STUDY OF HYDROGEN-OXYGEN FLAMES FOR MELTING FURNACE

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ABSTRACT

The glass and aluminum industries are equally responsible for a total of 46 Mt CO_2 in Europe each year. Replacing fossil fuels with green hydrogen can substantially reduce CO_2 emissions and in addition can increase the energy efficiency and enable higher furnace throughput without negatively affecting the lifetime of a furnace. Furthermore, different H_2 concentration mixtures can be used without affecting product quality, thus offering flexibility between natural gas and electricity. Switching to a new fuel with drastically different combustion properties is however a strategy that needs to be de-risked with adequate understanding of the impacts on burner, furnace, and product quality. The present study focuses on the cases of oxy-fuel combustion of hydrogen and mixtures with methane, where the use of different radiation models is analyzed for prediction of radiative heat transfer in the furnace and the flame lengths above coaxial burner studied experimentally.

Weighted-Sum-Gray-Gases-Models (WSGGM) are widely used for modelling of gaseous radiative properties. However, a vast majority of these models are unsuitable for hydrogen combustion due to the fact that typical H_2O to CO_2 molar ratio for hydrogen combustion flue gases lays outside models' applicability range (for most models the limit is $H_2O/CO_2 < 2$ or 4).
Only a few models have been found that are valid for the entire range of molar ratios, and only one of them, [2], is valid for high temperatures typically found in H_2 combustion. The models proposed by Bordbar et al. [1,3] and Losacker et al. [2] have been implemented in ANSYS Fluent and compared in a simple 2D channel case (see Fig. 2). The predicted absorption coefficient is shown in Fig. 3, where the predictions of the original WSGGM, not suitable for H_2 combustion, are shown too. The original WSGGM makes no distinction between the pure H_2 and 80% H_2 / 20% CH_4 cases. The models of Bordbar et al. [1,3] and Losacker et al. [2] are in good agreement with each other for low temperature cases, but the results deviate for higher temperatures, most likely due to the upper temperature limit of 2400 K for the Bordbar model. The most appropriate model will be selected for the full-scale simulations for prediction of radiative heat transfer in the furnace and for validation towards the experimental results.

Flame radiation and flame length measurements of hydrogen and methane flames have been performed with a laboratory scale jet in co-flow burner. The flame length was measured using OH* chemiluminescence imaging, measuring the length of area where the main heat release occurred. The flame radiative heat flux was measured using a heat flux sensor. As shown in Figure 3 the general diffusion flame length behavior with a transition to turbulent length is still well

reproduced by the central fuel jet Reynolds number in coaxial configuration. Adding hydrogen to the fuel reduces flame length and sharpens the laminar-turbulent transition region as a result of higher temperature and stoichiometric mixture fraction.

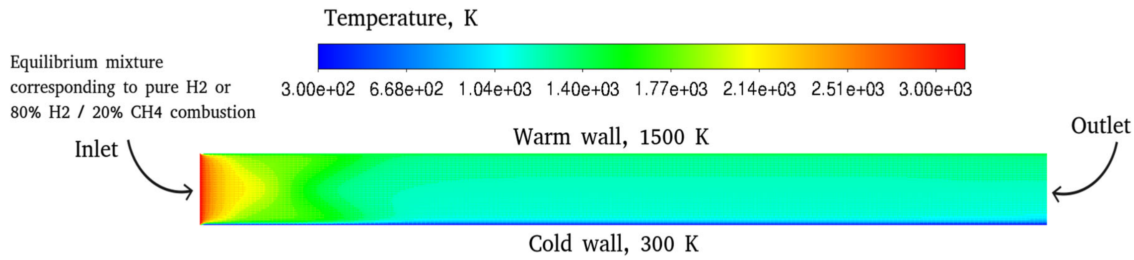

Figure 1. Simplified case for radiation models testing

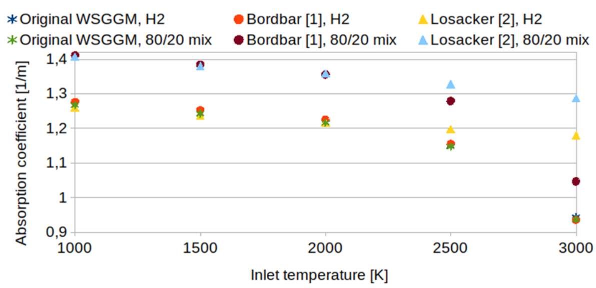

Figure 2. 1Comparison of the average absorption coefficient predicted by different WSGG models for a range of channel temperatures.

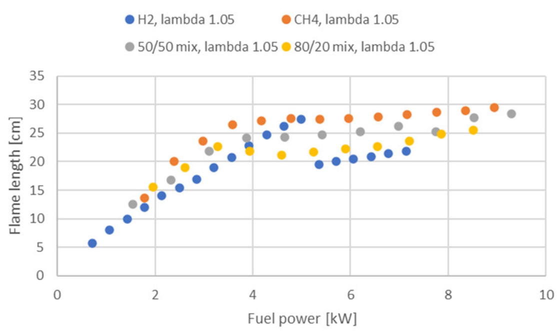

Figure 3. Flame lengths as function of fuel power for H2, CH4, 50/50 and 80/20 mix of H2/CH4 by volume in pure oxygen

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