CONSISTENT CMC MODELING FOR LES OF A TURBULENT ACETONE SPRAY FLAME

S. Ukai, A. Kronenburg and O. Stein
kronenburg@itv.uni-stuttgart.de
Institut für Technische Verbrennung, Universität Stuttgart, 70174 Stuttgart, Germany

Liquid spray fuel combustion systems have been used for a wide range of applications. However, the numerical simulation of liquid spray combustion still remains a challenging task due to its multi-scale nature associated with turbulence, chemical reactions and particle interactions. The large eddy simulation (LES) method has been developed to reduce the computational load by modeling the unresolved small scale turbulence, and it has been validated in various types of flow. However, it is not simple to extend LES to turbulent combustion studies since the chemical reactions introduce new time and length scales that require extra modeling efforts. Therefore, various combustion models have been developed, and the conditional moment closure (CMC) model is one model that shows good capabilities in describing the turbulent combustion [1]. Moreover, the droplet interactions with turbulent flames are quite complex and not yet fully understood. A reliable model to couple droplet behavior with the LES-CMC methodology is the aim of the present study. Recently, multiphase effects in the CMC equations were investigated, and additional unclosed terms were introduced [2]. However, the effects of these terms are not fully analyzed yet.

The present study attempts to merge the past developments of turbulent combustion and turbulence-spray interactions, and will analyze the recent acetone spray experiment of Masri & Gounder [3] that provides well-defined boundary conditions. LES based on Favre-filtered transport equations is carried out to describe the large scale flow motion and the mixing, and the dynamic Smagorinsky model is used to close the subgrid stresses. The droplet behavior is modeled by the Lagrangian method that assumes the particle is unresolved and a point source of fuel. The aim is to model combustion using a CMC formulation which is consistent with the governing equations of two-phase flow [2]. Our previous study [4] applied the conventional CMC formulation to spray combustion, and it was found that the numerical simulation predicted overall higher temperature than measured. A possible explanation is that conventional CMC assumes the acetone vapor to instantaneously react and adjusts the chemical composition based on the mixture fraction, so that finite rate chemistry effects are neglected to some extent. Thus, this study will examine the additional terms occurring in the consistent CMC formulation, the modeling of which is expected to result in more accurate predictions.

References

[1] Navarro-Martinez, A. Kronenburg, and F. Di Mare., “Conditional moment closure for large eddy simulations”, *Flow, Turb. Combust.*, 75:245–274 (2005).

[2] M. Mortensen and R. W. Bilger., “Derivation of the conditional moment closure equations for spray combustion”, *Combustion and Flame*, 156:62-72 (2009).

[3] A. R. Masri and J. D. Gounder., “Turbulent spray flames of acetone and ethanol spray approaching extinction”, *Combustion Science and Technology*, 182(4):702–715 (2010).

[4] Ukai, S., Kronenburg, A. and O. Stein, “Large Eddy Simulation of Turbulent Acetone Spray Combustion with Conditional Moment Closure”, *25th Deutscher Flammentag*, Karlsruhe, Germany (2011).