Combustion Characteristics of Hydrogen-Air Premixed Gas in a Sub-millimeter Scale Catalytic Combustor using Platinum Catalyst with Porous Media Support

Wonyoung Choi, Sejin Kwon and Hyun Dong Shin
Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon, Korea

A power source for a micro scale system also has to be micro scale. But conventional batteries are not effective to micro power source due to small energy density. Micro combustor has much larger energy density than conventional batteries[1]. Especially micro combustor is suitable for the heat source of micro reactor or reformer that need appropriate high temperature for reliable operation. But conventional combustion is difficult to be applied to small space due to flame instability[2]. Catalytic combustion was applied to micro combustor as an alternative method. Catalytic combustion is sustained by surface reaction of fuel and oxidizer on catalyst. Flame quenching does not occur due to inexistence of flame[3]. And the amount of heat loss is smaller than conventional combustion because reaction temperature is relatively low. These characteristics of catalytic combustion are suitable for micro combustor[4].

The objective of this research is to investigate the catalytic combustion characteristics of hydrogen-air premixture in micro scale with platinum catalyst on porous media. A sub-millimeter scale catalytic combustor was fabricated. Platinum catalyst is coated on porous ceramics support that has large surface area. The support is installed in the combustion chamber as catalyst bed and the premixed gas is supplied to the combustor. The temperature distributions in the combustor were measured using infrared thermal imager. Fig. 1 shows the parts view of the combustor. The shape of the combustion chamber is like a small rectangular button. And it has gas inlet and outlet on each side of the chamber wall. Fig. 2 is the schematics of the combustion chamber.

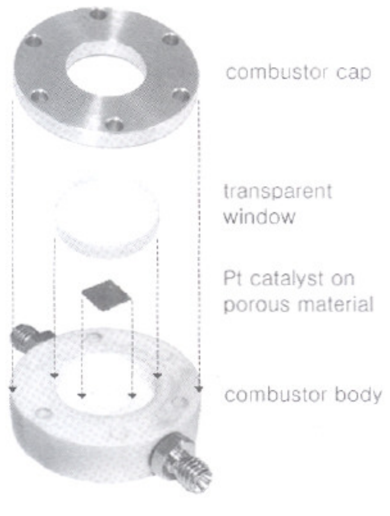

Fig. 1 Parts view of the sub-millimeter scale catalytic combustor

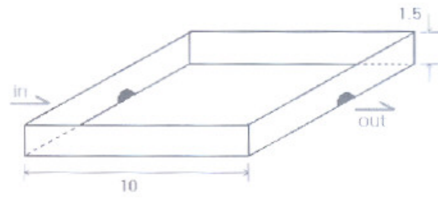

Fig. 2 The structure of the combustion chamber (the size is in millimeter)

Pt catalyst is coated on porous material support using incipient wetness method. Porosity and average pore diameter of the support are 70% and 50 micrometers. The concentration of catalyst was 0.75 wt%.

The reaction was directly observed using MgF_2 window which transmits visible light. The conversion rate was measured by gas chromatography. Temperature distribution in the combustion chamber was scanned by infrared thermography. GaAs transparent to infrared ray was used as the window part of the combustor. Table 1 shows the experiment parameters. Upper 4 rows in Table 1 mean change in volume flow rate. The other 2 rows are the case of different equivalence ratio.

Table 1. Experiment parameters

equivalence ratio	volume flow rate (ml/min)			Pt catalyst concentration (wt%)	Re
	sum	H_2	air		
1.0	84	25	59	0.75	19.6
	169	50	119		39.5
	253	75	178		59.2
	338	100	238		79.0
0.2	650	50	600		147.2
1.0	169	50	169		39.5

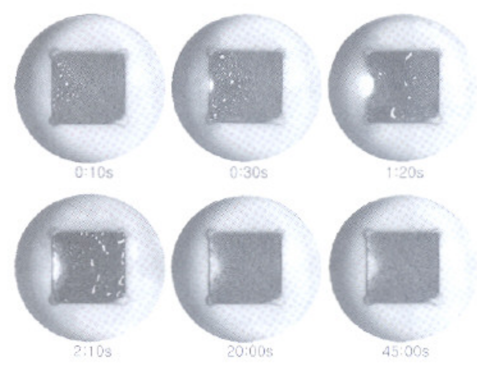

Fig. 3 Reaction in the combustion chamber observed directly with time

Fig. 3 shows the result of direct observation in the combustion chamber with time. Left side of the chamber is inlet and the other side is exhaust. Reaction started as soon as the premixed gas was supplied to combustor. Initially some water drop was located around the inlet. But as time passed, all of the water was vaporized due to continuous heat generation. After 20 minutes, no prominent change occurred. Bright region was formed in the vicinity of the inlet. The conversion rate was above 97%. That means almost all supplied fuel reacted perfectly although the combustion chamber is small.

Fig. 4 is the temperature distribution in the combustion chamber with time under various volume flow rate of premixed gas. The left side of each square is inlet of premixed gas. Hot region was formed around the inlet for all volume flow rate. This area is the same as the bright region observed directly. That means all of the catalytic reaction is completed through the small portion in the combustion chamber. Maximum temperature was above 700℃ in the steady state. However the temperature on the other portion except the activated region was much lower. Therefore the average temperature of the combustion chamber was also much lower. As the volume flow rate went up, the average temperature and the area of hot zone increased. And the time to reach steady state is also shorter for larger volume flow rate

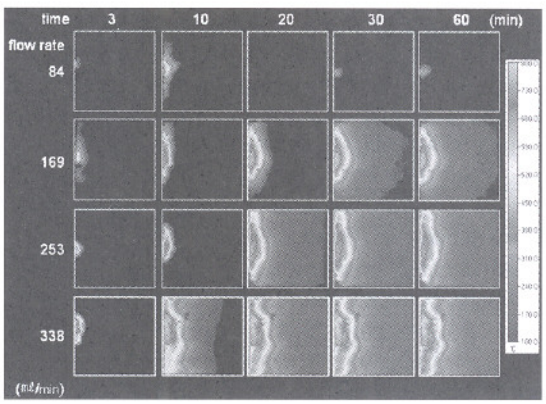

Fig. 4 History of temperature distribution in the combustion chamber with time under various volume flow rate of supplied hydrogen-air premixture

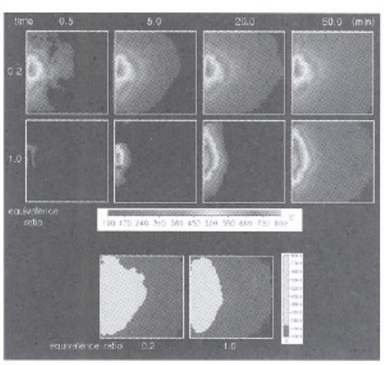

Fig. 5 Comparison of temperature distribution in the combustion chamber between different equivalence ratios

Fig. 5 shows the temperature distributions when the equivalence ratios are 1.0 and 0.2. The hot region was broader in the case of 0.2 at the same time. Especially the difference of temperature distribution between two cases was obvious before 20 minutes. Both activated regions were located around the inlet for each case. But the area where the temperature is higher than 200℃ was much larger when the equivalence ratio was 0.2. That means the temperature distribution becomes evener for lower equivalence ratio.

The space where the reaction occurs is the pore in the support. Average pore diameter is 50 micrometers. In spite of such small space, almost all of the fuel reacted stably for all experiment conditions. This means catalytic combustion is a good solution to be used for micro scale heat source.

The average temperature and the area of activated region in the combustion chamber increased as the volume flow rate of the premixed gas went up. If the equivalence ratio was low, the area of activated portion in the combustion chamber increased. The results of this research will be important design factors for the development of high-power micro heat source.

Acknowledgement

This work has been done with the support of Korea Science and Engineering Foundation (KOSEF) through the Combustion Engineering Center (CERC)

References

[1] H.B. Na, et al., J. of KSPE, Vol. 7, No. 4 (2003), pp.27-32

[2] W. Choi, et al., J. of KOSCO, Vol. 10, No .1 (2005), pp.20-26

[3] S. Tanaka, et al., Chem. Eng. J., Vol. 101 (2004), pp.143-149

[4] W. Choi, et al., J. of KOSCO, Vol. 10, No. 3 (2005), pp.17-24