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Combustion Modeling and Simulation in Era of the Fourth Industrial Revolution

Abstract

Combustion modeling and simulation (M&S) has been one of the major themes of combustion research and development (R&D) efforts. For combustion M&S there are still many unresolved issues including turbulence-chemistry interaction of crucial importance in most industrial combustion facilities. Conditional averaging has been a powerful tool together the flamelet concept to resolve turbulence-chemistry coupling and to estimate nonlinear chemical reaction rates in the mean field. In this talk basic concepts of conditional averaging will be reviewed with some results in turbulent premixed and nonpremixed flames. The conditional moment closure method was recently extended in the form of Lagrangian formulation and Eulerian CMC with tabulated chemistry and heat loss to cope with complicated engineering problems at reduced computational cost. The conditional averaging approach also allowed new intuition on the relationships among mean orientation vector, mean curvature, flame surface density and turbulent burning velocity in turbulent premixed combustion.

Combustion M&S also has the role to bridge the gap between fundamental R&D and practical application in energy, material processing and transportation industries. A digital twin which serves for optimal design and maintenance as the central theme of the fourth industrial revolution may be constructed in the cyber space through combination of Computer Aided Engineering (CAE) simulation based on governing equations and models and big data obtained from many sensors through Internet of things (IOT). Most M&S for industrial applications has been performed by commercial softwares such as STAR-CCM or ANSYS-Fluent, while open

sources such as OpenFOAM suggests a new paradigm in M&S through the network of users and developers worldwide. For such efforts it is necessary to have proper understanding of the numerics coupled with multiphysical principles to handle complex phenomena in multiphase flows involving chemistry, sprays, particles, electromagnetics, etc. Some examples will be shown on OpenFOAM applied in industrial combustion facilities and how they can be extended to develop surrogate models as a digital twin for the facilities in the design stage or in current operation. The surrogate model, also called a model of models, may be developed from multiple fidelity results by the open source Dakota, with the lower fidelity data calibrated for better accuracy by higher fidelity data or actual measurements in the physical space.

Short CV

Prof. Huh got his MS and PhD degrees at MIT in 1983 and spent some years as a postdoc in University of Wisconsin, Madison and Imperial College of Science & Technology, London. He has been in charge of Combustion Laboratory at POSTECH (Pohang University of Science and Technology) since 1990 and served as the Head of the Mechanical Engineering Department and the Chairman of BK21 program during 2012-2014 at POSTECH, Korea. He served as the president of Korean Society of Combustion for the period, 2012-2013. For over 20 years his laboratory worked on the conditional averaging method, a modeling framework regarded as consistent and versatile as compared with the flamelet based models in turbulent combustion. He has had many research projects, recently using OpenFOAM, to perform multiphysics simulations of burners/furnaces, IC engines and material processing reactors involving gas, liquid and solid phase fuels with automotive, steel making and power plant engineering industries.