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THERMAL COAL DRYING WITH THE HIGH VOLATILE MATTER OUTPUT

An analysis of modern technologies of drying of coals with high content of volatile. Industrial applications received steam dryer with a fluidized bed with capacity of 55 tons/h, in which the coolant is inert nitrogen, and the necessary heat is generated by waste gases of the gasifier, the heat transfer is carried out by means of hot water.

Thermal coal drying with a volatile output demands development of a special technological mode for coal ignition and explosion prevention. That's why it is necessary to reduce up to a minimum the oxygen contents in the drying agent. Main principle is direct contact exception of coal with the heat-carrier. Such principle is realized in indirect heating dryers, which basic constructive element is a drum supplied with a shirt for heating by steam or other heat-carrier. The given decision lack is low drying efficiency because of in each time moment only the part of drying coal contacts with a heating surface of a rotating drying drum and as consequence heat transfer speed is reduced.

With the purpose of this lack elimination the drying drum working cavity is filled by many cylindrical tubes through which it is passed steam or other heat-carrier [1]. Due to contact area increase a heat transfer speed and the thermal drying process efficiency have grown. The negative side of the present technology consists in a material over crushing and formation a lot of coal dust that increases explosion hazard of process.

In this respect other technological decision [2] differs perfectly. According to it earlier mentioned tubes is assumed to be used for moving under action of own drying coal weight while the heat-carrier is led to the drying drum working cavity and thus the external tube surface heat is provided. As the result, it takes place the portion load of coal drying without its over crushing. A tube diameter is usually 150 mm. At drying of a coal trifle -3 mm size its humidity has decreased with 20 up to 4 %. The temperature on a tube surface was more than 120°C. Industrial drying plants of such type have productivity on initial coal from 95 till 420 t/h (on dry mass) and provide humidity dried product at a level of 4,5-8,0 %. Such plants are fully-automated. The basic process regulators are frequency of drying drum rotation and steam pressure, used as the heat-carrier. Pressure steam achieves 10 op. The drying drum with 220 t/h productivity has 6,5 m diameter, and its length is 9 m. The number of tube is 150.

The combined drying of direct and indirect heating is described in the USA patent [3], according to which drying unit (fig. 1) includes a cylindrical rotating drying drum which is put in furnace with torches. The drying drum is covered by thermo plates which are placed on a preliminary indirect heating site in such a way, that they provide hashing air, and on a direct heating site they are used for an air direction into a drying drum.

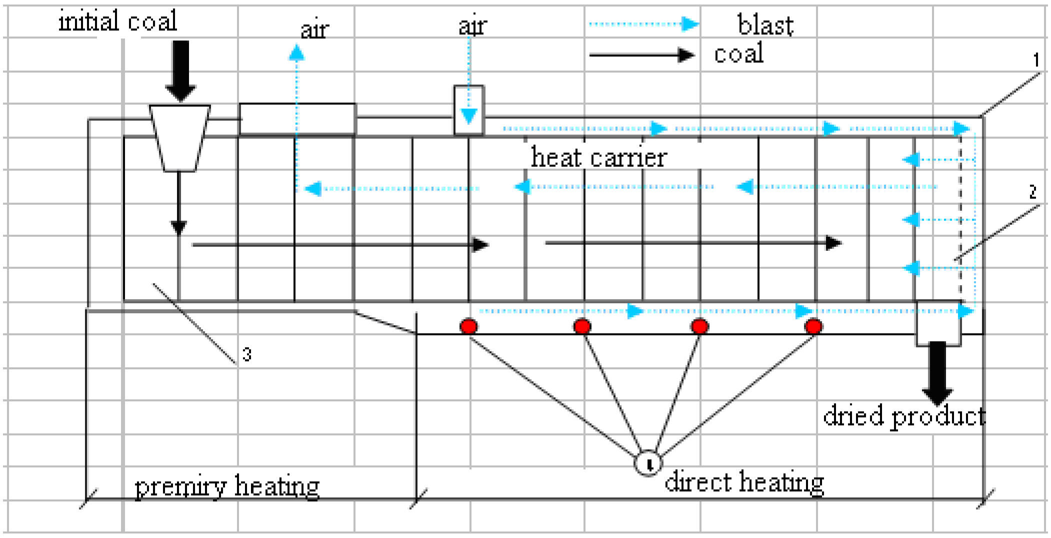

Fig. 1. A drying drum with the combined heating system:
1 -furnace; 2 - a drying drum; 3 –thermo plates; 4 - torches

At wet coal falling in a drying drum its indirect heating takes place by means of hot furnace gases, which heat a drum external surface. At passing of one third working zone lengths there is a transition to direct heating at direct contact of coal and the heat-carrier. The direct heat transfer is carried out in a counter flow mode.

More perfect on mass and heat transfer speed are dryers with a boiling layer some versions of which can be applied at coal processing with the high contents of flying. One of such designs is a multistage dryer with a boiling layer. The two stage dryer [4] is known in which initial coal of - 5 mm size are dried at the first stage in a boiling layer at temperature 150-290°C and air speeds of 1,2-2,4 km/s, and at the second stage - at temperature 290-350°C and air speed of 2,4-3,7 km/s. The main part of a moisture (40-60 %) leaves at the first stage while at the second stage the material humidity is reduced only to 1 %. At drying in a boiling layer high dispersion material fractions is captured by a working stream and for this purpose the dust removal cyclone is set on the exit. Condensers are established for a residual moisture removal from an air stream. Such drying agent clearing provides its circulation under condition of mixing with hot air portion before submission in a dryer working zone. In one step an ascending air stream speed is not less than 5,5 km/s that can break a normal coal liquefaction mode. The more boiling layer stages, the less specific power consumption (kJ/kg of a moisture), less both capital and operational expenses and less strict requirements to the drying agent quality. For increase thermal efficiency dryers with a boiling layer is equipped with submersible heat exchanger [5]. In this case convective heat transfer by means of a gas stream is supplemented with its conductive form due to heat exchanger accommodation in a liquated particle layer. As the value of heat transfer factors depends on a hydro dynamical mode it is necessary to take into account a place, the submersible thermo element form and properties, and also the characteristic of a gas stream and liquated a layer. So, liquating quality of particles is defined mainly by their size and the form.

At coal processing with a high flying output it is more safely and more economically applying steam drying units with a boiling layer which are recently developed in Japan and Germany [6] and differed not only by a high heat transfer, but also by recycling of the latent drying agent heat. One of the first such installations is HDC 360 which was started in operation in 1983 in Germany at drying of close-burning coal with the contents of 21-24 % flying on by-product coke plant in Bottrop (fig. 2). Productivity of a such drying plant is 10 t/h. The material input and output humidity has been accordingly 12 and 0,1 %. Soppy steam was used as the heat-carrier in conditions of the closed steam cycle. The temperature dried products reached 200 °C.

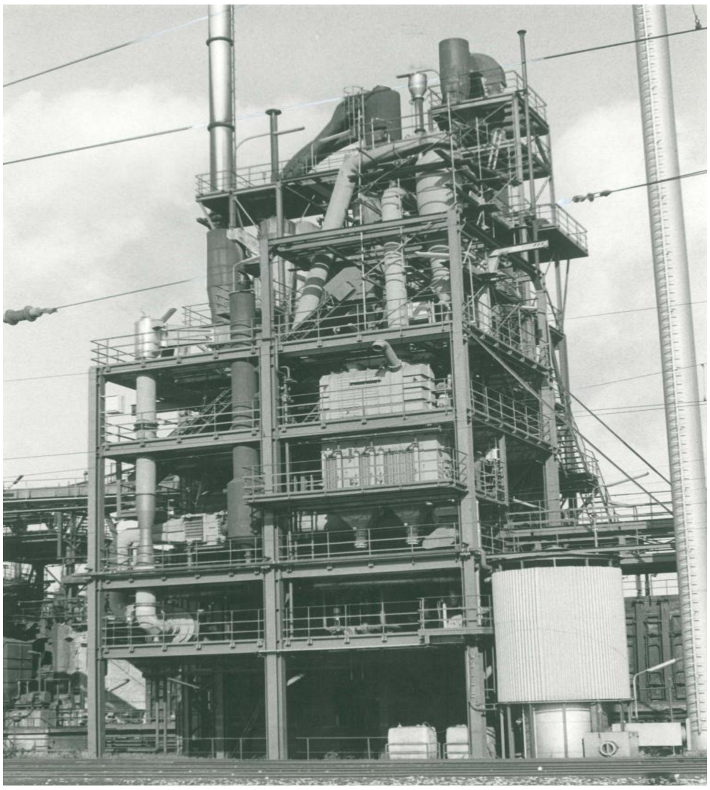

Fig. 2. A boiling layer dryer with for processing coking coal

The modern drying unit example with a boiling layer can be such a dryer as HDC 9250, six units of which are now set on thermal power station IGCC in state Mississippi (the USA) for thermal lignite processing of 46 % humidity. The final material humidity is 18 %. The contents flying in lignite is 19-26 %.

Fig. 3. Installation of boiling layer dryers HDC 9250 on thermal power stations IGCC (the USA, state Mississippi)

Productivity of dryers such as HDC 9250 is 55 t/h on dry mass. As the heat-carrier inert nitrogen which circulates in the closed contour is used. Necessary heat is received due to departing gases of the gasifier, thus the heat transfer is carried out by hot water. The temperature dried product on an output achieves 90°C.

All drying devices considered above are working by a superficial heating principle, at the same time drying speed is determined by conditions of a heat transfer from a surface into a depth of drying material mass.

For volumetric material heating the microwave field is used. According to the technological decision [7] at first initial coal is divided on large, fine and thin classes. After enrichment of the specified machine classes, the received concentrates are exposed to mechanical coal-water separation, at that in addition coal sludge passes also thermal microwave drying at temperature below 90 °C due to high-frequency processing in a frequency range from 915 up to 2450 MHz. For the constant superficial humidity control of initial coal photo gauges are established above the feeding conveyor on 1,5-3 m width and 30-60 m length. Depending on initial humidity the microwave field of the certain intensity is imposed that excludes overheating and ignition of coal particles. Kinetic dependences of microwave coal drying with a low metamorphism degree and a high flying output are submitted on fig. 4 [8]. These kinetic drying curves show, that speed of microwave drying process appreciably depends on a field capacity. So, at capacity of high-frequency radiation 1500 W drying cycle duration is twice less, than at capacity 750 W. In material heat avoidance the working temperature is supported not above 105°C. The bottom graph (fig. 4-б) shows, that microwave drying parameters are influenced also by a material weight that is caused by its non-uniformity heating. That’s why particles are tried to be hold during drying in a mobile condition.

Microwave processing precedes the basic thermal drying process or finishes it. At the microwave dryer installation in front of the basic drying unit the volumetric material heating is effectively realized therefore the internal moisture is superseded on a firm particle surface, thus perfect conditions for the subsequent convective heat exchange are created.

If the microwave dryer follows the usual drying unit, its purpose is reduced to evaporation of 30 % of the most difficult extracting moisture. For example, the boiling layer dryer is supplemented with the microwave generator, thus the size of grade apertures through which the gas ascending stream moves, is less than a wave length in a working frequency range that excludes outflow of high-frequency radiation in surrounding space. One of such dryers is declared in Doling’s patent [9] which has suggested to use the reflected waves energy and the distributive grate at it serves not only for a material moving and an ascending stream creation of the gas agent, but also for reflection of waves which energy is used more effectively therefore speed of thermal drying process grows in 2-4 times. The collateral useful effect at microwave generator use is drying coal sulfur removal, result of which is sulfur destruction (FeS2) with allocation of sulfurous connections such as H_2S, COS, SO_2, and at microwave processing of fine ground coal in alkaline solutions the sulfur removal degree is 70-80 % without its deterioration of coking coal abilities [10]. Despite of microwave coal drying availability, its practical application is limited because of significant capital and working costs, and also of coal ignition at its local over heating.

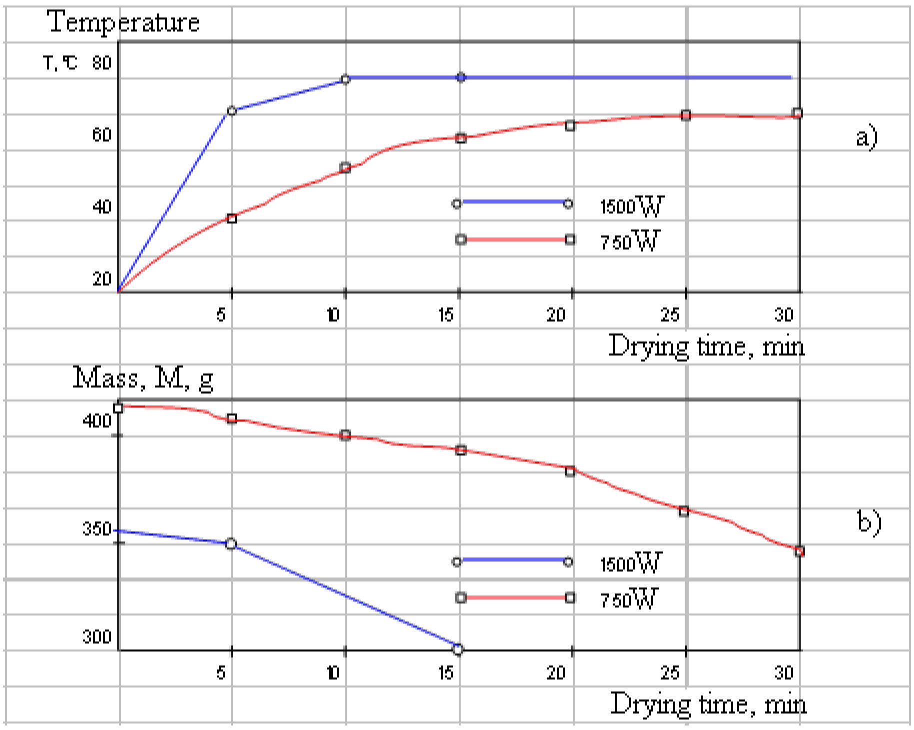

Fig. 4. Kinetic coal dryings curves with a high flying output:
a - dependence of drying time on heating temperature;
b - dependence of drying time on weight of drying coal

For reliability increasing of drying coal with a high flying output, indirect heating drying devices have been developed on the basis of the screw conveyor. The rotating screw presence in such devices provides high heat transfer factor which numerical value is 45-102 W (K·m^2). For increasing thermal efficiency and power input reductions a filling degree and working temperature are increased. Speed of drying grows at its operation on the medium lowered pressure. The typical design of such dryer (fig. 5) includes the case with a casing which is heated by hot water or heat. A moisture removal is carried out in some stages [11]. At the first stage coal is dried in the open case at temperature 80-150 °C up to humidity of 8-12 %, then it moves in a separate tight drum where thermal drying takes place at temperature 90-260 °C under superfluous pressure steam 0,5op, and then at the final phase dried product is cooled and unloaded in the bin. Change of heating intensity from fast on slow at two-level transition provides displacement low flying hydrocarbons from a coal grain surface and as consequence pores are stopped and repeated liquid phase adsorption is reduced to a minimum.

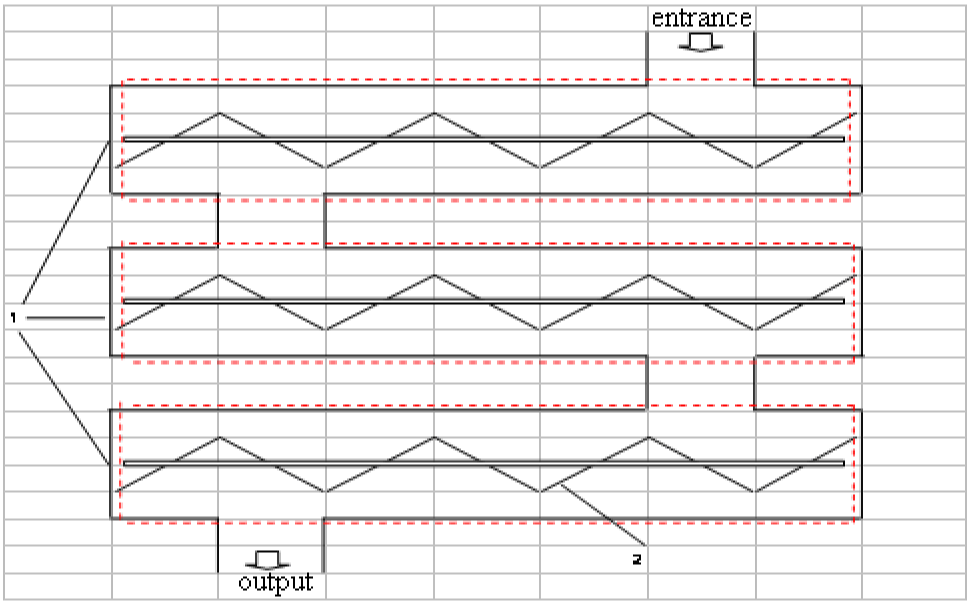

Fig. 5. Three staged dryer based on the screw conveyor:
1 - a casing; 2 – a screw conveyor

At coal processing with a high flying output on such dryer superheated steams or nitrogen is used as the heat-carrier. At a standard size choice of dryer coal physical properties (fineness, abrasives, an internal friction corner, flying contents) and the unit parameters (productivity, a filling degree, diameter and speed of the screw, a driving motor capacity) are considered.

Essentially other approach is application of direct heating dryers in which the drying agent is superheated steams (SSD). Generally, the usual direct heating dryer can be transferred in a SSD-installation mode. For a long time it is known, that as the heat-carrier it is more preferable to apply superheated steams, but only recently this approach receives a practical embodiment in dryers of new generation. Their essential advantage is high speed of drying as superheated steam possesses a significant thermal capacity and the increased working temperature that provide higher efficiency of thermal installation, thus coal explosion is excluded for the oxygen lack at coal heat processing. Their disadvantages are significant capital expenses that are caused by dryer production from stainless steel, presence of reliable condensation in order to prevent air hit in a working zone and outflow superheated steam, and also equipment heat exchange by special cleaners for firm particle removal accumulated during condensation steam. The Japanese experts developed dryer SHR with power recuperation [12] which works in the closed thermal cycle in such sequence:

- Preliminary heating wet coal;
- Transformation of the allocated moisture in superheated steams;
- Superheated steam compression for its temperature increase;
- Drying coal by superheated steam in a boiling particle layer;
- Thermal cycle closure due to return of superheated steam physical heat for preliminary heating of a wet material.

After comparison with usual direct heating thermal units, dryer with recuperation and processing dried products in a boiling layer has a lot of advantages which are resulted in the table.

Drier indexs	Direct heating drier	Dryer with recuperation
Productivity, t/h	15	15
Ratio air: steam, t/h	335	241
Blast feeding, thousand. m^3/h	415	290
Drive power, kW	900	630
Heat power, MW	15,5	9,0
Heat power recuperation index, MW	0	5,5
Capital charges, mln euro	1,35	2,85
Operating charges млн. евро	2,90	1,96

At coal processing by superheated steam for short time it is achieved not only its dehydration, but also partial sulfur removal, the result of that is technological quality improvement of dried products. For more full use of the physical and latent heat of the working steam, a dryer are integrated with thermal power stations, where due to the steam mechanical recompression electric power is produced in amount, at least, 0,2 kWh from each kg evaporated a moisture.

Perspective direction in the field of drying coal with the high flying contents is their cold dehydration by means of water removing agent of liquated dimethyl-ether (LDE) type which has a boiling point - 24,8 °C, and steam formation pressure at temperature 25,0°C - 0,59 MPa, that allows to clear easily coal of the organic extractor due to end process decompression, thus 95 % of a moisture are deduced. Despite of a wide use of this technology in other industries at coal enrichment it has not found industrial application yet because of high capital and operation charges on extraction.

Conclusions

1. The resulted equipment analysis for coal thermal drying with a high flying output has shown preference of indirect heating dryers, and also direct heating in a boiling layer because of their safety, reliability, moderate power inputs and a practical solvency.

2. The superheated steam application does not justify itself because of high capital and operating expenses.

3. Microwave installations do not provide uniform heating dried products thus danger of their ignition and explosion grows.

4. Technology deep cold coal dehydration by means of water removal organic extractors is not wide used because of its low profitability.

5. Steam dryers with a boiling layer have been got practical application for drying coal with a high flying output.

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