Dynamika procesu zgazowania i spalania otrzymanego gazu (Dynamics of gasification process and combustion of produced gas)

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Abstract

The numerical modelling and simulations of flow dynamics of multispecies reactive gas mixture in free space and in a porous medium are presented in this doctoral thesis. The thesis is focused on two important types of such processes:

- thermal conversion of porous material into gases. These processes are biomass pyrolysis and gasification.
- flows and complex chemical reactions of gaseous mixture. These processes are non-premixed combustion.

The mathematical model of biomass gasification is introduced and implemented into two Computational Fluid Dynamics codes: the commercial code ANSYS Fluent (see Kwiatkowski *et al.* 2013*b*,*c*) and the open-source code OpenFOAM (see Kwiatkowski *et al.* (2013*e*)). The implementations, which extend standard functionalities of the codes, were validated against experimental thermogravimetry analysis (TGA) (Kwiatkowski *et al.*, 2013*b*,*e*).

A macro-TGA experiment on pyrolysis and gasification of a thick wood particle is presented together with the corresponding numerical simulations. The results show that the effect of fragmentation appeared to be of crucial importance for gasification modelling (Kwiatkowski *et al.*, 2013*c*).

The composition and properties of the syngas produced during biomass gasification in a fixed bed gasifier were determined in the industrial scale experiments for two feedsctoks: turkey feathers (Dudyński *et al.*, 2012) and wood (Kwiatkowski & van Dyk, 2013)

The non-premixed combustion of these gases was investigated in the mixture fraction space. The temperatures of fuel and oxidiser are in the range accessible in industrial gasifiers, which naturally produce hot fuels. It

was found that with sufficiently hot fuel, MILD combustion (Cavaliere & de Joannon, 2004) can be achieved. Additional pre-heating of the oxidiser, moderate Exhaust Gas Recirculation (EGR) and increased scalar dissipation rate all promote MILD combustion, but fuel temperature remains the crucial parameter (Kwiatkowski *et al.*, 2013*d*).

The numerical simulations of the combustion process in the industrial chamber designed for burning low-calorific syngas from gasification of waste biomass proved that the temperature distribution within the chamber is relatively uniform (Kwiatkowski *et al.*, 2012). The numerical simulations also confirmed the existence of the characteristic frequency of the processes observed in high-speed camera recordings of the real industrial burning process (Kwiatkowski *et al.*, 2013*a*) .

The analysis of the NO formation and emission shows a difference between wood-derived syngas combustion, where thermal path is prominent, and combustion of the feathers-derived fuel. In the latter case thermal, prompt and N_2O paths of nitric oxides formation are marginal and the dominant source of NO is fuel-bound nitrogen (Kwiatkowski *et al.*, 2013*a*).

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