COMBUSTION WEBINAR

Solving the Population Balance Equation for Non-Inertial Particles Dynamics using PDF and Machine Learning: Application to Sooting Flames

Speaker: Dr. Luc Vervisch , the National Institute of Applied Sciences (INSA) Rouen Normandy (France) and CNRS

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Biography: Dr. Luc Vervisch is professor at the National Institute of Applied Sciences (INSA) Rouen Normandy (France) and researcher at the CNRS laboratory CORIA. He completed his PhD at Laboratoire National d'Hydraulique (LNH) in Chatou (Paris) in 1991, followed by a Post-Doc at Center for Turbulence Research (CTR) Stanford. His research focusses on turbulent reacting flows, combustion and flames. Luc was awarded a senior research position at Institut Universitaire de France (IUF) in 2014 and the Prix Jaffé of the French Academy of Sciences in 2015. He is currently member of the scientific council of IFP Energies Nouvelles and DFG Mercator Fellow at Simulation of Reactive Thermo-Fluid Systems, TU Darmstadt (Germany).

Abstract: Numerical modeling of non-inertial particles dynamics is usually addressed by solving a population balance equation (PBE). In addition to space and time, a discretization is required also in the particle-size space, which can cover a large range of variation controlled by strongly nonlinear phenomena. A novel approach is presented in which a hybrid stochastic/fixed-sectional method solving the PBE is used to train a combination of an artificial neural network (ANN) with a convolution neural network (CNN) and recurrent long short-term memory artificial neural layers (LSTM), to predict the time evolution of the PBE. Instead of solving directly for the particle number density over sections, the hybrid stochastic/fixed-sectional method decomposes the problem into the total number density and the probability density function (PDF) of sizes, allowing for an accurate treatment of surface growth/loss with a Monte Carlo method for training the neural networks. The input of the ANN is composed of the thermochemical parameters controlling the physics of nucleation, surface growth/loss and agglomeration/coagulation of the particles, and of the increment in time. The input of the CNN is the shape of the particle size distribution (PSD) discretized in section of sizes. From these inputs, in a flow simulation the ANN-CNN returns the PSD shape for the subsequent time step or a source term for the Eulerian transport of the particle size densities. The method is first evaluated in a canonical laminar premixed sooting flame of the literature and for a given level of accuracy, a significant computing cost reduction is achieved. Then, this novel methodology is applied to predict the particulate emissions from an aircraft engine combustion chamber.

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