Flue gases composition effects on reactive structure in HDDI Mild combustion

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ABSTRACT

Typical structure of diffusion flames in standard conditions can be significantly modified whether reactants are diluted and/or pre-heated. The increase of the fuel and/or oxidant flow dilution up to extreme conditions could lead to the formation of mixtures not ignitable so that the oxidation processes could be sustained just in case the pre-heating temperature of one of the two flows is high enough to promote the auto-ignition of the system. Such operative conditions are typical of Mild combustion processes. High initial enthalpy of the two flows and the low fuel and/or oxygen concentration can drastically modify the structure of the oxidative region as well as the physical and chemical kinetics respect to conventional diffusion flame. More specifically a combination of both heating and dilution of oxidant and/or fuel yields a not premixed combustion process named Hot Diluted Diffusion Ignition (HDDI). Four input conditions belong to such a configuration, whether fuel and/or oxidant are diluted and /or pre-heated. In this work the case of per-heated and diluted oxidant was considered, which is identified as HODO. In practical applications a common practice to ensure Mild combustion conditions is by recycling of hot exhausted gases since they provide for both the sensible enthalpy required for the fresh inlet mixture pre-heating and also the mixture dilution. Exhausted gases are mainly composed by steam and carbon dioxide. Therefore the analyses of the oxidative structure in condition typical of Mild combustion in systems diluted with nitrogen have been compared with results obtained in the case of H_2O and CO_2 dilution.

Numerical simulations have been carried on by means of commercial codes and kinetic mechanisms available in literature in order to analyze the change of the structures of the reactive region induced by pre-heating and dilution of the two flows. The model chosen for the schematization the physical process corresponds to an opposed jet configuration, where a hot diluted oxidant flow is fed toward a fuel flow at ambient temperature. The main parameters that easily give the meaning of what it can happens in an oxidative structure are the heat release and the temperature in the mixing layer. Therefore their profiles have been analyzed as a function of the mixture fraction Z, defined as

$$Z = \frac{\beta - \beta_{ox}}{\beta_{fuel} - \beta_{ox}} \qquad (1)$$

Under the hypothesis of equi-diffusivity, β is whatever conservative variable as well as β_f and β_{ox} its values in the fuel and oxidant flows respectively.

Results obtained for a pre-heating of oxidant flow at 1400K and an oxygen molar fraction varying from 0.21 to 0.03 have been reported in Fig.1. The shapes of heat release profiles have been considered as indicative of the structure of the oxidation region. In particular

profiles that show two positive peaks and a negative minimum value are indicative of high temperature combustion, where the composition of the mixture ensures high heat release and high system temperatures so that the oxidation process is self-sustaining. On the other hand, heat release profiles that present a single positive peak and no negative values are symptomatic of Mild Combustion. In such case oxidation reactions occur just by means of the high enthalpy content provided by the hot oxidant flow.

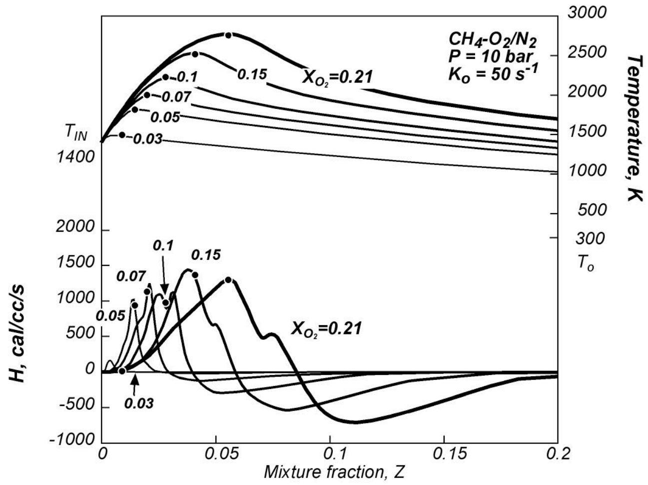

Fig.1 Temperature and H profile for CH4-O2/N2 system in HODO configuration

The presence of H_2O and/or CO_2 as diluent affects the process by changing both the oxidative structure and the occurrence of the different regimes, such as well shown in Fig. 2 where the profiles obtained by using H_2O (left) and CO_2 (right) as diluents have been reported. For instance the presence of H_2O widens the reactive region whereas CO_2 makes the Mild combustion regime occurs for higher oxygen molar fraction. These effects will be discussed in the final paper also on the basis of heat release profiles related to single species.

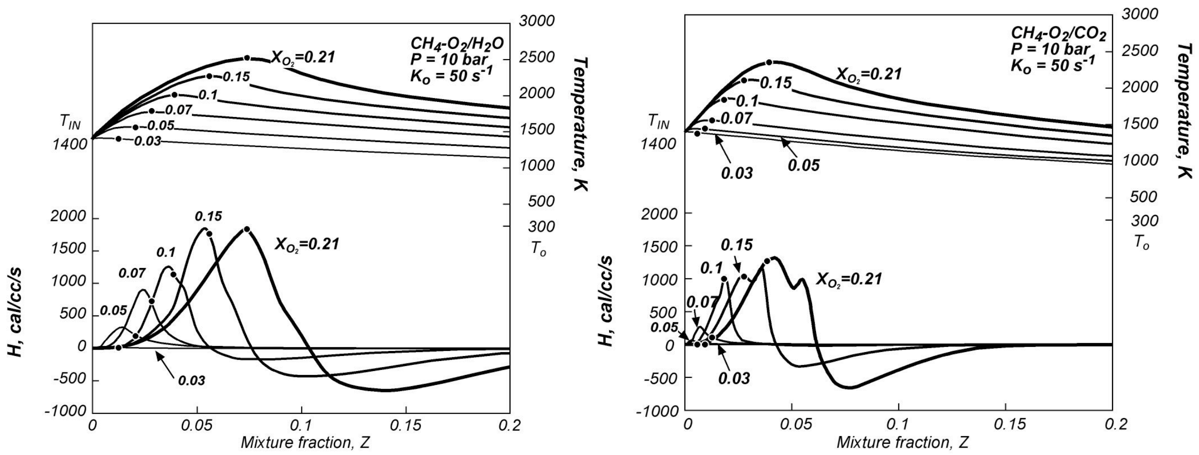

Fig. 2 Temperature and H by using (left) H_2O and (right) CO_2 as diluents.

Keywords: counter diffusion flame, dilution, flame structure, Mild combustion

Proposed Topic: New and Unconventional Combustion Processes and Technologies