In order to meet frequency restrictions (50Hz, –0%, +4%) the idle run frequency equal to 51Hz has been chosen. Therefore deviation is ±1Hz. It can be seen that these conditions are met for wide range of electrical load and for such heavy disturbance as switching on 15kW of load. Long term and environmental tests are still to be done. We also plan to install thermal sensors for monitoring and self-diagnostics of the entire generator set.

4. Conclusions

The designed digital controller meets the requirements. Down-speeding from 3000rpm to 1500rpm results in higher durability and longer MTBF what has direct economical advantage. At the same time new possibilities of such controller arise like monitoring and self-diagnostics of the entire generator set. The controller has a chance to become a commercial product.

T. Golec[1], W. Wójcik[2], A. Kotyra[2], Z. Hotra[3]
[1]Thermal Process Dept., Institute of Power Engineering, Warsaw, Poland,
[2]Lublin University of Technology, Lublin, Poland,
[3]Lviv Polytechnic National University, Lviv, Ukraine

ASSESSMENT OF PULVERISED COAL AND SECONDARY FUEL MIXTURES COMBUSTION USING IMAGE PROCESSING

Air stepping, which takes place in pulverised-coal burners, makes combustion less stable. Such a situation may lead to shifting the flame, unstable combustion and eventually to extinguishing of the flame. Adding secondary fuels such as waste fuels and biomass spoils combustion stability and leads to increasing corrosion and boiler slagging. Spatial distribution of radiation intensity (flame shape) and its changes in time domain deliver the quickest and straight information of combustion process itself. We have utilised flame images taken by CCD camera in a several combustion tests to find flame shape features, which would point a state of unstable combustion.

1. Introduction

The new regulations concerning the maximum allowable emission of harmful substances such as nitric and sulphuric oxides (known as NOx and SOx respectively) have given rise to disseminate new combustion techniques. Polish power industry is based mainly on hard coal, thus so called low-emission combustion of pulverised coal is of great importance. Low-emission combustion consists in the proper manipulation of fuel and air so as to create rich and poor flame zones which differs in oxygen content. It enables both synthesis narrowing and reduction of the formed nitric oxides. [1]

Air stepping, which takes place in pulverised coal burners, makes combustion less stable. Worse stability is caused by the shortage of oxygen in the area placed close the burner nozzle. Such a situation may lead to shifting the flame, unstable combustion and eventually to extinguishing of the flame.

One of the main objectives of this work was comparison of the ignition and combustion behaviour of different secondary fuel/coal mixtures in turbulent flame using CCD camera.

Combustion tests were performed in 0.5 MW_{th} laboratory stand at the Institute of Power Engineering. It enables scale down (10:1) combustion conditions of a full-scale swirl burner fired with pulverised fuel.

The stand was fired with milled secondary fuel – coal mixture samples. The samples were prepared and supplied by Stuttgart University (IVD) and International Flame Research foundation (IFRF BV) as well as taken from pulverised coal ducts during co-combustion tests at Łagisza power plant in Poland. Several fuel samples were investigated, namely reference hard and brown coals and these coals mixed with wood and paper sludge.

2. The laboratory stand

The test stand of horizontal layout consists of cylindrical combustion chamber, 0.7 m in diameter and 2.5 m long and is presented in Fig. 1. A model of low-NO_x swirl burner about 0.1 m in diameter is mounted at the front wall. The stand is equipped with all necessary supply systems: primary and secondary air, coal, and oil. The oil heater heats primary and secondary airs. Additionally, electrical heaters tune final temperatures of the airs. The oil and gas systems also provide oil and gas for the guns, which can be located in the very centre of the coal burner. Pulverised coal for combustion is prepared in advance and dumped into the coal feeder bunker. A two-worm dust conveyor supplies coal dust into primary air duct. All stand parameters (temperatures, airflows and velocities, coal and airflow, etc.) and results of gas analysis are continuously recorded by computerised system for data acquisition. Figure 1 shows details of the stand and positioning of the optical probe.

The combustion chamber has two lateral inspection openings on each side, which enables image acquisition. A standard CCD monochrome camera was used. To avoid disadvantageous influence of high temperature on camera work, it was equipped with a 0.5m boroscope that transmits the flame image. Camera mounting is depicted on Fig. 1 with an arrow. The camera was capable to acquire 25 frames per second, which was further stored on videotape.

Fig. 1. Combustion chamber at Institute of Power Engineering. CCD camera mounting is depicted with an arrow

3. Experiment

Experiments consisted in comparing flame stability of the fuel being examined (with wastes) and the reference pure fuel that came from the same source. First, the combustion chamber was warmed up by oil. When the temperature had been high enough, the feeding device was started and the air-coal mixture was delivered to the burner, simultaneously with the oil. After reaching the proper temperature level, the oil was switched off. Then the coal was the only burned fuel. Operational conditions of the stand, i.e. coal flow and quality, outlet velocities of the primary and secondary air were changed many times, so as to obtain both stable and unstable flames.

We have investigated the following fuels: [2]

a) reference hard coal from Poland,

b) mixture of paper sludge (10%) and Polish hard coal (90%)

c) reference brown coal from Germany,

d) mixture of paper sludge (10%) and 90% German brown coal (90%)

e) reference hard coal from Holland

f) mixture of waste wood (10%) and Dutch waste wood (90%)

During combustion trials, two types of flame have been observed:

– a flame that was attached to the burner nozzle, that corresponded to stable combustion,

– a flame that was detached with ignition point distant from the burner nozzle, that corresponded to unstable combustion.

Primary, secondary and tertiary air parameters such as temperature and velocity were kept constant during all runs at the same level as in full-scale burner. The only parameter, which was changed during experiments, is burners load regulated by the rotational speed of coal feeder. During stability tests burner load (speed of coal feeder) was changed until flame had lost its stability and finally disappeared. For each secondary fuel, standard test procedure consisted of two runs that differed, in order of combustion of mixture and reference coal.

Images, which were stored on videotape, were further digitised with a frame grabber. Frames consisted of gray levels (256) of individual pixels which corresponded to the radiation intensity distribution. Due to flame flickering 50 successive frames were averaged. Since the distance from the boroscope to the flame is much smaller than the flame length, it is possible to monitor only part of the flame near burner nozzle. The mounting of the boroscope is shown on Fig. 2.

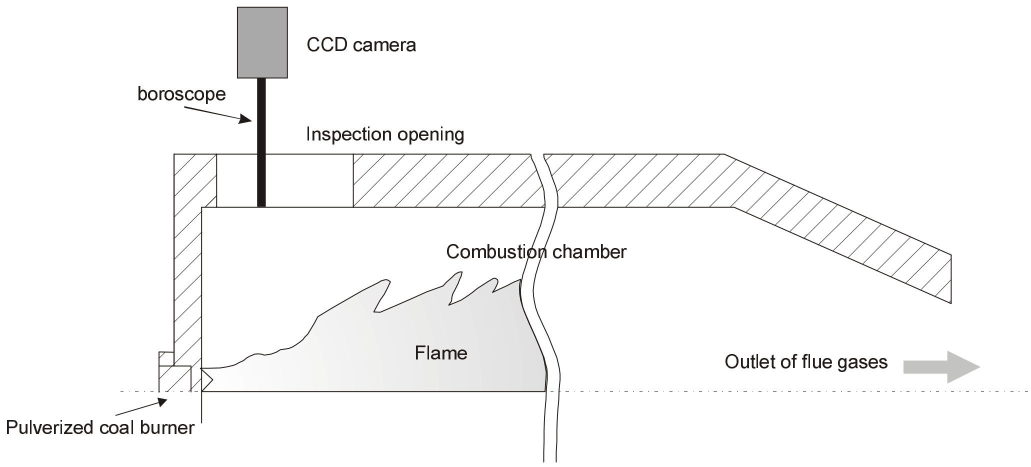

Fig. 2. CCD camera mounting

The flame shape is closely related to the spatial distribution of the chemical species produced during the combustion process. Changes in combustion inputs modify the geometry of the flame. We have calculated two parameters of the flame shape: length and brightness. It should be noticed, these parameters were measured within area bounded by aperture of the boroscope. However, narrowed flame length indicates ignition point. Because the boundary of flame is not clearly determined, defining the length of the flame is not simple. The region corresponded to flame has very high image intensity, often it is saturated, while the background has considerably lower image intensity. Thus, it is possible to extract flame border to be based only on pixel brightness [3]. It was assumed that flame boundary corresponds to decreasing of pixel brightness to 10% of the maximum value (saturation). The flame length L is defined as follows:

$$L = \max_i \{K_i\},$$

where K_i deontes i-th row of the image.

Flame brightness is defined as the sum of brightness of the each pixel contained within flame boundary. Some of flame images taken during combuation tests are shown on Fig.3.

Fig. 3. Flame images acquired during combustion test – unstable combustion

We have investigated influence of combustion stand parameters on flame length and brightness. The most important parameters of laboratory stand are feeder rotational speed (amount of fuel per unit of time) – V_{frs}, and outlet temperature of the flue gases – T_{fg}. These parameters can be expressed synthetically by a new parameter R:

$$R = V_{frs} \cdot T_{fg} .$$

Any other parameters of the combustion stand were kept constant. Selected results are shown on Fig. 4

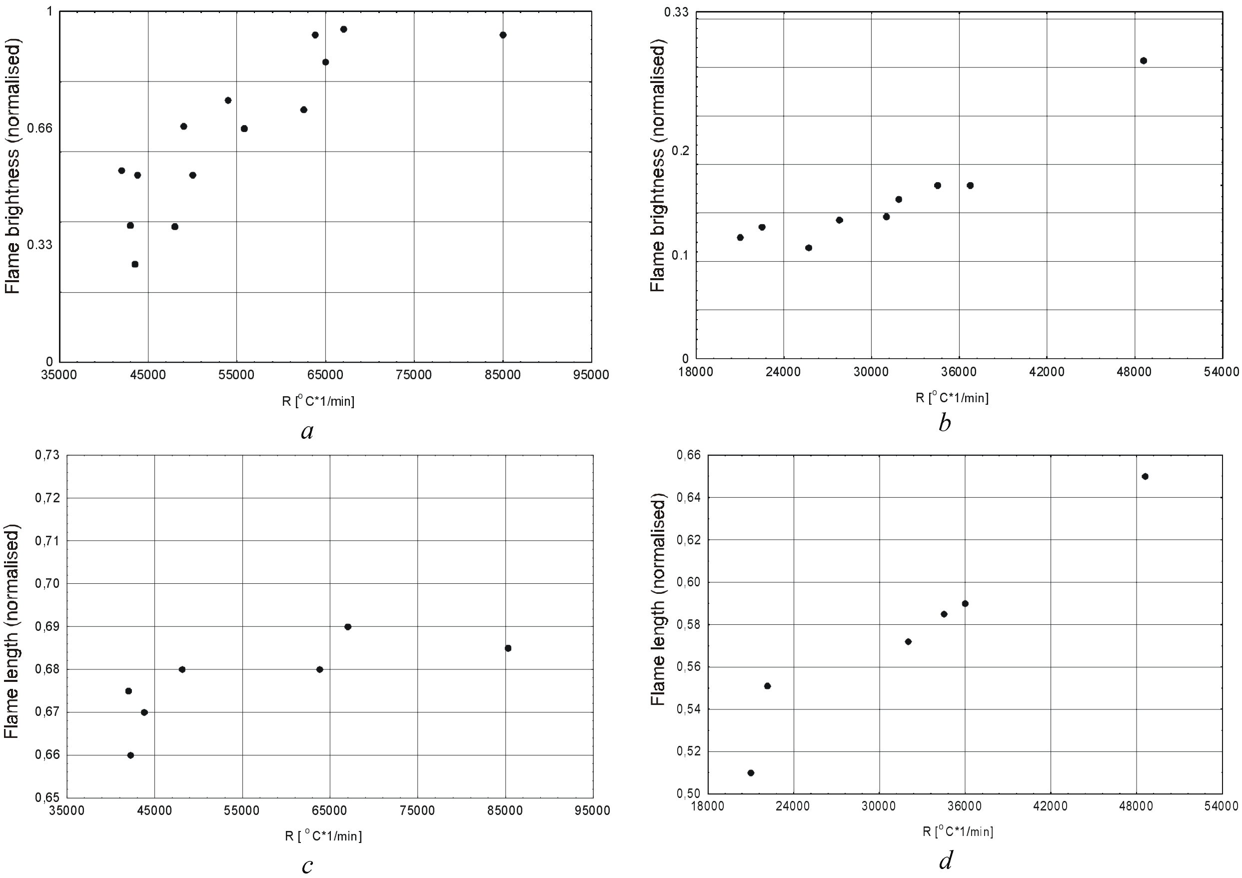

Fig. 4. Normalised flame brightness for: a) reference hard coal, b) mixture of paper sludge (10%) and hard coal (90%). Normalised flame length for: c) reference hard coal, d) mixture of paper sludge (10%) and hard coal (90%)

4. Conclusions

As a general, stable combustion occurred in the case of hard coal and mixture with paper sludge. The flame was very bright and close attached do the burner, especially, when only hard coal was burned. Adding secondary fuel makes flame less bright. Flame length remains almost unchanged for combustion of hard coal, when for the case of the mixture, it tends to be shorter and escapes from burner nozzle.

The flame parameters taken into consideration could be helpful in combustion assessment of coal mixtures. It shows great potential of using image processing in pulverised coal combustion analysis, even through simply defined flame image parameters.

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W. Kalita[1], M. Jakubowska[2], J. Kalenik[3]
[1]Dept. of Electronic and Comunication Systems, Rzeszów University of Technology, Rzeszów, Poland,
[2]Institute of Electronic Materials, Warszawa, Poland,
[3]Institute of Microelectronics and Optoelectronics, Warsaw University of Technology, Warszawa, Poland

MOLYBDENUM RESISTORS – ECONOMIC ALTERNATIVE FOR THICK FILM TECHNOLOGY

Parameters of improved, recently developed thick film resistors based on molybdenum oxide pastes were investigated. Resistors of aspect ratio 1:2 were printed on various substrates. AgPd, AgPt and Ag pastes were used for contacts preparation. Spread of fired resistance, TCR, long term stability, influence of contacts material, influence of thekind of substrate, under and overglaze were tested. Results were very prospective. Spread of as fired resistance is lowerthen 10 % in any case. TCR is dependent on sheet resistivity and is lower then 200ppm/K for all compositions.

1. Introduction

Still growing price of electronic pastes containing noble metals is one of main obstacles for application of thick film technology in microelectronics. The most evident example is palladium which is a component of palladium-silver pastes applied in microcircuits for conductive paths fabrication as well as for fabrication of ruthenium resistors contacts. Ruthenium price has grown very much for last ten years, nowadays it has exceeded the prise of gold and now is approaching the price of platinum. The main reason of such dynamic price growth is high demand for ruthenium on the world market (automobile catalyzers). So it seems necessary to carry out the investigation for lookig for new thick film materials containing no noble metals. Moreover, because of continuous growth of demand for electronic components, carrying such a research becomes a necessity justifieded by social aspects.

Resistive pastes series that is the object of this work was elaborated in 1998 [1, 2] and improved in 2002 [3, 4]. Resistors of this series do not need palladium – silver contacts. Silver or even nickel contacts may be applied succesfully. Ruthenium elimination and replacement it with non noble metals oxide glaze reduces cost of fabricated element containing resistive layers.

Traditional resistive pastes contain functional phase (conductive phase), glaze and organic vehicle. R-800 series molybdenum pastes do not contain separate conductive phase. Conductive phase creates as a result of chemical reaction of molybdenum trioxide and reduction agent – boron, both contained in the glaze. Molybdenum changes oxidation level as a result of this reaction.

$$MoO_3 + 2x/3B \rightarrow MoO_{3-x} + x/3B_2O_3.$$

Unstechiometric molybdenum dioxide that is a product of this reaction is responsible for electrical conduction of resistive layer.