Toward a progress variable combustion model for nonhomogeneous gas mixtures for nuclear power plants safety applications

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Abstract

During a hypothetical severe accident in a nuclear power plant, the generation of various inflammable gases as well as their concentration and distribution may aggravate the accident. Numerical investigation of such scenarios plays a key role in the continuous improvement of safety strategies and guidelines of existing nuclear power plants. CFD simulations contribute significantly to this improvement; however, in certain cases, they entail high computational costs, particularly when analyzing big volumes. The analysis of combustion sequences with potential flame acceleration and/or DDT in the containment building of a nuclear power plant is one of these cases. Progress-variable combustion models emerge as a compromise solution to limit this cost when studying such demanding sequences. This work presents a progress variable solver currently under development as part of the OpenHyCOmb research project (SUBV-5/2023) supported by Consejo de Seguridad Nuclear (Spain). The solver, implemented in OpenFOAM, is capable of handling multiple flammable gases, such as H_2 and/or CO. It enables the simulation of combustion sequences involving nonhomogeneous mixtures of multiple gas components including H_2O, CO_2, O_2, N_2, CO and H_2. The numerical approach relies on the burning velocity approach and utilizes a database generated using the CANTERA tool to obtain local laminar burning velocities as functions of pressure, temperature and composition of the different species considered. This approach allows the model to simulate the combustion under nonuniform temperature or pressure conditions, as well as in locally O_2-starved environments. Once validated, the model will be used to study prototypical sequences within the containment building. The contribution presents and discusses preliminary results for validation of the solver against both numerical and experimental data, including flame acceleration scenarios, such as those reproduced at ENACCEF-2 facility at CNRS-ICARE (France) [1].

[1] Bentaib A et al. (2022), Etson-samhyco-net benchmark on simulations of upward flame propagation experiment in representative hydrogen-air-steam mixtures of severe accidents containments atmosphere. 19th Int. Topical Meeting Nucl. Reactor Thermal Hydraulics (NURETH-19) pp. 1-11.