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DIRECT NUMERICAL SIMULATION OF FLASHBACK IN TURBULENT CHANNEL FLOW

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From the viewpoints of environmental and energy shortage problems, hydrogen is expected to be an alternative fuel to oil and natural gas [1]. Hydrogen combustion is stable in wide fuel concentration range and easily ignited because of its wide flammable range and high burning velocity. However, these characteristics of hydrogen combustion also have a risk of flashback, which is a transient upstream propagation of flame, and therefore make it difficult to develop the hydrogen combustor. The flashback has been studied by experiments and numerical simulations [2, 3, 4]. However, since measurable characteristics of flashback are limited in experiments and the computational cost of numerical simulations which consider detailed chemical reactions are very high, the mechanism has not been well understood. In this study, the effects of wall thermal boundary condition and ambient pressure on the characteristics of flashback of premixed hydrogen-air flames in turbulent channel flow are investigated by direct numerical simulation (DNS) [5, 6]. As a combustion model, a detailed chemical reaction model which considers 9 chemical species and 20 reactions [7] is used. Table 1 lists the computational conditions. The Reynolds number based on the centerline velocity and half-width of the channel for the unburned gas is about 3,000, and the total grid number is about 0.1 billion for all cases.

Figure 1 shows the instantaneous distributions of isosurfaces of temperature (1200 K) and secondary invariant of velocity gradient tensor, and streamwise velocity on a x-z plane at $y^+ \simeq 2$ in Case 2 at (a) $t = 0$ ms and (b) $t = 1.5$ ms. It is observed that the flame surface is wrinkled by the streak structure in the turbulent flow and that the negative velocity regions are located in the upstream regions of the leading edges of flashback, which are convex toward the unburnt side. Figure 2 shows the comparison of time variation of flashback speed. It is found that the flashback speed increases with increasing the ambient pressure and that it is larger in the case of adiabatic wall than that in the case of isothermal wall.

Table 1: Computational conditions.

Case	Ambient pressure [MPa]	Ambient temperature [K]	Wall condition	$x \times y \times z$ [mm]
1	0.1	750	Adiabatic	50 × 20 × 30
2	0.1	750	Isothermal (750 K)	50 × 20 × 30
3	0.2	750	Isothermal (750 K)	25 × 10 × 15

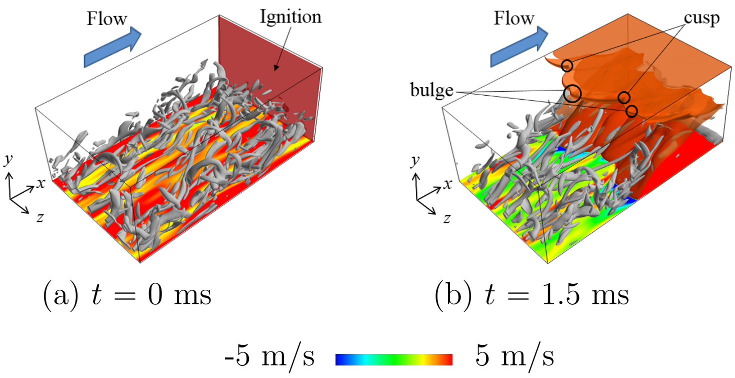

Figure 1: Instantaneous distributions of isosurfaces of temperature (1200 K) and secondary invariant of velocity gradient tensor, and streamwise velocity on a x-z plane at $y^+ \simeq 2$ in Case 2 at (a) $t =$ 0 ms and (b) $t = 2$ ms.

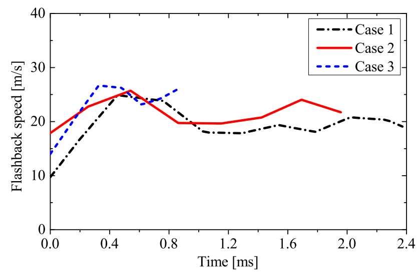

Figure 2: Comparison of time variation of flashback speed.

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