Interaction between Pre-Combustion Gas Injection from a Ramp Injector and Incident Shockwave in Supersonic Flow

T. Yamaguchi*, Y. Iwamura, T. Kudo, A. Hayakawa, H. Kobayashi

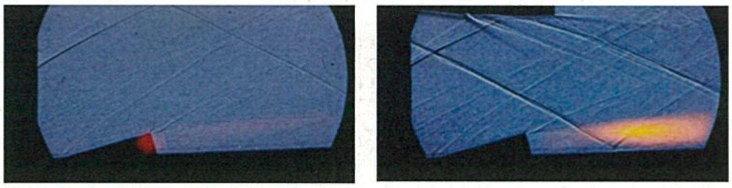
Institute of Fluid Science, Tohoku University, Japan

* yamaguchi@flame.ifs.tohoku.ac.jp

A SCRAMJET engine is expected as a propulsion system for a hypersonic airplane. Because of short residence time of inlet air, mixing and combustion should be completed in the combustor within millisecond time scale. In addition, the interaction between shockwaves and combustion region must be revealed. Ramp injector is expected as a promising injection method which can introduce streamwise vortices for mixing enhancement and reduce the total pressure loss.The aim of this study is to investigate the interaction between pre-combustion gas injection from a ramp injector and an incident shockwave in supersonic flow by experiments and numerical simulations.

The incident shockwave is formed by a shock generator, which has turning angle of 6 degrees, and introduced into region downstream of the ramp injector. H_2/Air mixture with equivalence ratio of 3.6 is ignited in the pre-combustion chamber before injection. The Mach number, total pressure, and total temperature of the inlet air are 2.5, 0.5 MPa, 673 K, respectively. Those properties of pre-combustion gas are 1.0, 0.6 MPa, 1500K, respectively.

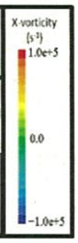
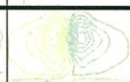
In this study, when the incident shockwave was introduced, combustion region was confirmed by flame emission (Fig.1), which shows that combustion was enhanced in the downstream of the shockwave. Wall pressure measurement and numerical simulation (Fig.2) indicates that high pressure region formed near the wall in the downstream of the reflected shockwave increases reaction rate between hydrogen and air. Numerical simulation (Table 1) also shows that baroclinic torque generated by pressure gradient of incident shockwave and density gradient between inlet air and injection gas facilitates mixing by increasing streamwise vorticity. Wall pressure measurement (Fig.2) also shows that shockwave entering into high temperature and low sonic speed zone like combustion region changes the shock angle to fulfill the relational equation among turning angle, shock angle and Mach number.

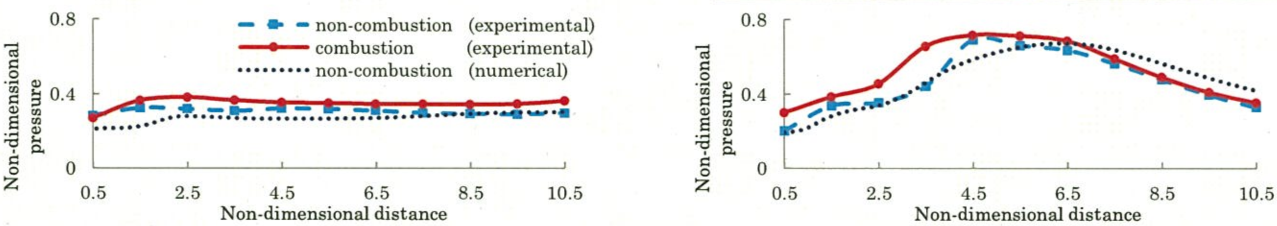


(a)Without shockwave (b)With shockwave

Fig.1 Flame emission image

Table 1 Profiles of streamwise vorticity

Contour point (x-axis)	10mm	50mm	100mm	
Without shockwave				
With shockwave				



(a)Without shockwave (b)With shockwave

Fig. 2 Profiles of wall pressure