Multi-layer Thermal Barrier Coating of a New Architecture

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ABSTRACT

Thermal barrier coating (TBC) provide a thermal and corrosion insulation layer able to decrease thermal loads on the surface of major operating metallic parts of gas turbines. The search for means to increase the operation temperature of turbines (necessary to increase their efficiency) is directed to creation of new materials for TBC, as well as new structures of TBC. The concept of the proposed technology is multi-layer TBC consisting of two-layer bondcoat and overlying topcoat oxide layer. The essential difference from existing designs of TBC is that the second layer of the bonding layer is made of an oxide and has the chemical composition similar to that of the adjacent overlying topcoat oxide layer

Keywords: thermal barrier coating, bondcoat, topcoat, multi-layer

1 INTRODUCTION

The cooling of gas turbine engine components with air blowing through the inner cavity provides a means for their operation capability at high (1000°C) temperatures. Further increase of the gas temperature however leads to higher thermal flow to operating turbine components, while intensification of their inner cooling is difficult to realize, since it leads to a higher temperature overfall through the side. This has a negative impact upon thermo-circling resource of operating turbine components. One of means to withstand high flowing gas temperature, while conserving the thermo-circling resource, is application of thermal barrier coatings providing a thermal flux decrease reaching the surface of major operating parts of turbines. TBCs are refractory-oxide ceramic coatings applied to the surfaces of metallic parts in the hottest part of gas-turbine engines, enabling modern engines to operate at significantly higher gas temperatures than their predecessors [1]. Improvement in the performance of TBCs still remains a key objective for further development of gas turbine applications. This requirement has thus led to a demand for TBCs with lower thermal conductivity and longer lifetime [2]. In an effort to improve the efficiency and durability of gas turbines, research and development of TBC coating systems are being conducted worldwide [3].

2 ADVANCED THERMAL BARRIER COATINGS

Advanced thermal barrier coating systems have the following construction. The substrate made of refractory alloy is coated with an intermetallic bonding layer upon which, in turn, a covering top layer of refractory oxide ceramics is deposited. The bonding layer is usually made of MCrAlY or else aluminum-containing alloy, while the top coat is stabilized zirconia. The search for means to increase the operation temperature of turbines (necessary to increase their efficiency) is directed to creation of new materials for bond and top layers, as well as new constructions of thermal barrier coats, e.g., multi-layer thermal barrier coating systems.

Known in the art is multi-layer thermal barrier bond coat consisting of metallic or intermetallic two- or tri-layer bonding layer, both layers of which are made of different metals or alloys, and an overlying oxide top layer [4]. The coating is prepared by deposition of a metallic or intermetallic two- or tri-layer bonding layer on a refractory substrate, on which the overlying oxide top layer is deposited. Two-layer bond coat have an oxidation resistant layer and a spallation resistant layer. The shortage of the prototype coating is insufficient persistence to thermal circling and degradation of the thermal barrier effect during exposure at operating temperatures due to application of different materials with non-similar thermal expansion coefficients. There are three borders between materials having different thermal expansion coefficients in this coat construction: substrate - first metallic layer of the bonding layer, first metallic layer of the bonding layer – second layer of the bonding layer, and second metallic layer of the bonding layer – top layer of refractory oxide ceramics. In the case of tri-layer bond coat there are four borders between materials having different thermal expansion coefficients. We proposed the construction of multi-layer thermal barrier bond coat that overcomes these drawbacks [5].

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3 BONDCOAT CONTAINING OXIDE LAYER

The essence of the disclosure is a multi-layer thermal barrier coating consisting of two-layer bonding layer and overlying top oxide layer with an intermetallic first bonding layer. In accordance with the disclosure, the second layer of the bonding layer is made of an oxide and has the chemical composition similar to that of the adjacent overlying top oxide layer and the method of coating fabrication including deposition to the substrate of a two-layer bonding layer and a overlying top layer, wherein the oxide layer of the bond layer is obtained by electron beam deposition method, while the overlying oxide top layer is obtained by atmosphere plasma spraying method.

Fig. 1 is a schematic construction of the proposed coating.

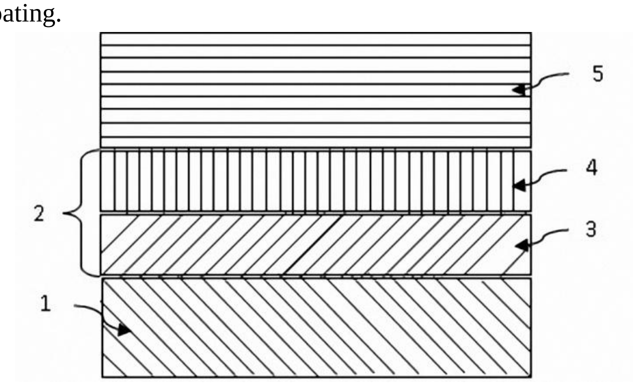

Fig. 1. Schematic construction of the multi-layer thermal barrier coating.

The structure comprises substrate made of refractory alloy (1) on which there is provided a bond coat layer (2) over which, in turn, the subsequent top layer (5) is deposited. Bonding layer (2) consists of two layers: an intermetallic (3) and the oxide (4). The ratio of thicknesses of layers (4) and (5) determines the correlation of mechanical and thermo-isolating performance of the covering. For those turbine components experiencing high mechanical force during operation, e.g. turbine blades, the ratio of thickness of layer (4) to that of layer (5) should be higher than for those turbine components experiencing lower mechanical load, e.g. combustion chamber.

Proposed invention is realized in the following way. The substrate of refractory alloy, for example MoTi1.15Fe3.14Ni23, cleaned by ultrasonic treatment and chemical methods, and is covered by a bonding layer on which, in turn, an overlying top layer of refractory oxide is deposited. The applied over the substrate bonding layer is comprised of two layers: the first layer is made of a metal alloy, e.g., TiCrAlY or other aluminum-containing alloy, e.g. MCoCrAlNi composition consisting of 2-25wt% Co, 4-21wt% Cr, 10-15wt% Al, 0.1-1wt% Hf, 0.1-1wt% Y, 0.1-1wt% Si, 0.1-1wt% Zr, and the balance nickel. The first metallic layer of bond coat can have a thickness of 0.005 – 0.2 mm and can be deposited by various methods, such as e-beam or cathode deposition methods etc. Second oxide layer of bond coat must be deposited from materials having high melting temperature and stability at high temperatures, for example M_2O_3, $MAlO_3$, $M_3Al_5O_{12}$, $MMgAl_{11}O_{19}$, $MMnAl_{11}O_{19}$, where M=La – Lu, Y,Sc, as well as Y-, or rare earth elements stabilized zirconium oxide cubic structure of $Zr_{1-x}Y_xO_2$.

The second layer of bond coat can have a thickness of 0.001 – 0.3 mm and is deposited by electron beam deposition and, due to that, possessing columnar structure. The top overlying layer is deposited on second oxide layer of bond coat, have the same composition, for example M_2O_3, $MAlO_3$, $M_3Al_5O_{12}$, $MMgAl_{11}O_{19}$, $MMnAl_{11}O_{19}$. The top overlying layer can have a thickness of 0.01 – 0.5 mm and must be deposited by plasma spraying and, due to that, possessing granular microstructure with pores. The oxide layer of the bonding layer and the overlying top layer have the same composition. Due to this, provided are similar thermal expansion coefficients of these two layers and a higher tolerance to thermo-circling of the product.

ACKNOWLEDGMENT

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