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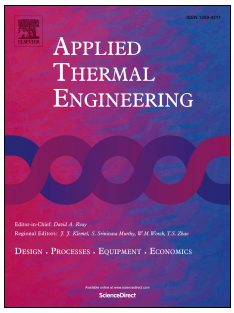

Reprint of "Experimental studies of single particle combustion in air and different oxy-fuel atmospheres"

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Experimental studies of single particle combustion in air and different oxy-fuel atmospheres

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HIGHLIGHTS

- Particle temperature during combustion was lower in O_2/CO_2 than in O_2/N_2 mixture.
- Greater temperature differences were observed for coal then for char particles.
- CO_2 hindered volatiles release and inhibited particle swelling during combustion.
- Presence of H_2O in oxy-fuel atmosphere increased temperature of combusted particle.

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ABSTRACT

In this work, direct observation of char and coal single particle combustion in different gases mixtures has been performed. Investigation focused on the influence of atmosphere composition on combustion process and especially on the comparison between combustion in air-like versus oxy-fuel dry and oxy-fuel wet conditions. For these tests, particles from Pittsburgh coal and South African Coal were prepared manually to cubical shape (approximately 2 mm and 4 mg). To investigate fuel type influence on oxy-fuel combustion, some tests were also conducted for Polish lignite coal from Turów mine. Experiments were carried out in a laboratory setup consisted of an electrically heated horizontal tube operated at 1223 K with observation windows for high speed video recording (1000 frames per second). During the experiments, particle internal temperature was measured to obtain comprehensive temperature–time history profile. Results revealed that particles burned at higher temperatures in high water vapour content mixtures than in dry O_2/CO_2 mixture. This behaviour was attributed to lower molar specific heat of water than of CO_2 and four times higher reaction rate for char–H_2O gasification reaction than char–CO_2 reaction. Also visible dynamic of combustion process recorded with the high speed camera differs for experiments carried with water vapour addition.

1. Introduction

Oxy-fuel combustion is a technology introduced with aim to help reduce CO_2 emission, which is especially urgent in recent times when demand for coal is still growing. In Poland, where more than 90% of electricity is generated from coal, the oxy-fuel technology with possible option of boilers' retrofitting, seems to be an especially attractive variant for CO_2 mitigation. However, oxy-fuel technology is only at pilot-scale and the knowledge of combustion mechanisms in changed atmosphere can be still perceived as insufficient.

Exhaust gas from oxy-fuel combustion contains mostly CO_2 an H_2O. Part of produced flue gas must be recycled to maintain proper heat exchange and safe operation within the boiler. Whether the recycled stream is dried or contains a significant amount of water is the matter of later optimization of combustion process as well as technical and economic analysis. But lately an agree is emerging, that at least some amount of water in recycled flue gases is inevitable [1,2]. So far a lot of effort was undertaken to investigate the difference between air and dry oxy-fuel combustion [2,3]. But it should be remembered, that H_2O as well as CO_2 can participate in char gasification reactions and from that point of view, possible interaction of H_2O in oxy-fuel combustion process should be better understood.

Char gasification reactions can significantly compete with combustion reactions but only under specific conditions. Those are high temperature and/or low oxygen concentration in gas mixture. In comparison to O_2–char reaction, gasification either with CO_2 or

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