Modeling of Aluminum Combustion in Air-breathing Combustor

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Abstract

The operation concept of a ducted rocket utilize two stages combustion; the first combustion in a fuel rich solid fuel gas generator and then the second combustion with the exhaust products of a gas generator with air through intakes at a main combustor. In order to increase specific impulse, thrust and suppress combustion instability, metal particle, such as aluminum or boron, can be added to the solid propellant of gas generator. In this study, aluminum combustion is modeled to investigate combustion characteristics of ducted rocket combustor. Aluminum combustion is applied and validated with experimental results of Dreizin et al.(1996), Yu et al.(2006).

Dreizin et al. conducted experimental studies of aluminum combustion in air environment using CO_2 laser as ignition source, and temporal variation of the particle diameter and the shape and size of the smoke cloud surrounding a burning particle were investigated. Yu et al. set up experimental apparatus in order to simulate air-breathing rocket combustor in the shape of dump combustor. Nano and micro sized aluminum particle is injected to combustor , and ignited by ethylene-oxygen pilot flame. Boundary layer and combustor exit temperature profile with varied overall equivalence ratio and particle size are obtained. Our numerical results are compared to above experimental data, and comparable agreement between numerical results and experimental data was obtained (Fig. 1 and 2).

Aluminum combustion characteristics in air-breathing rocket combustor is also studied. Aluminum particle is injected from gas generator as product of fuel rich solid propellant, with other gas composition. Mixing characteristics of gas and particle, and combustion phenomena of aluminum particle in a combustor are presented. Numerical investigations were performed with the intention of understanding of major parameters of combustion efficiency of the combustor, including mass flow ratio of fuel gas and intake air, size of metal particles, through an unsteady numerical simulation (Fig. 3, 4, 5). As a results, large sized aluminum particles, above 100μm, are barely combusted in the combustor. However small sized aluminum particles, below 10μm, are combusted vigorously, so play an important role increasing overall combustor temperature (Fig. 5).

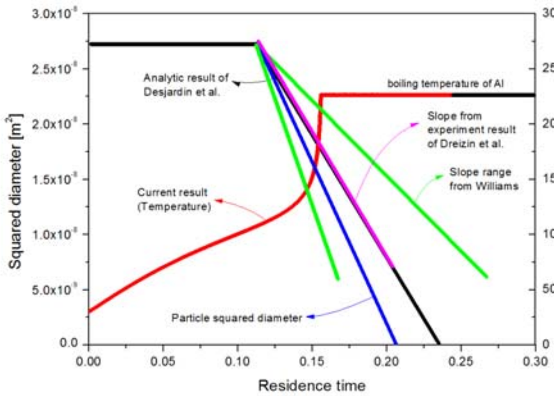

Figure 1. Temperature and diameter history of combusting falling aluminum particles

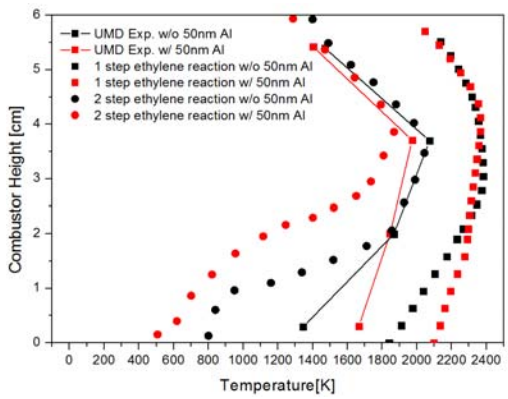

Figure 2. Comparison of temperature distributions at combustor exit

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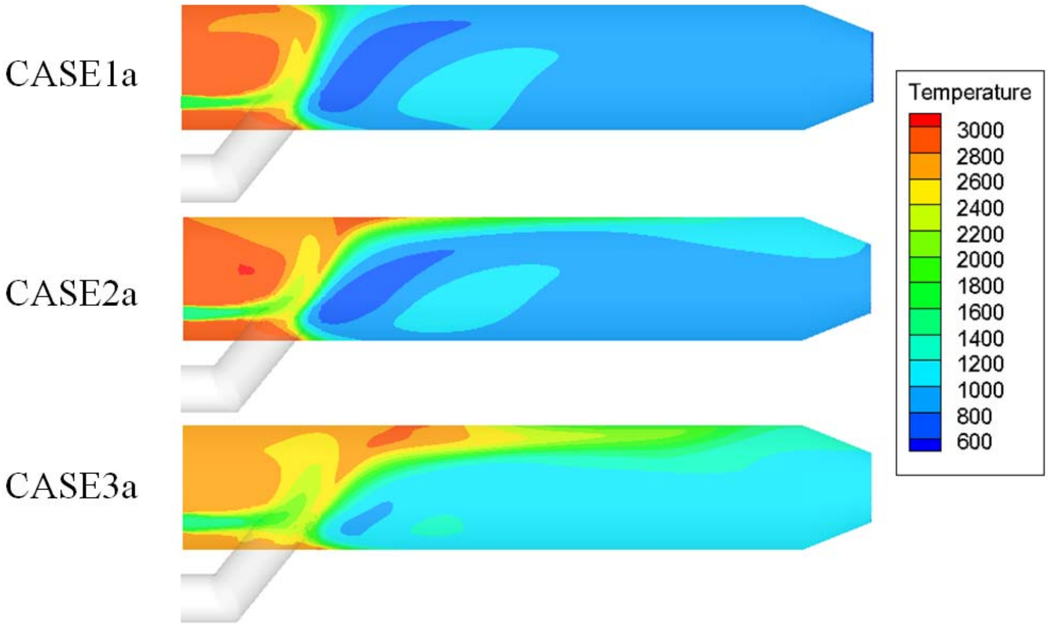

Figure 3 Sliced contours of temperature varied with air mass flow rate
of a combustor in suspension of aluminum

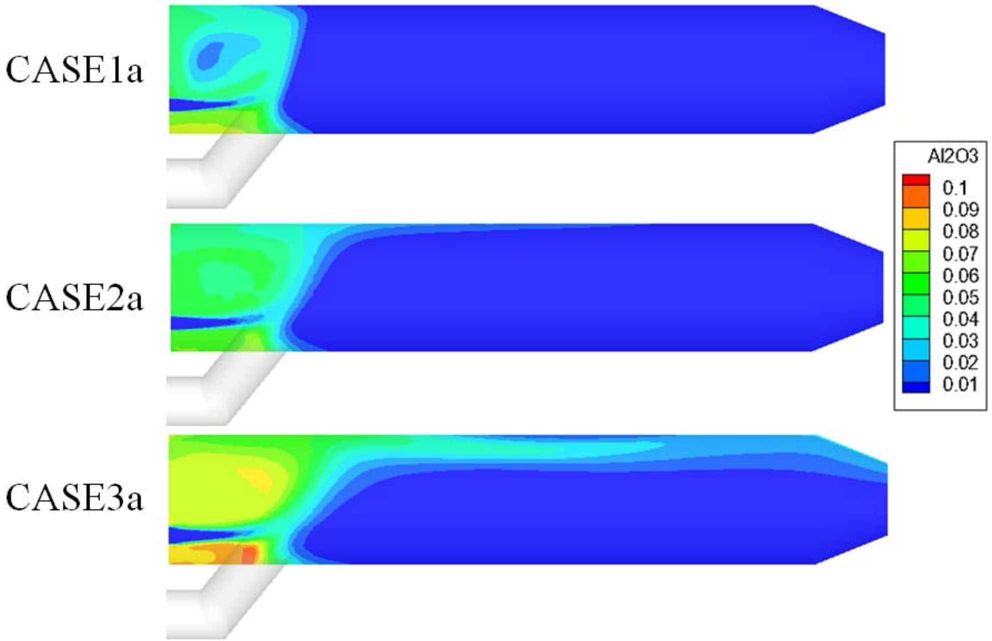

Figure 4. Sliced contours of aluminum oxide mole fraction
varied with air mass flow rate of a combustor
in suspension of aluminum

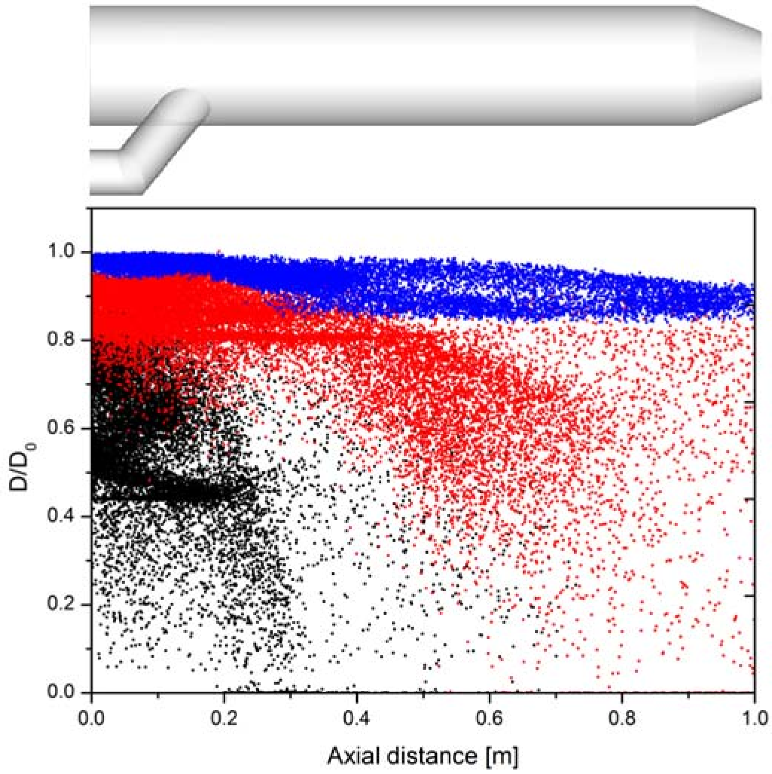

Figure 5. Distribution of non-dimensional particle diameter along the center axis