Wrocław University of Technology, Faculty of Mechanical and Power Engineering

ABSTRACT OF DOCTORAL THESIS

„Selected aspects of pulverized coal oxyfuel combustion”

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In dissertation have been analyzed selected, significant processes (aspects) influencing overall combustion behaviour and its effectiveness during oxyfuel combustion (also called oxy, oxycoal, combustion in oxygen) of pulverized lignite coal. Oxyfuel technology is an innovative concept of power plants units allowing to achieve – due to substitution of oxidizer, which in conventional combustion is air, by oxygen – high CO_2 concentrations in flue gases. This implies that formed in combustion of carbonaceous fuels carbon dioxide (greenhouse gas considered as main pollutant from combustion process) may be easily separated from other flue gases components, this is less complicated than capturing CO_2 in traditional coal fired power units, in the aforementioned case its concentration in flue gas is low (approx. 15%) and capture process is expensive. Due to oxyfuel combustion almost all emitted from combustion carbon dioxide may be captured (zero emission technology) and used in technologies of Enhanced Oil Recovery, Underground Gasification or compressed and stored (CO_2 sequestration – Carbon Capture and Storage). Oxyfuel technology requires conducting fundamental research so as to reveal its mechanisms and mutual relationship between combustion parameters.

The scope of research and conducted analyses covered processes and stages important for pulverized lignite combustion process as a whole and influencing its effectiveness in combustion chambers. This selected stages and parameters were: ignition (temperature, delay time, intensity), devolatilization (pyrolysis) and rate of combustion – reactivity, which is influenced also by char properties, composition of gas atmosphere, fuel and process properties. Conducted research took into account type of coal, particles size, water content and composition of gas atmosphere (air and O_2/CO_2 mixture of different vol. ratios in case of ignition and combustion, N_2 and CO_2 in case of pyrolysis (devolatilization)). Main fuel of

interest was lignite from Polish opencast and power plant Turów (K8), as potentially, important for Poland, energy resource, requiring however improvements in its combustion technology regarding lowering of pollutant emissions to environment. Special attention was paid to role of water (moisture) in coal on investigated parameters, because one of lignite characteristics is its high water content (up to 70%). Combustion of such fuel enhances energy requirements for preliminary water evaporation, which lowers the combustion effectiveness. In parallel formed water vapour influences mechanism of combustion e.g. by changing heat transport to coal particles. One of the aim of research was to determine optimal, allowed water content in coal guaranteeing stable and efficient combusiton.

Scope of research on preliminary step was modernization of ignition test facility (inlet, outlet, interior) and then covered detailed research and analyses of ignition process taking into account determination of minimal (critical) ignition temperatures, ignition delay times and ignition intesities.

By means of thermogravimetric analysis it was analyzed the influence of different O_2/CO_2 atmoshperes, various moisture content, particles size on combustion parameters, e.g. characteristic points – ITR, PT, BT (ignition point, maximum combustion rate point, burnout point). Rates of combustion were also determined.

Sequentially, in drop tube reactor, experiments of flash pyrolysis (devolatilization), in CO_2 and N_2, atmospheres were carried out for lignite of various moisture content. Subject of analysis was influence of moisture content and gas atmoshpere on total fuel mass loss and mass losses of C, H, N fuel elements i.e. amounts of volatiles released, volatiles composition and char reactivity.

Conducted research covered also numerical modeling of radiation heat transfer in combustion chamber of drop tube reactor – in OXY20, OXY30 and air atmoshperes for lignite and hard coal of various moisture content using different radiation models. This aspect was analyzed because in oxyfuel combustion dramatically changes the role and contribution of radiation in boiler's combustion chamber. Calculations with numerical model had practical significance and could be partially validated. Own research on combustion process modeling and radiation heat transfer based on Ansys Fluent CFD (Computational Fluid Dynamics) software. The aim of analyses were influence of gas atmosphere (OXY20, OXY30, air), water content in coal (7 i 15%) and radiation model on combustion behaviour. Ansys Fluent allows to depict flow conditions accompanied with combustion. By default present in this program and widely used for air combustion Weighted Sum of Gray Gases (WSGGM) radiation model was modified because its assumptions do not qualify for its application in oxyfuel combustion, hence necessity of modifications.

The main thesis states that it is possible to apply pulverized lignite with specified predrying level and with particles distribution below 0,2 mm, for oxyfuel combustion process, in range of oxygen concentration between 25-30 %, allowing achievement of stable ignition and high combustion efficiency accompanied with limited greenhouse gas emission. Furthermore, application of $O_2/CO_2/H_2O$ instead of air atmosphere may result in beneficial impact on coal combustion mechanism and radiation heat transfer and also on char structure favouring char reactivity increase.

It was demonstrated that there is significant influence of water content and particles size of Turów lignite on fundamental combustion parameters as: characteristic ignition temperatures, rate of combustion, burnout time and volatiles composition in flash pyrolysis. Determination of optimal water content in coal and optimal particle size distribution is possible for selected oxyfuel atmosphere. Results of computer modeling of radiation heat transfer depicted parameters as transmissivity, emissivity and absorptivity of flue gases.

Obtained results may serve as better understanding of phenomena accompanying oxyfuel combustion processes, which gives oportunity for better controlling of this process and possibility of effective coal usage (especially lignite with various moisture content) in this process. Research data give background essential for boiler design (with special regard to burners) and information about mathematical modeling of radiation heat transfer.