Aerodynamic and Ignition Study of High-Speed Hydrogen Jet from High-Pressure Tank

Keiko B. AOMI[1], A. Koichi HAYASHI[2], and Satoru OGAWA[1]

[1] CFD Technology Center, National Aerospace Laboratory

7-44-1 Jindaiji Higashi, Chofu, Tokyo 182-8522, Japan

Email: aomi@nal.go.jp

[2]Dept. of Mechanical Engineering, Aoyama Gakuin University

KEY WORDS: Fuel cell, Ignition, Hydrogen tank, Detonation, Numerical Simulation

Energy problems: amounts of consumption are far exceeding more amounts of the reproduction of the fossil gas, and environmental problems such as green house effects are the critical issue for nowadays. We are trying to make break-through and Ballard[1] has recreated the old concept of the fuel cell which powered the space shuttle GEMINI in 1960's for more practical modern use.

The fuel cells have following good points; hydrogen, the most abundant element in our universe, is the fuel; pollution-free, the byproduct is water and become fuel again in principle; never needing electrical recharging as long as fuel is re-supplied. The fuel cells will play a key role in the future supplying our demand for energy. The fuel carrier system of a high-pressure (about 400 atm or more) hydrogen tank is being used at this stage. This means we will carry hydrogen gas in the high-pressure tank in our car and its safety has to be guaranteed. The fuel can be detonated there.

In our present work we simulate the situation that the hydrogen tank has a tiny hole; the hydrogen gas is ejected from the high-pressure tank into air under atmospheric pressure. We are trying to ascertain what happens if tank pressure is high and a tiny ignition point is near by.

Theoretical formulation is that the conservation laws of mass, momentum, energy, and species masses govern the whole process. Chemical reactions of hydrogen/air take place while igniting. A clear picture of the process can be obtained by using the numerical method to simulate the equations.

The phenomena of hydrogen jet leaking from a tiny hole to air under ambient pressure, can be seen many places. In first stage we use a similar configuration of our previous work for the lifted jet flame[2]. Considering the tiny hole has 1 mm diameter, hydrogen gas is jetted out from the hole. The calculations are performed on the axisymmetrical region which shown in Fig. 1. Boundary conditions are: axisymmetrical condition on the left boundary; the Thompson non-reflection conditions[3] on the upper boundary; zero normal gradient on the right boundary; and non-slip wall on the bottom side boundary. As for the numerical method, the well-known finite volume method is used. Reaction term is developed implicitly while the Euler's first order explicit method for other terms. The Harten-Yee's non-MUSCL modified-flux type TVD scheme is applied to discrete dissipative terms. Chemical kinetics are chosen to be Warntz H_2-air model of 20 elementary reactions with 9 species of H_2, O_2, O, H, HO_2, H_2O_2, H_2O, and N as an inert. Transport properties are based on the polynomial expression.

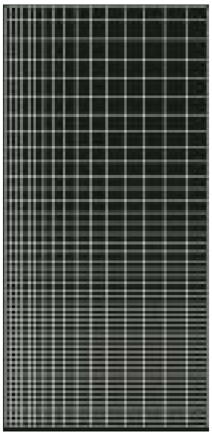

Fig. 1

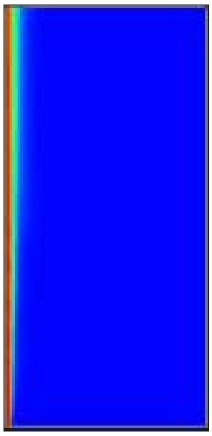

Fig. 2

The computational domain size is selected to be 2 cm x 5 cm and the grid size is 161 x 477 in cross stream-wise and stream-wise respectively at the present stage. A near steady state is achieved under axisymmetrical assumption. The preliminary results are shown in Fig. 2: hydrogen is jetted with the velocity of 1000 m/s to mix with air. The pure hydrogen region is shown by red while the blue area is air. We see what happens if there is any ignition sources such as a piece of cigar ash. In the case of ignition, the unsteady behavior of igniting and burning, will be shown at the conference.

References

1. Tom KOPPEL, “Powering the Future”, John Willy & Sons, 1999
2. Burtsitsig Bai et. al, 18th ICDERS, 2001
3. Thompson, K. W., J. Comp. Phys., 68, 1-24, 1987