DEVELOPMENT OF THERMAL BARRIER COATINGS WITH EXCELLENT DELAMINATION RESISTANT PROPERTY BY EXTREME INTERNAL OXIDATION

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In Japan, the proportion of thermal power generation has increased since after the Great East Japan Earthquake in 2011, accounting for approximately 85% in 2015. Compared to other power generations, thermal power plants have a large amount of carbon dioxide emissions relative to the amount of power generation. Therefore, it is an urgent task to reduce carbon dioxide emissions by improving the efficiency of thermal power plants.
Increasing the turbine inlet gas temperature improves the efficiency of the gas turbine thermal power plants. However, high-temperature components, such as rotating blades, are close to their maximum service temperature. Therefore, application of the thermal barrier coating (TBC) on the turbine blade substrate is needed to protect a structure. The TBC system usually consists of ceramic top-coating (TC) and intermediate metallic bond-coating (BC) on a Ni-based superalloy substrate. To reduce the effect of the heat flux on the structure, heat resistant material, such as Yttria-Stabilized Zirconia (YSZ), is commonly used for TC layer. While, for BC, MCrAlY (M: Co and/or Ni) alloy is commonly used to protect the substrate from oxidation and corrosion, as well as to improve the bonding strength between the TC and the BC layers. However, delamination of the TBC can occur, because of significant thermal stresses generated when the coating cools down from high to room temperature. Therefore, improvement of TBC delamination resistance is indispensable.

Delamination of the TBC is caused by the Thermally Grown Oxide (TGO) formed at the interface between TC and BC, because of the discrepancy in the thermal expansion coefficient between TGO and TC or BC. Therefore, the TBC formation control is important to improve the delamination resistance of TBC. Previously, authors have succeeded in improving the delamination resistance of TBC by adding cerium (Ce) to the CoNiCrAlY alloy as a BC which assist the formation of the inward TGO. The inward TGO reduces the thermal stress experienced by TBC through the formation of vertical cracks initiated by the inward TGO. However, the inward TGO only forms when the temperature is over 1100°C, which is higher than the substrate temperature during the gas turbine thermal power plants operation temperature. As a result of further research, authors have succeeded in reducing the inward TGO formation temperature to 1000ºC close to the actual use environment by adding ceria (CeO_2) instead of Ce to the BC materials.
In our studies, it was improved that the TBC delamination resistance thanks to the introduction of internal oxidation during BC formation using High Velocity Oxy-Fuel (HVOF) technique. It was showed that internal oxidation introduced during the film formation proceeded sufficient inward oxide at high-temperature exposure (900°C) and exhibited high delamination resistance. Thus, adding CeO_2 to the CoNiCrAlY alloy and introducing internal oxidation during BC formation is efficient to reduce the inward oxide formation temperature.
However, when the inward oxide is introduced to BC, the internal oxidation might reduce the oxidation resistance of TBC system. In addition, oxidation and corrosion of the substrate can occur due to direct exposure to the combustion environment through vertical cracks. Therefore, it is needed to develop a new BC combining oxidation resistance and delamination resistance. Two-layer BC is considered. The first layer of the BC, located on the substrate side, has less internal oxidation and helps in the protection of the substrate. The second layer of the BC, located on the TC side, has a lot of internal oxides and improves the coating delamination resistance. Thus, it possible to develop TBC compatible with delamination resistance properties and substrate protection properties.

The aim of our study is to improve the delamination resistance of TBC and develop TBC with reduced inward TGO formation temperature. For this purpose, TBC with CeO_2 and ZrO_2 added to the BC material were prepared. To perform TBC specimens with internal oxide in the BC, BC materials with several particle sizes and several BC spraying methods were used. The internal oxide amount and delamination resistant property of these TBC specimens were evaluated with SEM observation and four-point bending test. And also, the high-temperature oxidation behavior and the delamination resistance of TBC with two layers of BC, aiming to achieve both delamination resistance and substrate protection, were evaluated.