Advanced Modeling and Simulation of Turbulent Sprays
Analysis of small-scale effects for large-eddy simulation

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Introduction

Application

Spray and atomization have been extensively studied in the past due to their broad applications in areas such as agricultural spraying, chemical coatings, pharmaceutical synthesis, fuel spray in engines and so on. Droplet size distribution and breakup pattern are the most important characteristics of spray since it determines the performance, efficiency, or safety. For example, in agricultural sprays, the goal is to control the number of fine droplets with diameter of 100 micron or less, since they will drift in air and cause contamination and damage to non-target crops, animals and humans.

The main challenge in the study of atomization is the complicated topological changes that occur, including primary breakup and secondary breakup, as well as droplet coalescence. These challenges, together with the mixing and small scale effect of turbulent, have placed great difficulties on both experimental and numerical ways of investigation. Thus, even today, spray and atomization are still not completely understood.

Methodology

There have been several numerical techniques developed to address the multiphase flow problem:

- Lagrangian method, such as front tracking.
- Eulerian method, such as volume of fluid (VOF), level set (LS).
- We will adopt coupled level set and volume of fluid (CLSVOF), which has both the advantage of level set being able to capture surface geometry and volume of fluid being able to conserve mass within the interface.

Our goal

- Develop and validate the DNS of coupled level set and volume of fluid method.
- Perform study on DNS data and develop LES model.
- Investigate on the effect of flow and fluid properties on spray.

Approach

CLSVOF

Level set method tracks the evolution of phase interface, while volume of fluid tracks the evolution of volume interior and exterior of the interface. Recently, people have developed a way to couple the two methods, to produce a mass conserving and straightforward curvature computing method.

LES

Large eddy simulation (LES) is a much more affordable way comparing to DNS. For multiphase flow, the key is to find the sub-grid scale (SGS) interface terms.

Result

Summary

- We are interested in DNS and LES modeling of multiphase turbulent spray and evaluating the droplet size distribution. Coupled level set and volume of fluid (CLSVOF) will be used together with DNS and LES, to track the evolution of multiphase interface.
- We will develop the LES sub-grid model for the terms that accounts for the surface tension and small scale interface geometry effect. Collaborating with the experimental group in The Dow Chemical Company, we will validate our DNS and LES model.
- We will investigate the effect of flow and fluid properties on spray, such as the shape of nozzle orifice, rheology properties and Weber number.

Reference


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