A HOLISTIC CFD DIGITAL TWIN MODEL OF A REAL CEMENT KILN

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ABSTRACT

To reduce carbon dioxide emissions in the cement production industry, detailed simulation tools are necessary to optimize the cement production process. This work aims to offer insight into the combustion and co-processing of alternative solid fuels, providing guidance towards increased thermal substitution rate of fossil fuels with alternative fuels of increased biomass content and reduced carbon footprint. A 3D CFD digital-twin model that simulates the processes within an industrial rotary cement kiln with emphasis on the interactions between the main burner, the material bed and the kiln walls has been developed. The CFD code provides the solution of the gas – fuel mixture under steady state RANS simulations. The boundary conditions are imposed from real kiln operating conditions. To minimize computational cost, the clinker bed is modelled by a quasi-1D approach, instead of being part of the CFD solution which would necessitate a two-phase fully coupled model1. This quasi-1D model discretizes the clinker bed into multiple bins and captures the thermochemical conversion of the raw material to the final products along the axial direction. It is coupled with the CFD code in a two-way manner. In the parallel execution of the CFD code, the computational domain is decomposed into several subdomains each assigned to a rank. Each rank computes and transfers heat flux from the gas phase towards the clinker bed through convection and radiation for the bins that are allocated to it. A global sum operation is subsequently executed to aggregate the outcomes from all parallel processes. Leveraging the cost-effectiveness of the quasi-1D model, each solver utilizes the cumulative heat flux along the axial distributions to determine the bed species and temperature profiles for the entire kiln length. Finally, the coating thickness of the adherent clinker material is determined by an iterative procedure2. The outer shell temperature of the kiln is predicted using a 1D radial model and is compared with measured values. Employing a trial-and-error methodology the coating thickness is adjusted until these temperatures agree to a specified tolerance. To circumvent the need for constant remeshing in this iterative process, the coating is modelled using a blocked-off approach.

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KEYWORDS: Digital twin, Cement, CFD, Simulation

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