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EFFECT OF POWER PLANT STEAM BOILERS' CONTROL SYSTEM ON THE STABILITY OF FUELLING

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Abstract

Combustion processes in furnace installations are characterised by parameters varying with time, thus fluctuating more or less around the required value. This concerns velocity distribution of the air flowing into the combustion chamber as well as the fuel, thus fuel–air concentration will change in space and time, resulting in pressure and temperature fluctuations.

In furnace installations, however, flame is the best 'stability' indicator usually more intensively signalling disturbances occurring in any unit of the equipment.

Keywords: combustion stability, steam boiler.

1. Introduction

The pulsation of burning in pulverized coal fuelled equipment indicates somewhat periodical burning disturbance with frequency independent of equipment geometry, depending mainly on mixture formation, gasification, and ignition process. Therefore, anomalies of this type may be explained from the burning and flow, with fluctuation frequency mainly depending on fuel quality.

Pressure fluctuation coming with internal furnace instability is dangerous from the aspect of safety because it soon results in repeated stress failure in the boiler's structural materials.

Therefore it is essential to know the elasticity and eigenfrequency of boiler construction units, especially the membrane wall of the furnace.

Reinforcing the boiler structure will reduce its elasticity and increase the wall's eigenfrequency.

Another method for avoiding boiler construction resonance is to modify the exciting source of resonance. This requires knowing of factors determining the exciting source – in this case pressure fluctuation due to internal instability.

In the case of fuelling with pulverized coal of low caloric value, the characteristic frequency of fluctuations is much below the eigenfrequency of the furnace installation calculated from its geometry therefore it cannot be influenced with acoustic methods.

In contrast to acoustic instability, internal instability does not emerge unexpectedly, but increases gradually with the worsening of firing conditions.

In the case of pulverized coal fuelling, the burnable content of the coal pulver – air mixture has an essential influence on flame stability. To increasing inert content of coal a decreasing concentration of burnable component belongs, thus heat release per mass unit decreases but heat extraction by the furnace remains and the coal pulver – air mixture even needs excess heat.

If heat release decreases due to concentration drop to the extent where heat extraction by the furnace cannot be balanced any more, flame will extinguish. Experience shows that with increasing inert component of the coal, fire extinction temperature considerably increases.

The ratio of flame propagation velocity to coal pulver – air mixture outlet velocity is the next important parameter of flame stability. With leaving velocity lower than flame propagation velocity, flame extinction may occur, with higher one, the flame decays.

Flame propagation velocity is mainly depending on the ash content, its stability on the grinding degree.

The causes of burning pulsation can be understood from the conditions of stable burning and stable ignition.

Conditions of safe ignition are:

1. formation of a burnable mixture,
2. continuous energy supply.

The stability of ignition is ensured when the injected coal – air mixture ignites near to the burner and the ignition front has an approximately constant position, furthermore, appropriately high temperatures have been formed.

The theoretical air demand for a given coal quality can be determined from its composition. Furthermore, knowing the air excess factor in the operating equipment and the composition of the coal, heat and flue gas release can be calculated.

Simultaneous input of fuel from inert and lignite layers (open mining) leads to increase of total ash content and fluctuation of caloric value within a wide range.

The coal's caloric value varies with differing proportion of inert matter not participating in the burning process but consuming heat from the flame. With constant air quantity injected with the given mass flow of pulverized coal, the decreasing burning component proportion (increasing inert proportion) raises excess air, thus decreasing temperature.

Laboratory tests of pulver coal burning showed that with reducing temperature at first the pulver coal flame began to pulsate, and further reduction led to extinction. Extinction temperature was found characteristic of the given coal quality.

According to the model, with significant coal caloric value changes due to the inert content variation in the fuel, air demand also changes. In the case of constant air quantity, the temperature of the furnace chamber would change [1,2,3].

2. Analysis of Characteristics Influencing Furnace Stability

The quality of lignite may considerably vary with mining technologies and geological conditions and differ from the boiler design values, essentially influencing the stability of burning by changing conditions.

From among the main input parameters of lignite fuelled steam boilers, the fluctuation and change of caloric value and composition (ash, moisture, sulphur) influence heat release fluctuation, thus also furnace pressure fluctuation and fuelling efficiency. Disadvantageous pressure fluctuations mean repeating stresses for the boiler structure, causing rapid fatigue of its material.

Because of the above, caloric value and composition variations of the feeding lignite have been investigated. For open cut lignite, great and extreme fluctuations and deviations have been observed in coal quality, and in the rate of caloric value change (*Figs. 1, 2*).

Diagrams show that percentage curves of caloric value and ash content are with good approximation mirror images of each other, that is, low caloric value belongs to a high ash content and vice versa.

High and extreme fluctuations and deviations can be observed in every case compared to coal quality and to the caloric value change rate reckoned with in boiler design.

Big fluctuations may lead to permanently changing service state for the boilers that cannot be balanced by the control system, thus, due to the disturbances, after a shorter or longer operating period, fatigue may occur.

In the case of constant moisture content, coal caloric value change originates primarily from inert fraction change.

Inert or ballast materials' grinding differs from that of lignite. Ballast materials are well grindable, while lignite containing wood and xylitol cracks to splints instead of becoming pulverized. In the grist incombustible

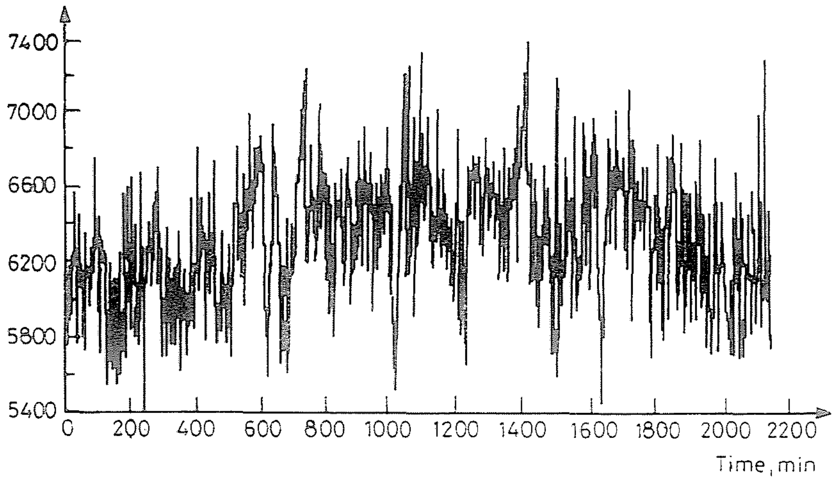

Fig. 1. Coal caloric value fluctuation (kJ/kg) [3]

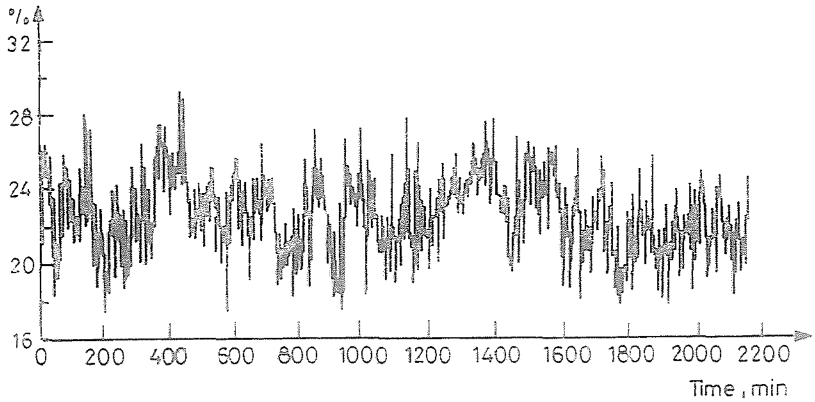

Fig. 2. Ash content fluctuation (%) [3]

grains are in multiple quantity measured to other combustible fractions. further deteriorating the conditions of burning.

The indirect influence of fraction distribution on the stability of fuelling explains the importance of dealing with grist fineness. In the given technology system, grist fineness (optimum grain size) can only be adjusted with a movable air separator clack.

3. Control System's Effect on Combustion Stability

Detailed description of repeated mechanical and thermal stresses on boilers' structure is unnecessary here as our earlier experiment results obtained in power plants showed undoubtedly unfavourable changes in steam parameters and electrical output due to considerable decrease or increase of lignite caloric value.

Leaving out of consideration the small damping effect of coal quality fluctuation depending on the number of operating bunkers and momentary bunker floors, the effect of quality and caloric value fluctuation of the coal combusted in the boilers of the power plant appears along the whole combustion system.

In addition to harms to other furnace installation units (superheater, preheater, etc.), coal quality fluctuation considerably increases repeating medium and short cycle stresses of the structural units.

The influence of coal quality on furnace pressure fluctuation has been examined.

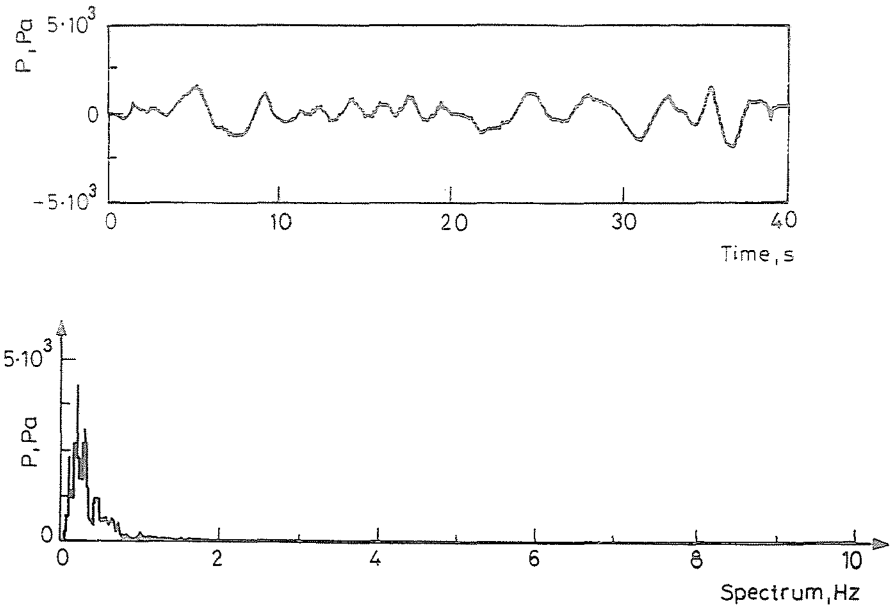

Fig. 3. Time function and amplitude-frequency spectrum of pressure fluctuation in the furnace [3]

Pressure fluctuations induced in the furnace have a stochastic character. This is well represented by time functions and amplitude – frequency spectra (*Fig. 3*). Dominant frequency range of the pressure oscillations:

$$\Delta f = 0.1 \div 0.4 \text{ Hz} .$$

In the case of greater coal quality fluctuations, deterministic components increasingly dominated, especially at higher loads (*Fig. 4*).

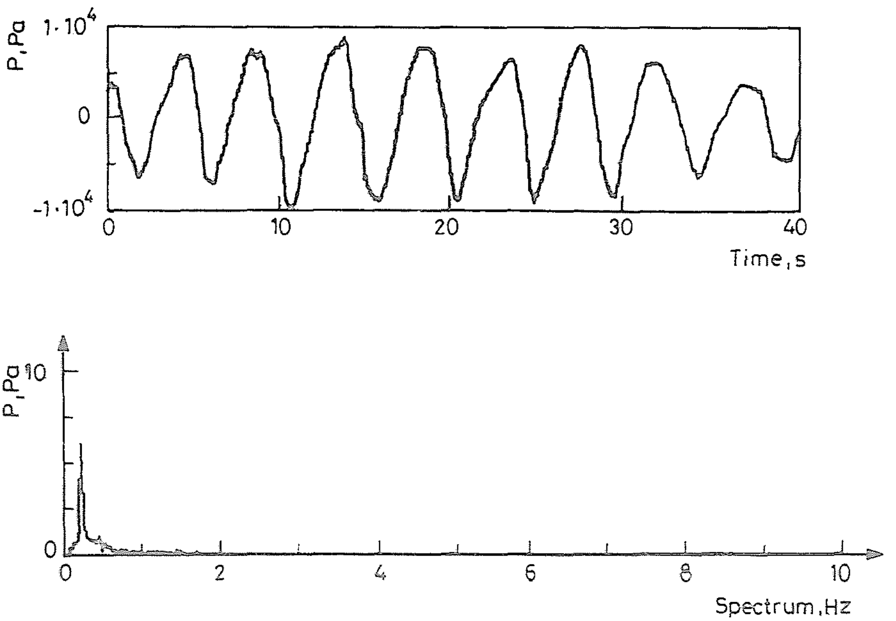

Fig. 4. Time function and amplitude-frequency spectrum of pressure fluctuation in the furnace in the case of the reacting of the air supplying system [3]

In these service states the air control system reaches the stability limit or exceeds it and starts to oscillate. This explains the forming of quasi sinusoidal pressure oscillations in two operating states. The phenomenon occurs with great deviations and changing rate when the coal has significantly lower caloric value. If the pure combustible, bituminous wood, xyloid lignite reduces output steam temperature due to coarser grist compared to the ballast, then the control loop corrects, giving in higher mass flow with more air. An increasing amount of air comes to the decreasing heat release, amplifying pressure oscillation, thus disturbing equilibrium of the control loop. This can be avoided by reducing the proportional factor of changing the time constants.

4. Summary

Analyses were primarily focused on the effect of great fluctuations of coal quality and composition, as the main causes of pulsation, on burning instabilities in the combustion chamber.

The effect of coal caloric value reduction due to ash content increase on boiler operation can be seen from the increase of repeating medium and short cycle stresses.

Long-period coal quality worsening results in changes of boiler parameters exceeding the parameter fluctuation range of normal operation. If the output goes under the given limit, operation can be maintained by oil burners. Even if good quality coal is fed in rapidly, restoration of the earlier operation state also requires a longer period. Load change rate considerably exceeding the specified value and the increased parameter change rate due to it cause repeating medium cycle stresses for the boiler construction.

Measurements results verify that also small deviation of coal caloric value leads to considerably higher furnace pressure and temperature fluctuation.

From the aspect of fuelling technology, the appearance of periodical and more frequent high amplitude pressure fluctuations in the furnace signals loss of stability. From the aspect of operation, low frequency repeating periodical pressure and temperature fluctuations characterizing burning pulsation cause short cycle repeating stress for the boiler's structural units.

Fraction distribution has a considerable effect on the stability of burning. Ballast material reacts to grinding otherwise than lignite. Ballast will be overground, while the most valuable xylitol lignite becomes a coarse aggregation of granules, thus in the grist the proportion of ballast will be multiple of the proportion of the flammable components, further deteriorating the conditions of burning. Therefore, to ensure better fuelling, it is expedient to aim at the obtaining of the most valuable, coarser fraction distribution by using the technological possibilities of the given system.

The change of ballast material share in the fuel is a cause of considerable caloric value fluctuation with air demand also considerably fluctuating. The control loop will follow this fluctuation and correct the system with a certain delay. In the time of the correction, burning would already require an air amount belonging to another, in an unfavourable case worse fuel composition. Thus, pressure fluctuation in the furnace will be further amplified due to reaction on the air supplying system, and a self-exciting, unstable state may form resulting in large amplitude quasi sinusoidal pressure oscillations.

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