Influence of Coal Dust on the Performances of the Boilers Within Heating Plants

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Abstract

Thus, each type of fuel, each installation, is characterized by a certain economic grinding fineness which is determined depending on the fuel's qualities and on the installation's special characteristics. The equipment wear currently remains argument that are against the introduction of high granulosity pulverized coal burning. The pneumatic transport needs relatively high speeds of the carrying fluid which produce significant pressure rises, friction and clashing between the solid phase particles and thermal plants erosion. A high concentration leads to the intensification of wear. The quality of the materials the components subject to wear by the fuel dust are made of will influence the wear speed.

Keywords: boiler, coal, dust

Physical properties of coal dust

The coal dust is made of a mixture of particles with dimensions up to 300–500–1000 microns where the particles with dimensions between 20 and 50 microns prevail.

Under microscope examination, the dust particles have an irregular shape that, in most cases, depends on the fuel's nature and, to a lesser extent, on the dust preparation method. The great difference between the dust particle's shape and the regular geometrical shapes (cube or sphere) constitutes the main difficulty in calculating the size of the dust particle's surface. Due to the great quantity of fibre residues within the pit-coal dust particles, their shape differs a lot from the regular geometrical shapes.

The coal dust absorbs a large air quantity and, therefore, the freshly poured dust is a spongy mass which travels easily and which, under poured state, has a low weight. In time, under the influence of light vibrations that are produced in each installation, as well as due to the pressure created by the weight of the superior layers, the dust mass becomes more compact. The density of poured and pressed dust depends on the nature of the material and on the grinding fineness, being as an average equal to 0.8–0.9 t/m. Upon calculating the bunkers capacity, the density of the poured dust must be taken as an average of 0.7 t/m^3.

The natural slope of the slowly poured dust is 25/30g and varies depending on the fuel's quality and on the grinding fineness. Under the influence of light shocks, the dust in the vibrating or rotating recipient behaves like water. One can sink within a coal dust bunker, for this reason it is forbidden to descend into a coal dust bunker without prior precautions. The efficiency of dust elimination through small orifices depends on the fuel's quality and on the dust's granulometric composition.

In the presence of fine particles with high content of volatile matters that tend to aggregate rapidly, it is possible that the coal dust will not pour out through small orifices. Grinding the coal dust to high granularity or separating the fine particles improves the elimination process.

When mixed with air, the dust forms a fluid-structured emulsion which, the same as liquids, is easily transported. Due to this property, both in case of long distances (at 25 to 1 concentration) as well as in the usual dust preparation systems (1 to 29 concentration), pneumatic transport is used.

The coal dust stores are exposed to ignition risk, combustion points being formed inside (flameless burning) due to the high content of volatile matter and there is a risk of explosion.

Granulometric analysis of coal dust

The granulometric analysis of coal dust consists of sample acquisition and sifting through several sieves which differ by orifice sizes.

The operation of granulometric analysis power installations usually employs two types of sieves, with 88 and 200 orifice sizes. In order to obtain more complete dust characteristic, it is sifted by means of five sieves whose orifices are usually 60, 75, 88, 120 and 200 microns. The value of the reject determined on a conventional sieve constitutes the characteristic of grinding fineness and it is marked with "R".

The dimension of the sieve orifice or the sieve's number is marked as an index. Therefore, markings such as R88 or R70 indicate the value of the reject per sieves whose orifice size is 88 or 70 μm.

The dust quantity passing through the sieve is the so-called "passing" and it is marked with "D".

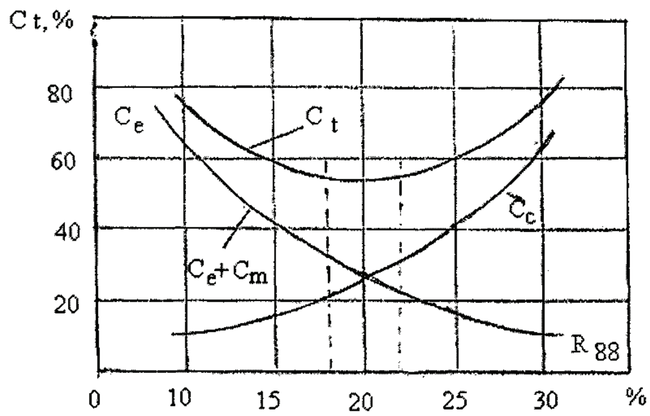

Fig. 1 Economic grinding fineness graph

Rys. 1. Wykres zużycia powierzchni

The dimension of the sieve orifice is also marked as an index. The sifted dust quantity is expressed in percentage of the initial sample quantity. Therefore, for each sieve characterized by a certain number, the following equation can be written:

$$Rx + Dx = 100 \qquad [\%]$$

Thus, the dust quality can be appreciated both by means of the reject as well as by means of the sifted dust quantity.

The optimum coal dust grinding fineness

During the grinding process, when the rejects by sieve are reduced in case the dust is ground to a finer state, the uncovered sieve surface increases. Proportional to the surface size, the specific energy consumption necessary for the dust preparation also increases. For this reason, in order to increase the flow rate of the dust preparation equipment, it is recommended that the ground dust have larger particles. Nevertheless, the installation's lucrativeness is not only determined by the dust preparation equipment's operation.

The usage of the large particle dust burdens its burning process and causes the increase of fuel loss through incomplete burning in the heating chamber. The entire installation will be very profitable when the sum of the expenses necessary for the dust preparation and burning will be minimal. The grinding fineness for which the general losses are minimal is called the economic grinding fineness.

It is generally difficult to determine the economic fineness, because it is influenced by several local factors. For this reason, generally speaking, the economic grinding fineness can be determined with sufficient accuracy only when it is determined separately for each installation. If one relates the sum of the expenses necessary for the dust preparation and burning to 1 ton of fuel, this relationship can be expressed as follows:

$$c_t = c_e + c_m + c_{serv} + c_c \qquad \text{[thousand lei]}$$

where: c_e – are the expenses referring to fuel, namely to the price of energy consumption necessary for the dust preparation, in lei/ton; c_m – expenses referring to metal losses, equipment wear and to the dust preparation in lei/ton; c_{serv} – other expenses for various services: oiling, servicing, redemption; c_c – cost of fuel loss by burning, in lei/ton.

Figure 1 illustrates the curves drawn in view of determining the economic grinding fineness.

The ascending curve, c_e, indicates the variation of fuel losses during burning; the descending curve, ce+cm, indicates the variation of energy consumption necessary for the dust preparation. The curve with downward convexity represents the variation of the sum of expenses.

The optimum grinding fineness corresponding to the minimum sum of these expenses is situated, in this special case, between the R88 = 18–22% limits.

Thus, each type of fuel, each installation, is characterized by a certain economic grinding fineness which is determined depending on the fuel's qualities and on the installation's special characteristics.

At the same time, in practice, good results were obtained for a less fine grinding, as one goes from fuel with low volatile material content to fuel with high volatile material content.

Equipment wear during coal dust burning

The usage of high granularity coal dust increases, in certain cases, the fear of equipment wear.

The equipment wear currently remains the basic argument used by those that are against the introduction of high granulosity pulverized coal burning. Nevertheless, after several years of burning high granulosity dust within various boiler systems of various constructions within a series of plants and after the grinding granulosity reached a relatively high value, R88 = 50% and more, one can state that no increase in the equipment's wear can be noticed.

Tab. 1. The values of the average speed of the burning gases upon their passing through the different elements of system

Tab. 1. Wartości średniej prędkości spalanych gazów po przejściu przez różne elementy układu

Boiler system name	Built boilers	
	first phase v, m/s	second phase v, m/s
Steam overheater	8.75	6.1
Economizer	10.3	8.0
Air pre-heater: tubular or with plates	12.4	9.4
Exhauster's aspiration	13.7	12.4
in the general burnt gases channel	15.4	16.8

If the elements of the boiler system and its auxiliary equipment were well built, they do not tend to wear due to ashes and do not have such relevant spots: passing to the burning of large particle dust does not change the situation in any way. The special experience after the operation of boiler systems within thermal plants which is described by the burning of large particle dust with Rgs up to 50% is an additional and convincing proof for the above. The wear problem is reduced, therefore, to the problem of the speeds of the gases saturated with ashes residues. The boiler systems that operate with fine dust or with large particle dust did not show differences in wear. Even by operating with fine dust, the exhausters' life span was maximum 1.5–2.0 months.

The cleaning of burning gases by means of a cyclone system made it possible to almost double, up to 3–4 months, the exhausters' operation life. From the data resulting from the sifting of the dust sample that was taken directly from the cyclone system's elimination devices, when the boiler system operates with large granulosity dust and with R88 up to 50%, it is demonstrated that the cyclone system entraps the quite fine dust, the sifting through the 88 sieve being 29–50%.

Table 1 shows the values of the average speed of the burning gases upon their passing through the different elements of the boiler system, at a load of 160 t/h. In those elements wear is noticed for a series of plants.

Coal dust's influence on the connection pipes between the separator and the boilers' burners

The direct burning dust preparation schemes also contain a pneumatic transport section where the dust particles are led to the burner by means of a carrier fluid.

The pneumatic transport needs relatively high speeds of the carrying fluid which produce significant pressure rises, friction and clashing between the solid phase particles and the transport pipes' erosion. In order to maintain these effects as minimum as possible, the transport speed must be as low as possible. The inferior limit of this speed is the one at which the particles begin to separate from the current.

As far as the horizontal pneumatic transport is concerned, the minimum speed is the speed at which the particles begin to lay on the pipe's bottom; as for the vertical speed, the speed at which the pipe's or grinder's clogging begins. Both the sedimentation speed as well as the clogging speed depend on the nature of the carrying agent, on its temperature, on the specific weight of the solid phase, on the particles' average diameter, on the solid phase concentration, on the pipe's length and on the pipe's tightness resistance.

The dedicated literature recommends the following pneumatic transport speeds for the coal dust: for air 20–25 m/s, for burning gases and air mixture 12–20 m/s, within the descending drying pit 20–35 m/s, within the grinder's exhaust pipe with fan 22–30 m/s.

It is recommended that the pipe's slope be at least 45°. If one part of the pipe must be placed horizontally or with a slope which is less than 45°, then the transport speed will have to be increased.

The pipes' bends must be built with an average curve radius Rave > 3 d in order to reduce the pressure losses and the erosion.

Generally, bends with two 45° returns are used, which avoid the occurrence of pulsations an of the dust concentrations noted in the case of 90° bends, ensuring a continuous flow and a good dust distribution within the burner's cross-section. The coal dust pipes are usually made of steel or steel sheet pipes with rectangular section, joint by welding, the pipe's wall thickness being 10–20 mm, after the coal dust's abrasive effect.

In order to reduce the bends' wear, the parts that are exposed to high wearing are built with greater thickness, are easily interchangeable, and are possibly made of special materials (basalt, concrete), etc.

In the case of metal sheet pipes designed for brown coal, the exposed areas reach operation periods of approx. 16,000 hours.

Coal dust's influence on the erosion of the heat exchange surfaces

A problem which is still not completely solved in the construction of the inferior solid fuels' burning installations is the eroding effect of the ashes. The material's erosion by the ashes particles takes four different forms: "adhesive" wear which occurs during the materials' sliding processes, the wear by "grooving" when the material is deeply scratched, the "layer" wear, when the process is limited to the external surface of the material and the decisive part is played by the existing superficial layer or the one created by wear; wear by "fatigue" which occurs in the superficial layer of the material under the impact of the ashes particles or of the variable stress indicating that the erosion can have two different causes: repeated deformation caused by the impact of particles which displaces a certain volume of the material and the material's cutting by the particles.

In the case of hard and fragile materials, the wear by repeated deformation prevails and, for the soft materials, the erosion by cutting prevails.

In order to reduce the erosion caused by the solid particles dislodged by the burning gases during the construction and operation of the steam boilers which use solid fuels, a series of measures are taken, some of them depending on the erosive agent and on the dislodging fluid, others depending on the pipes' material and their arrangement in clusters. Among these, we mention the reduction of the ashes concentration within the burning gases and of the particle's speed. A high concentration leads to the intensification of wear. The high ashes concentrations appear during the changing of the dislodging fluid.

Generally, for boilers with high parameters, a pipe erosion of approx. 0.2 mm/year is acceptable, which leads to an approx. 2 mm erosion of the pipes in a period of approx. 10–12 years, the equivalent of the yield period. This thickness loss falls within the surplus corresponding to the safety coefficient of the pipes builders, the provision of an additional surplus for erosion not being necessary, as compared to the one resulting from the pipe's resistance calculation. In this way, the optimum speed is thus chosen so that the pipes can last for a period of minimum 10–12 years. This speed limitation is supported by local protection methods in the dangerous areas, as presented.

Another group of methods seeks the modification of the erosive agent's properties, among which the increase of the fuel's grinding fineness, the reduction of its ashes content, the modification of the erosive particle's shape.

As far as the quality of the steel used for the construction of serpentines is concerned, it must be noted that steel with large granulosity is recommended, that carbon steel resists better than the alloy steel, as a consequence of the surface cold-hardening carried out by means of the particles' impact.

Conclusions

- The grinding behaviour of the coal depends on its origin, on the mineral and petrographic composition, on the ashes content, on the equipment used for grinding-sizing and on the working conditions.
- The particles' dimensions determine different effects concerning wear in the case of the majority of equipment which they come into contact with, in this case only the post-grinding circuits being analysed.
- The pneumatic transport conditions depend on the material's granulometry and it will determine, at high transport speeds, an increase of the wear of the pipes and of the other components in the transport system, especially exhausters.
- The quality of the materials the components subject to wear by the fuel dust are made of will influence the wear speed and the choice of those structures that cover the costs either by reducing the necessary replacement parts, or by means of the low acquisition cost of these components.

Literatura – References

1. ANGELESCU, A. - Mediul ambiant şi dezvoltarea durabilă (The environment and the long-lasting development,) A.S.E. Publishing House, Bucharest, 1999.
2. DAVID, I. – Transportul poluanţilor în medii fluide (Transport of pollutants in fluid media), U.P.T. Publishing House, Timişoara, 1996.
3. UNGUREANU, C. – Combustibili.Instalaţiide ardere.Cazane ((Fuels. Burning installations. Boilers.), Politehnica Publishing House, Timişoara, 2006.

Wpływ pyłu węglowego na wydajność kotłów w ciepłowniach

~~Każda instalacja ciepłowni jest projektowana dla paliwa o ściśle określonych parametrach. Proces zużycia instalacji jest obecnie argumentem za spalaniem paliwa o optymalnym uziarnieniu. Transport pneumatyczny jest prowadzonym przy stosunkowo dużych prędkościach nośnika, co powoduje znaczny wzrost ciśnienia, tarcia i ilości zderzeń między cząstkami fazy stałej i ścianami instalacji powodując erozję. Wysoka koncentracja fazy stałej prowadzi do wzrostu erozji. Jakość materiałów z których wykonane są elementy instalacji ma wpływ na prędkość zużycia.~~

Słowa kluczowe: kocioł, węgiel, pyły