## §7. Experimental and Analytical Research on Temperature Rise of an Oxidation Catalyst Due to the Combustion Heat of Hydrogen

Tanaka, M., Uda, T.

Tritium removal system for the processing of exhaust gas from LHD under the deuterium plasma experiment is oxidation of tritiated hydrogen and hydrocarbon to water by packed type catalytic oxidation reactors, followed by adsorption process on a molecular sieve bed. The exhaust gas will primarily consist of hydrogen isotope gas. In order to oxidize hydrogen gas, therefore, oxygen gas or air must be added to the exhaust gas and hydrogen isotope gas must be diluted to less than the concentration of explosion limit. Because the oxidation reaction of hydrogen is exothermic reaction, the temperature on the oxidation catalyst will rise due to the combustion heat of hydrogen gas. To evaluate the temperature rise on the oxidation catalyst, we assumed adiabatic reaction device and examined a temperature rise in an oxidation reactor by a simple one-dimensional model and experiment.

(i) Analytical model

Figure 1 shows the schematic diagram for one-dimensional analytical model for an adiabatic reactor. The heat and material balance equations can be expressed as follows;

$$F_t C_{p,m} \frac{dT}{dz} = S\rho(-r_{H_2m})(-\Delta H_r)_{H_2} \qquad (1)$$

$$F_{H_2} \frac{dx_{H_2}}{dz} = S\rho(-r_{H_2m}) \qquad (2)$$

Here, $F_t$: feed rate of air, $F_{H_2}$: feed rate of hydrogen composition, $C_{p,m}$: specific heat at constant pressure, S: cross section of reactor, $\rho$: apparent density of catalyst, T: temperature of catalyst layer, $x_{H_2}$: conversion rate of hydrogen, $r_{H2,m}$: rate of reaction, $(\Delta H_r)_{H2}$: heat of reaction

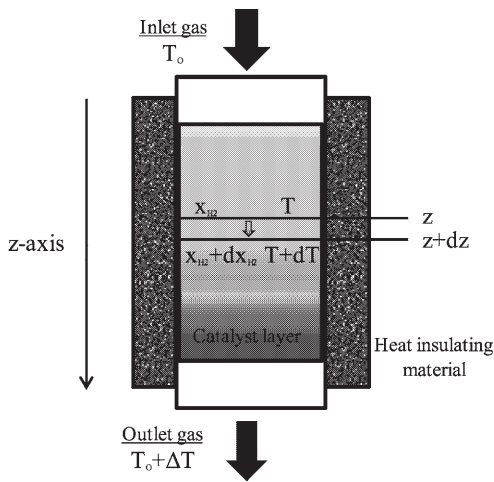per one molar hydrogen ($\Delta H°_{298K}$=286 kJ/mol).

Then, dividing expression (1) by expression (2) and integrate the equation by giving $y_{H2}$ ($=F_{H2}/F_t$) as a molar fraction of hydrogen and $T=T_o$ at $x_{H2}=0$ as the initial condition,

$$T = \frac{(-\Delta H_r)_{H_2} y_{H_2}}{C_{p,m}} x_{H_2} + T_0 = \Delta T + T_0 \qquad (3)$$

The right hand first term indicates temperature rise in outlet gas due to hydrogen oxidation reaction. Temperature rise is proportion to hydrogen concentration, if the hydrogen conversion rate $x_{H2}$ is unity.

(ii) Comparison of analytical and experimental results

For the evaluation of temperature rise due to hydrogen oxidation, the honeycomb type catalyst impregnated with palladium was used as the oxidation catalyst. The shape of a honeycomb catalyst was 56 mm in a diameter and 50 mm in a length and the cell density was 400 cell/inch$^2$. The impregnated weight of palladium was 4g/L. The reactor was covered with a thick layer of glass wool as heat insulating material. Feed flow rate was 6 Nm$^3$/h and hydrogen molar fraction in air was the range of 0.001 and 0.009. Inlet gas temperature was heated up to 142°C. The catalyst had an adequate performance to oxide whole hydrogen gas in the supplied air at 142°C, in spite of hydrogen concentration. Figure 2 shows the comparison of analytical and experimental results. Experimental values agree well with the theoretical results less than 0.005 of hydrogen molar fraction. On the other hands, in the case of more than 0.005, experimental values were slightly lower than analytical results. It would be caused due to insufficient thermal insulation. It is considered, however, that the simple one-dimensional adiabatic reactor model can be applied to this catalytic reactor system. As an actual problem, temperature rise due to heat of reaction makes it difficult to control the catalyst temperature. Furthermore, in the case of hydrogen concentration of around 4%, temperature on catalyst will increase to about 400 °C. It is possibility to affect a lifetime of the catalyst and the reactor components. Therefore, it is desirable to lower concentration of hydrogen gas in processing gas in practical application.



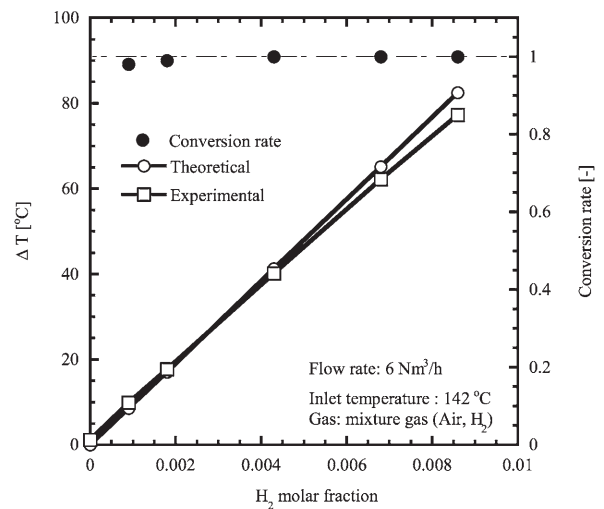Fig.1 Schematic diagram of an analytical model for one-dimensional adiabatic reactor



Fig.2 Comparison of analytical and experimental results