Numerical Investigation of Spray Combustion and Flow in LOX/H_2 Subscale Rocket Combustors

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Two different LOX/H_2 subscale rocket combustors are investigated: the Mascotte single injector 10 bar test case [1] set up by ONERA and the ASTRIUM subscale chamber test case [2]. The test cases have been treated at the International Workshops on Rocket Combustion Modeling in 2001 and 2006 respectively.

The applied 3D CFD tool *Rocflam3* is currently under development at ASTRIUM Space Transportation in Ottobrunn as designated successor of the 2D/axisymmetric in-house code *Rocflam-II*. For the present work, *Rocflam3* solves the Favre Averaged Navier-Stokes equations and uses k-ε turbulence modeling. Turbulent combustion is treated via an equilibrium based presumed PDF (probability density function) approach with a mixture fraction formulation. Therefore, an additional equation is solved for the mixture fraction variance. A Lagrangian spray module is employed for propellant droplet tracking and modeling the evaporation of the droplets. After a short overview of the numerics in *Rocflam3*, the simulation results of the test cases are analyzed in detail. Thereby, 2D/axisymmetric and three-dimensional simulations of both combustors shall be compared with each other and with experimental data.

The Mascotte combustor works at a chamber pressure of $p_c = 10bar$ and a mixture ratio of $O/F = 2.11$. The chamber has one coaxial injector located on the center axis. Oxygen is injected in subcritical state and therefore treated by the Lagrangian spray module. Although the combustion chamber has a square cross-section, simulations are usually performed on an axisymmetric grid for a cylindrical geometry. In this work, simulations on three different grid geometries shall be examined: a 2D/axisymmetric geometry, a three-dimensional circle segment and a three-dimensional square segment. To compare the simulation results with experimental data, an instantaneous OH emission image and mean temperature profiles are available. The *Rocflam3* simulations show good agreement with both of them. The temperature and mixture ratio fields of the 2D/axisymmetric simulation are shown in Figure 1. The paper shall contain a discussion of the simulation settings, the flow field, the droplet trajectories and the droplet evaporation.

The considered load point of the ASTRIUM subscale chamber lies at a chamber pressure of $p_c = 100bar$ and a mixture ratio of $O/F = 6$. The cylindrical chamber employs nineteen coaxial injectors. One is located on the center axis and the others on two concentric rings around the axis. The oxygen is injected in transcritical state ($p > p_{crit}$, $T < T_{crit}$) and is treated by the Lagrangian spray module in *Rocflam3*. For this test case the focus lies on the correct computation of the chamber pressure and the wall heat flux profile which is available from calorimetric heat flux measurements. The temperature and mixture ratio fields of the

2D/axisymmetric simulation are shown in Figure 2. Simulating the subscale chamber on an axisymmetric grid is certainly a notable simplification which shall be assessed by comparing the results with ones from three-dimensional computations.

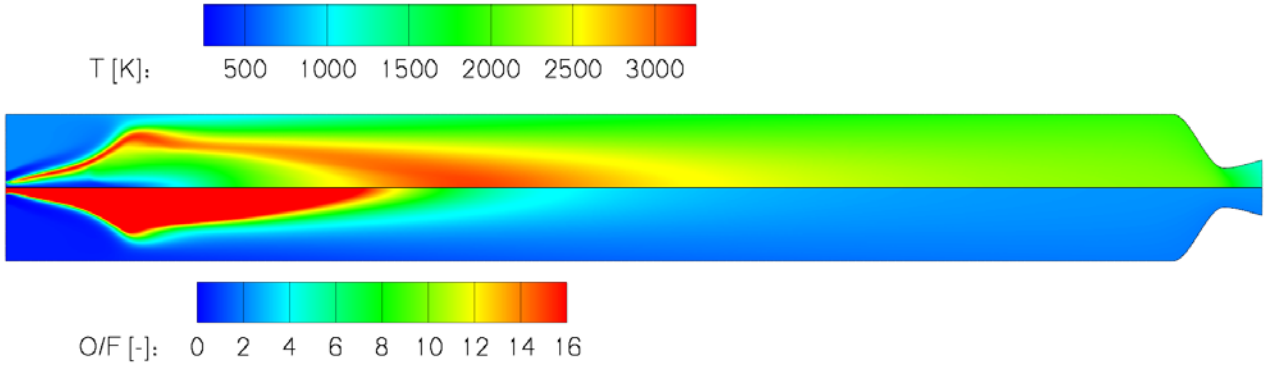

Figure 1: Mascotte single injector combustor: axisymmetric temperature (top) and mixture ratio (bottom) fields

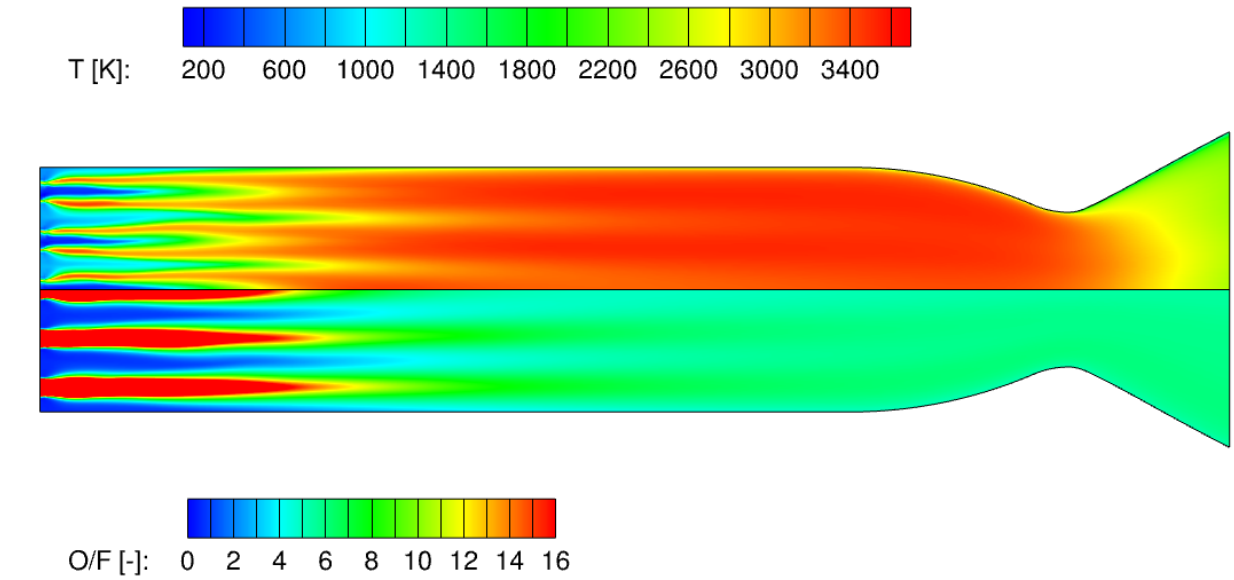

Figure 2: ASTRIUM subscale combustor: axisymmetric temperature (top) and mixture ratio (bottom) fields

References

[1] L. Vingert and M. Habiballah, "Test Case RCM-2: Mascotte single injector 10 bar," in *Proceedings of the 2nd International Workshop on Rocket Combustion Modeling - Atomization, Combustion and Heat Transfer*, Lampolshausen, 2001.

[2] O. Knab and D. Preclik, "RCM Test-Case RCM-3: "EADS-ST Subscale Chamber"," in *Proceedings of the 3rd International Workshop Rocket Combustion Modeling*, Paris, 2006.