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Comparison of studies on flow and flame structures in different swirl combustors

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Abstract Swirling gas combustion and two-phase combustion (spray-air or particle-air combustion) are widely encountered in gas-turbine combustors and internal combustion engines. In experimental studies of practical combustors frequently it is difficult to get the detailed information inside the combustors. Most of numerical simulation is Reynolds-averaged (RANS) modeling, which cannot give detailed flow and flame structures. Some investigators reported their results using large-eddy simulation (LES) with different combustion models. The present authors did systematic LES studies on swirling gas combustion and two-phase combustion using second-order moment (SOM) and EBU combustion models. The statistic results are assessed by the measurement results. The instantaneous results show the flow and combustion behavior in different swirl combustors.
Keywords: swirling gas combustion; swirling two-phase combustion; large-eddy simulation

1. Introduction

Swirling gas combustion and two-phase combustion (spray-air or particle-air combustion) are widely encountered in gas-turbine combustors and internal combustion engines. Many experimental and numerical studies have been done to understand the flow and combustion behavior in swirl combustors. However, in experimental studies of practical combustors frequently it is difficult to measure the detailed velocity, temperature and species concentration fields inside the solid-wall combustors by using the optical instrumentation due to the difficulty in opening the optical windows on the walls, and frequently only the measurement results at the exit are obtained. For numerical simulation, previously RANS (Reynolds-averaged N-S) modeling of swirling combustion has been studied [1, 2, 3], which can give only time-averaged results and erase the instantaneous results for understanding the flow and flame structures. Recently, the direct numerical simulation (DNS) has been used to study the swirling gas combustion and two-phase combustion [4, 5], but due to the large computation requirement, the DNS cannot simulate practical combustors. A best compromise is the large-eddy simulation (LES). The LES, with less computation requirement than DNS, can give the instantaneous results to understand the flow and flame structures and more accurate statistical results than those obtained by RANS modeling. Some LES studies for swirling gas combustion and two-phase combustion were reported, for example in Ref. [6, 7] using different combustion models. During more than last ten years, the present author and his colleagues did systematic LES studies on swirling gas and two-phase combustion using LES, mostly with a self-proposed second-order moment (SOM) combustion model and also an EBU combustion model. The statistical results were assessed by experiments, and the instantaneous results show different flow and flame structures in different swirl combustors. In this paper, a summary of these studies will be given for their comparison and further analysis

2. Different Combustors to be Studied

Different swirl combustors were studied by the present author. Case 1 is the simulated combustor for swirling methane-air diffusion combustion measured in our laboratory [8]. The combustor is shown in Fig.1. Case 2 is a combustor for swirling propane-air diffusion combustion simulated in Ref. [9]. The combustor is shown in Fig.2.

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