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The radiative characteristics of $NH_3/N_2/O_2$ non-premixed flame on a 10 kW test furnace

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Abstract

The total radiative heat flux and the radiation spectra under the condition of the ammonia fuel combustion in a 10 kW test furnace were measured to clarify the radiative characteristics in this study. The concentration of oxygen in the oxidizer was varied for the purpose of increasing the flame temperature and radiative heat flux. The results showed that radiative heat flux under the condition of the oxygen enriched (30 vol.%) ammonia non-premixed flame formed in a 10 kW test furnace was more than that of the methane/air non-premixed flame. The peak position of the radiative heat flux measured in case of the ammonia combustion shifted to the downstream region from the burner in comparison with the methane combustion. On the other hand, the oxygen enriched flame shifted back to the upstream side from the burner

Keywords: Ammonia, Alternative fuel, Oxygen enriched combustion, Radiative heat flux, Spectrum, Non-premixed flame

Nomenclature

Q_{O2}	Amount of oxygen in the oxidizer [volume %]
Q_{N2}	Amount of nitrogen in the oxidizer [volume %]
Ω	Ratio of oxygen concentration in the oxidizer defined the equation (2)
λ	wavelength[m]

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1. Introduction

There are severe issues on increasing amount of carbon dioxide (CO_2) emission in the world. Many studies are devoted on alternative fuels. One of superior candidates is the utilization of hydrogen energy which can realize a low-carbon and hydrogen-based society. Ammonia might play an important role which is zero emission of CO_2, and is useful for hydrogen energy carrier as a clean energy. Additionally, ammonia is an easily-liquefiable fuel with pressure of about 0.8 MPa and temperature of 294 K. Commercially, ammonia is produced in large quantity by the Haber–Bosch process. It is also to be produced by using catalyst with renewable energy sources, such as wind energy and solar energy.

The ammonia has advantages to be used as an alternative fuel. The thermo-physical properties of an ammonia fuel are similar to those of propane. Lower heating value of ammonia is 3358 (kcal/m^3_N). Although it is smaller than that of methane (8557 (kcal/m^3_N)), it is larger than that of hydrogen (2570 (kcal/m^3_N)). Therefore, the ammonia has a possibility to be employed directly to industrial furnaces, gas turbines and reciprocating engines as a fuel. Also, the ammonia does not emit CO_2 during its combustion process as shown in equation (1).

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \quad (1)$$

A large amount of CO_2 reduction is expected in case of introducing an ammonia gas as a fuel to boilers and industrial furnaces. It is important to know the radiative characteristics of heat flux produced by combustion gas of ammonia fuel since the radiative heat flux accounts more than 80 percent in generated heat quantity inside a furnace. Many studies have done on radiative characteristics in case of combustion of fuels based hydrocarbons whereas there are only few researchers who studied radiative characteristics in case of ammonia combustion in industrial furnaces. In this study, we aim firstly to obtain and evaluate the experimental radiative heat flux and spectrum data from ammonia combustion in a 10 kW test furnace of which data could reveal the difference between ammonia combustion and methane one.

Also above mentioned ammonia combustion, which doesn't include carbon atoms and results in generating neither CO_2 nor any soot, emits less radiative heat flux than methane combustion. This is one of issues on ammonia combustion employed to an industrial field. Thereby, a radiative heat flux from ammonia combustion has to be strengthened at the same level as that from hydrocarbon based combustion. The Stefan-Boltzmann law says that the total radiative heat flux is in proportion to fourth powers of temperature on a black body. The oxygen enriched combustion, which means that oxygen concentration was increased in the oxidizer than the air, increased the flame temperature [1] and radiative heat flux. And this made the flame stable at the same time [2]. As to secondary objective in this study, we researched the effect of enriched oxygen in the oxidizer for characteristics of a radiative heat flux in a 10 kW test furnace with a non-premixed type burner.

2. Experiments

2.1 Experimental apparatus

Figure1 shows an experimental schematic diagram. A furnace is 1400 mm long and its inner wall is surrounded with the adiabatic material named ISOWOOL (ISOLITE Insulating Products Co. LTD. Japan). On a top of the furnace there are six ports equipped with thermocouples which are positioned at Z=100 mm, 200 mm, 300 mm, 500 mm, 750 mm, 1000 mm from the exit surface of a burner, where we define Z=0 mm