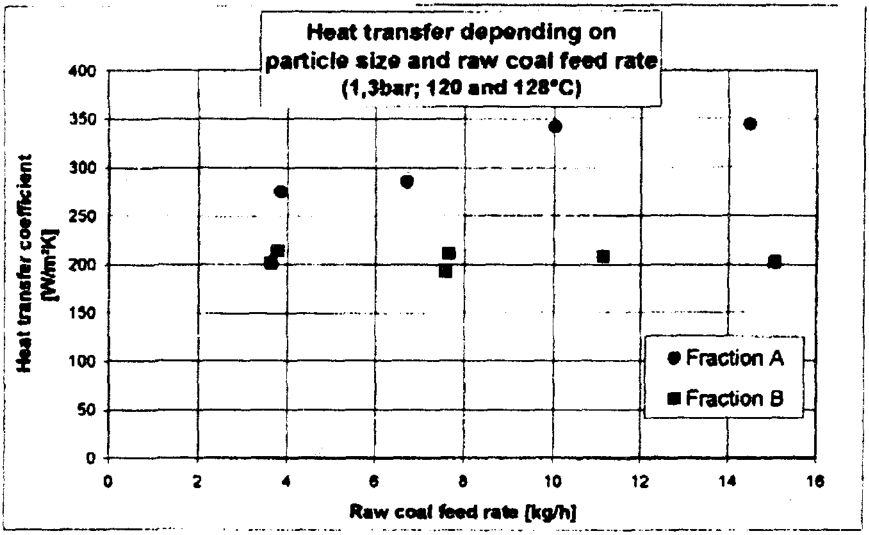


Figure 5: Heat transfer coefficient depending on raw coal feed rate

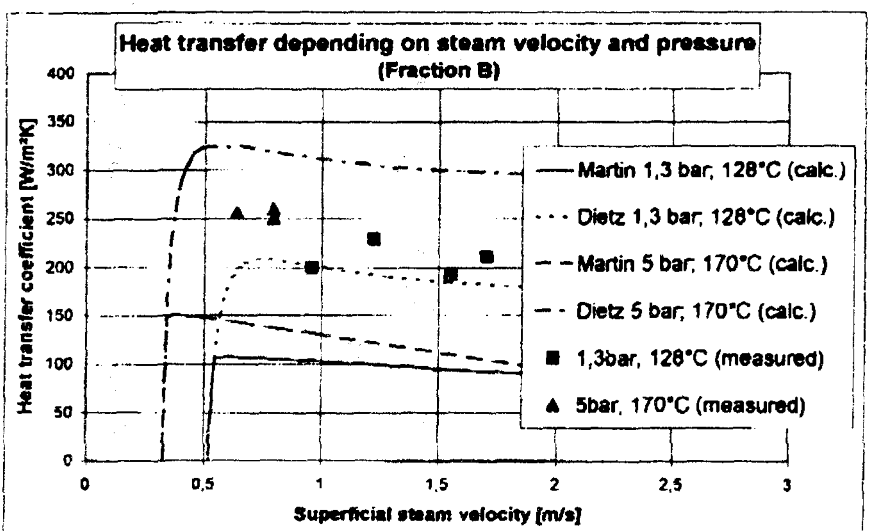


Figure 6: Heat transfer coefficient depending on pressure

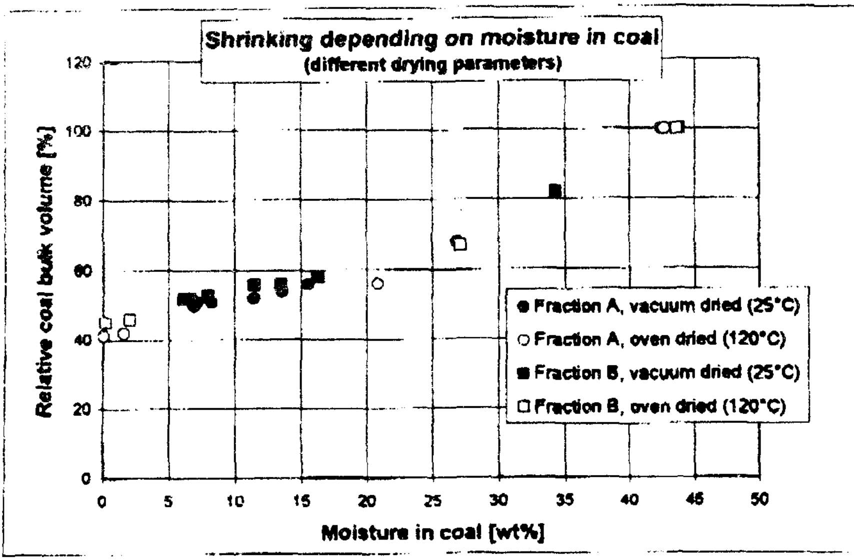


Figure 7: Shrinking behaviour depending on coal moisture

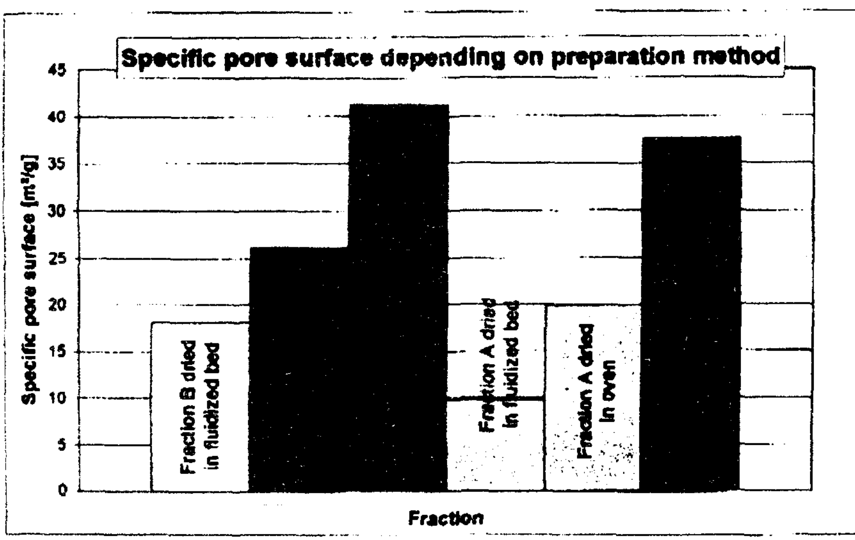
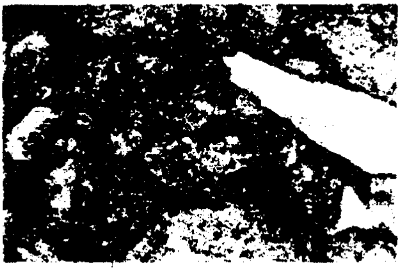
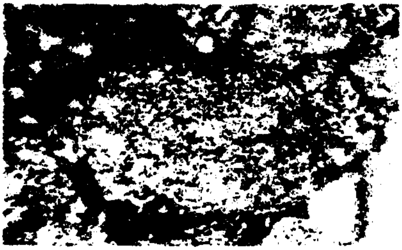


Figure 8: Pore surfaces depending on different preparation methods



Raw coal

Dry coal from fluidized bed (128°C)



Dry coal from oven (120°C)

Freeze dried coal (-30°C)

Figure 9: Light microscopic photos of r[illegible]d differently dried coal