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SIMULATION OF OXY-FUEL COMBUSTION PROCESSES IN INDUSTRIAL FURNACES

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For a variety of reasons, oxy-fuel combustion, i.e. the combustion of a fuel (most often natural gas) with pure oxygen instead of air, has become firmly established in thermal processing applications in recent years. Increased thermal efficiencies and heat transfer rates allow for a more productive operation of industrial furnaces, even despite the increased operational cost for the oxygen supply. In glass manufacturing, oxy-fuel combustion is considered to be one of the foremost solutions to operate glass melting furnaces at very high furnace temperatures without producing excessive amounts of pollutants such as nitrous oxides (NO_X).

The use of computational fluid dynamics to design and optimize industrial furnaces has become more and more widespread. Advances in computer hardware and the development of ever more sophisticated models and numerical solver algorithms allow for the numerical description of complex physical and chemical processes such as turbulent flows, combustion and heat transfer in realistic geometries; the analysis and optimization of industrial furnaces by means of numerical simulation has become routine. However, these models for turbulence, combustion and other phenomena are based on simplifying assumptions which may pose limits to their applicability in certain situations.

In a recent research project, Gas- und Wärme- Institut Essen e. V. (GWI) investigated the applicability of a number of combustion models for industrial oxy-fuel combustion processes. The results of OH chemoluminiscence imaging techniques and detailed 2D field measurements of characteristic chemical species distributions in a semi-industrial burner test rig were compared with CFD simulations based on a variety of commonly used combustion models. The comparisons showed that many popular combustion models found in commercial CFD codes fail to capture the characteristics of oxy-fuel combustion. Models using a mixture fraction approach in combination with a non-adiabatic data table generated by either an equilibrium or a flamelet model seemed to have problems with the impact of strong heat losses on the chemistry, while models based on the Eddy Dissipation Model suffered from the drastically simplified chemistry description found in the 2- and 4-step reaction mechanisms that were used. Only the more sophisticated Eddy Dissipation Concept in combination with a

rather more comprehensive reaction mechanism (17 species, 50 elementary reactions) was able to describe the oxy-fuel combustion process in good agreement with the measured data, although at prohibitive computational cost. A more detailed chemical reaction pathway analysis showed that the severely reduced 2- and 4-step reaction mechanisms were not applicable for oxy-fuel combustion. This result was corroborated by spectral radiometric measurements. It was found that at the moment, the capability to simulate oxy-fuel industrial furnaces is severely limited.

In the course of a follow-up research project, GWI, in cooperation with its partners, is currently working on improving reaction models for oxy-fuel combustion processes in industrial applications, combining sufficient accuracy with manageable numerical cost.