Numerical Study of Air Vitiation Effects on Scramjet Performance with Different Fueled Combustion Heater

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In order to provide effective means for extrapolating ground test data to flight, experimental and numerical investigations had been carried out to study air vitiation effects on test scramjet. On account of the combustion-heated facilities are widely applied in propulsion tests below Mach 8.0 for scramjet development, we need to elaborately evaluate vitiation effects of on scramjet performance with different fueled combustion heater. At present, the combustion heater using hydrogen and hydrocarbon combustion often was used to heat air. To design the test system applied for propulsion test, how to match vitiated air up to clean air with certain parameters is a key. Many test medium flow "match" conditions have been used in scramjet test, e.g. HPM and UPT conditions[1]. These conditions match various combinations of pressure, temperature, enthalpy, velocity, or Mach number entering the inlet or entering the combustor. The addition of water and carbon dioxide (major contaminants) to the flow in a combustion-heated facility results in an altered molecular weight, gamma, and heat capacity of the simulated air stream relative to the flight conditions. Because of the altered properties of the combustion-heated flow, the stream velocity, Mach number, and temperature cannot be simultaneously matched[2].

This paper focuses on test scramjet performance with four different fueled combustion heater (H2,CH4, alcohol and kerosene), based on the same test flow match conditions. Under clean air or flight condition, the scramjet performance also is evaluated and analyzed.

Using Northwestern Polytechnic University (NWPU) direct-scramjet combustor as test model(Fig.1), we contrasted the simulation results (obtained by AHL3D flow solver) with experiment(Fig.2) [3]. The simulated results are close to measured wall pressures of comparative experiments, and could "distinguish" the vitiation effects of species contaminants in test gas. AHL3D flow solver can be applied to investigation of air vitiation effects on scramjet performance.

CFD simulations of reacting flowfield in the scramjet under the same facility test medium flow "match" conditions are conducted using AHL3D flow solver. Finite volume method is used to discretize Favre-averaged Navier-Stokes equations, and $k-\omega$ turbulence model is employed to account for the turbulent effect. The conservative form of the equations is solved using a diagonal implicit finite-volume method, which solves this system using two sweeps of point Gauss-Seidel relaxation. The inviscid fluxes are computed using Steger-Warming scheme with 3rd-orer accurate MUSCL interpolation. The combustion is modeled with a reduced chemical kinetic model. The simulation results and analysis can help to deepen understanding of

contamination effects, and explain the differences in scramjet tests performance with different fueled combustion heater.

References

1. Thomas Fetterhoff, Steve Bancroft, Wade Burfitt, et al. Development of technologies in the u.s. For test and evaluation of high speed/hypersonic systems [R]. ISABE Paper 2009-1213, 2009.
2. Pellet G.L., Bruno C, and Chinitz W. Review of air vitiation effects on scramjet ignition and flameholding combustion processes [R]. ATAA Paper 2002-3880, 2000.
3. Le, Jialing, Liu, Weixiong, Song, Wenyan, et al. Experimental and numerical investigation of air vitiation effects on scramjet test performance [R]. AIAA Paper 2009-7344, 2009.

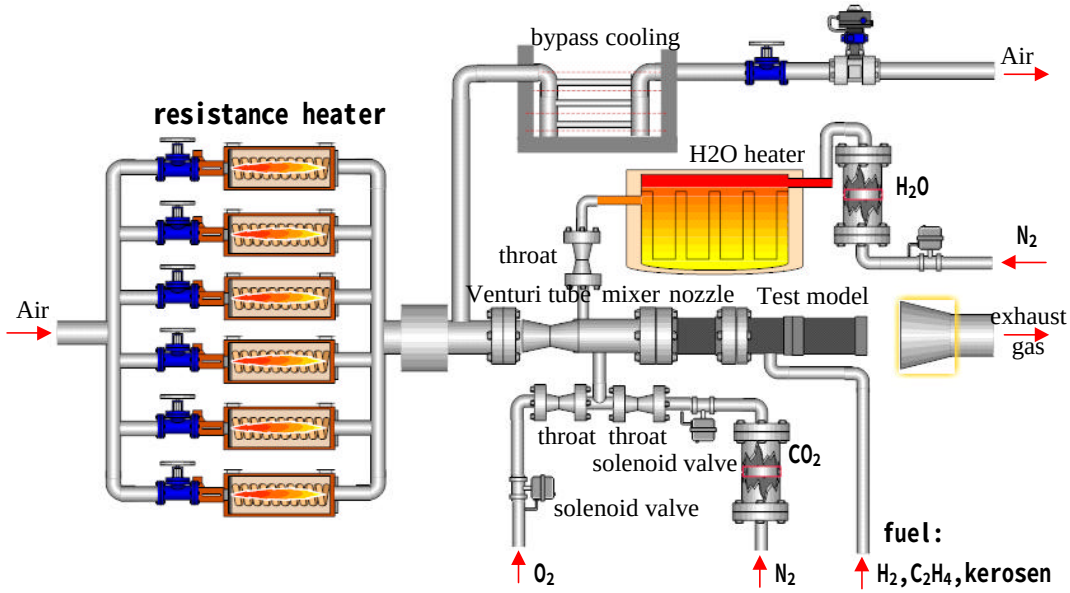

Fig.1 direct-connect resistance heated facility

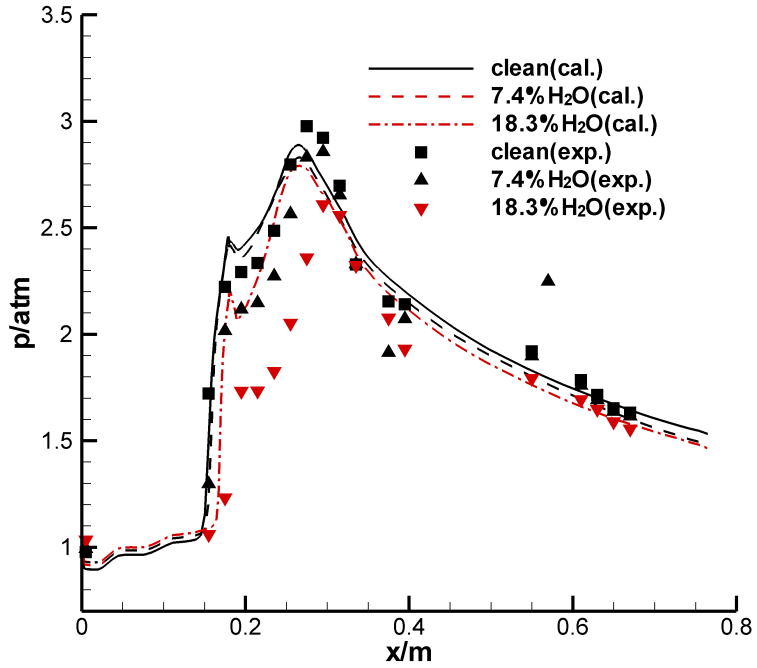

Fig.2 wall pressure distribution in the combustion chamber(upper wall, fuel:H_2, Φ=0.42)