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IGNITION OF PULVERISED COAL AND ALTERNATIVE FUELS IN OXYGEN-RICH ATMOSPHERE

M.Sc.Eng. Konrad Babul

Supervisor: Prof. Wiesław Rybak, PhD, Eng.

Abstract:

Reduction in carbon dioxide emissions is a key challenge for modern power engineering. Due to required reduction in carbon dioxide emissions, a new technology based on combustion of pulverised coal in oxygen-rich atmosphere – O_2/CO_2 (so-called Oxy-fuel) – is being developed. This technology provides a stream of flue gases with high CO_2 concentration as required by CCS installations. In comparison to conventional air combustion, change of oxidizing atmosphere in the combustion chamber may have significant impact on heat exchange as well as combustion, ignition and flame stability in the combustion chamber. Design and operating conditions applied for individual boiler installations will result from such a change. What is more, implementation of this new technology requires defining design guidelines , that will allow to obtain a stable ignition and flame propagation in the combustion chamber as well as minimization of fire and explosion hazards.

In the recent years there took place a significant development in research on oxygen-rich atmosphere combustion technology, but many issues connected with individual processes involving ignition and combustion of pulverised coal in O_2/CO_2 atmosphere as well as technical solutions still require clarification before this technology can progress from the stage of laboratory and pilot research to a full technological scale. Wide range of various types of test facilities and devices , no standardized measurement methodology and very large number of process parameters that affect likelihood of solid fuels to ignition provide no unequivocal answer to influence of O_2/CO_2 atmosphere process conditions on ignition and flame propagation.

The main aim of this study is to recognize ignition mechanism in oxygen-rich atmosphere as well as influence that solid fuel properties and concentration of oxygen may have on this mechanism. In order to explain about the influence of type of gaseous environment on ignition mechanism, the research included in this work has been made in reference to ignition in air. Detailed aims include analysis of physicochemical processes leading to ignition of a fuel particle and pulverised coal cloud in O_2/CO_2 mixture as well as attempts to assess the influence of a change in geometric profile of a pulverised coal flame on operating conditions of a burner.

In the thesis of the study there is postulated that change of air into oxygen-rich (O_2/CO_2) atmosphere affects ignition and flame stability of pulverised coal and pulverised alternative fuels.

As the basic fuels for the research there were chosen coals, that are used in Polish and foreign power plants. What is more, taking into consideration energy potential of a biomass and its huge potential in connection with possible implementation of Oxy-fuel technology, the research is also based on various types of biomasses. The research material was selected to present samples diversified in terms of their properties, yet representative for a particular fuel group. The research was performed with the use of advanced laboratory devices, including measuring instrumentation such as LECO TruSpec CHNS analyser system, IKA C2000 calorimeter, digital microscope, spectrometer and test facilities and research stations at which it was determined: ignition parameters for a single fuel particle, temperature and induction time for ignition of a pulverised cloud of solid fuels, thermogravimetric analysis (TGA) with differential scanning calorimetry (DSC). Research on ignition and flame structure has been also carried out with the use of large laboratory-scale installation with 400 kW_{th} swirl burner.

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Ignition condition analysis for coal and biomass fuel particles was carried out for the following oxygen concentration levels: 15% O_2/85% CO_2 to 40% O_2/60% CO_2 and in normal air conditions. Under the same oxidizing atmosphere conditions single particles of lignites were characterized by the lowest ignition temperature. Then temperature, then there were agricultural waste biomasses, wood biomasses, bituminous coals and anthracite. Results obtained for various types of coals are fully compliant with results presented in literature which shows that increasing coal rank results in increase in the value of minimum temperature of ignition. With regard to research conditions both, wood biomasses and agricultural waste biomasses are characterized by lower rank of coal in comparison to lignite, however they have much higher minimum temperatures of ignition. This leads to a conclusion that in case of a single biomass particle both, high content of volatile matter and low rank of coal are not the determinants which may clearly indicate on more advantageous conditions for ignition of this type of fuel. This results from a large number of parameters and complexity of reaction systems which may lead to fuel ignition.

The research conducted on ignition of a single solid fuel particle showed that change of N_2 into CO_2 in oxidizing atmosphere led to an increase in minimum temperature of ignition for all types of fuels. It confirmed the proposition of this thesis stating that change of air into oxygen-rich (O_2/CO_2) atmosphere affects ignition and flame stability of pulverised coal and pulverised alternative fuels. The reason for such change in temperatures of ignition lies with lower values of diffusion coefficient and higher thermal capacity of O_2/CO_2 atmosphere in comparison to O_2/N_2 atmosphere. Change of oxidizing atmosphere from O_2/N_2 to O_2/CO_2 led to increase of induction time for ignition of a pulverised coal cloud with the same temperature of the reaction chamber. It has been also noticed that the type of fuel has greater impact on temperature of ignition of a single particle and a pulverised coal cloud than a change in oxidizing atmosphere from N_2 to CO_2. An algorithm of filtration and image processing has been developed to enable monitoring changes in the profile of a flame depending on a change in parameters of design and operation of a swirl burner. On the basis of research conducted with the use of large laboratory-scale installation with 400 kW_{th} swirl burner it has been proven that the same ignition conditions and flame stability in both, air and O_2/CO_2 atmosphere cannot be obtained for a swirl burner without implementation of design changes in the burner system.

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