Principal Research Results

Development of Environmental Barrier Coating on Ceramics for Gas Turbine – Development of test equipment for evaluating recession resistance of ceramics in high temperature gas flow with water vapor –

Background

In ceramic gas turbine-applied ceramics for gas turbine hot section parts, a drastic increase in thermal efficiency can be expected and a reduction in the amount of cooling air can be achieved simultaneously. However, it has been found that recession of ceramics caused by reaction with water vapor and vaporization is progressing in the combustion gas flow. In order to prevent the recession, it is essential that an environmental barrier coating (EBC) is developed, and to achieve this, it is necessary to evaluate the recession resistance of ceramic materials quantitatively for search of EBC materials. Furthermore, the exposure test in combustion gas flow by means of conventional large-scale burner rig equipment is accompanied with difficulty because the test is demanded for a long time, and small-scale and simple test equipment capable of evaluating the recession resistance of ceramic materials (coating materials) is necessary.

Objectives

The purpose of this study is to develop a small-scale and simple test equipment for evaluating recession resistance of ceramic materials (coating materials);

Principal Results

1. Development of test equipment for evaluating recession resistance of ceramic materials

A test equipment for evaluating the recession resistance of ceramic materials, which is able to control the atmosphere gas flow conditions (water vapor partial pressure, gas temperature, gas flow velocity), was devised and developed (Fig. 1, Table 1). The test equipment adopting a high temperature electric furnace and containing heat transfer promoter made of ceramics is small-scale, and is able to examine long-time exposure tests under the gas flow velocity conditions up to about 10m/s.

2. Exposure test results of alumina for certification

By using the developed test equipment, the exposure tests *1 of alumina evaluated in combustion gas flow by means of burner rig equipment *2 are performed. Test results are as follows;

(1) The developed test equipment is able to cause the recession of alumina. The weight of alumina measured after the exposure tests decreases almost linearly against the exposure time (Fig. 2). Thus, the evaluation using the weight loss rate is possible the same way as the burner rig equipment.

(2) The influence of gas temperature and water vapor partial pressure on the weight loss rate of alumina is examined, and apparent activation energy and power low exponent on the water vapor partial pressure are almost correspondent with the results of the burner rig equipment exposed in combustion gas flow (Fig. 3, Fig. 4, and Table 2).

From the above-mentioned results, the developed test equipment can evaluate the recession resistance of ceramic materials, and it can be utilized for search and evaluation of coating materials for EBC.

Future Developments

We are going to evaluate the recession resistance of high purity zirconia *3 (Yttria stabilized zirconia) as a candidate material for EBC by using developed test equipment.

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Reference

I. Yuri, et al., 2009, “Development of environmental barrier coating on ceramics for gas turbine – Development of test equipment using electric furnace for environmental resistance evaluation of coating materials–”, CRIEPI Report Q08033 (in Japanese)

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*1 : Test condition: gas temperature 1300-1500℃, water vapor partial pressure 40-70kPa, gas flow velocity 1-8m/s, atmospheric pressure (0.1MPa), Exposed geometry of specimen: 16mm wide × 5mm deep × 1mm thickness.

*2 : I. Yuri and T. Hisamatsu, Am. Soc. Mech. Eng., Pap. GT2003-38886(2003)

*3 : I. Yuri, S. Najima and T. Hisamatsu, J. Soc. Mat. Sci., 55-1(2006), pp. 72-77 (in Japanese)

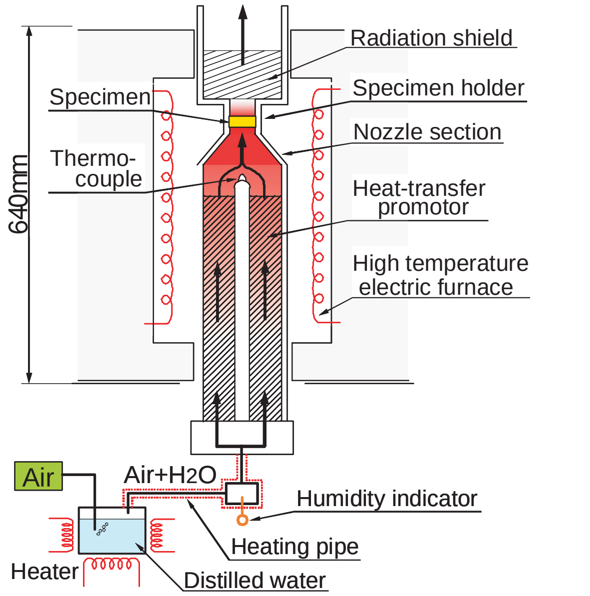

Fig.1 Sectional view of developed test equipment

Table 1 Design specifications

●Gas temperature: MAX. 1700℃
●Test pressure: Atmospheric pressure (0.1MPa)
●Gas composition: Air+H_2O or Carrier gas+H_2O
●Water vapor partial pressure: MAX. 70kPa
●Gas flow velocity: MAX. 10m/s
●Specimen size: 5×20×1mm (basis)
●Equipment size: 1800W×1850H×950Dmm

In this equipment, the atmosphere gas flow condition (water vapor partial pressure, amount of air, etc.) is controlled automatically.

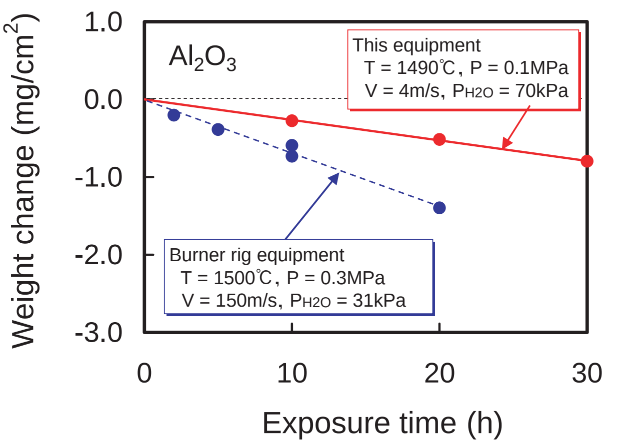

Fig.2 Relationship between exposure time and specific weight change

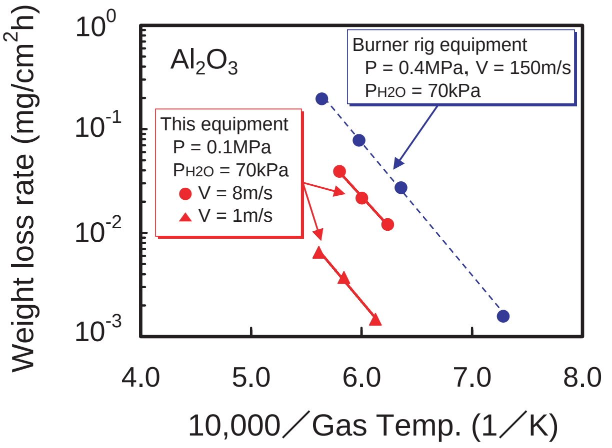

Fig.3 Effect of gas temperature on weight loss rate

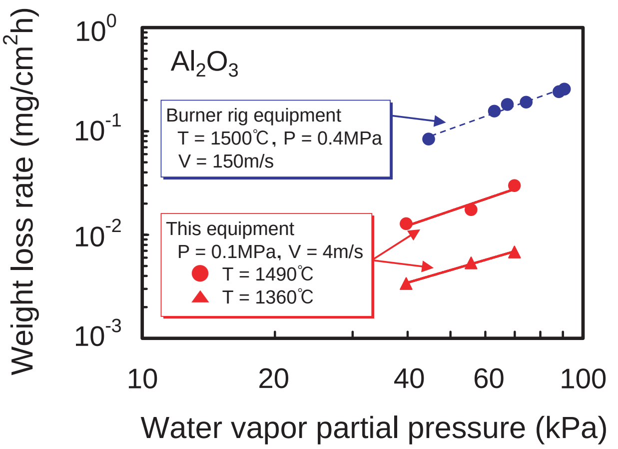

Fig.4 Effect of water vapor partial pressure on weight loss rate

Table 2 Effect of gas temperature and water vapor partial pressure

	E (kJ/mol)	n
This equipment	220 ～ 270	1.2 ～ 1.5
Burner rig equipment	240	1.3 ～ 1.5

Note: Weight loss rate k_w(mg/cm^{2}h) in burner rig is expressed by the following equation;

$$k_w = c \cdot \exp\left(-\frac{E}{RT}\right) \cdot (P_{H_2O})^n \cdot \frac{Re^{0.8}}{P}$$

c: Constant, E: Apparent activation energy (kJ/mol),
R: Gas constant (8.31kJ/kmol·K), T: Gas temp. (K),
P_{H2O}: Water vapor partial pressure (MPa),
n: Power low exponent on water vapor partial pressure,
Re: Reynolds number, P: Gas pressure (MPa)