THERMAL STRESS ANALYSIS OF DOUBLE-CERAMIC-LAYERED THERMAL BARRIER COATINGS BASED ON RARE EARTH ELEMENT

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So far, many studies have been conducted to increase the operating temperature of gas turbine engine because it enables to achieve the high efficiency with lower emission. As a part of continuous studies, various thermal barrier coatings (TBCs) have been applied onto hot-components as an efficient thermal insulating system. A typical TBC system consists of four layers: a metallic substrate, bond-coats, top-coats and thermally grown oxide between bond-coats and top-coats. Conventionally, top-coats are made of ceramic material such as 8% mol yttria stabilized zirconia (8YSZ) because of its low conductivity. However, 8YSZ based TBC suffers from considerable damage during the operating above 1200° due to the phase transformation and sintering, resulting in volume change and a decrease of strain tolerance.[1] Therefore, several oxide groups having the pyrochlore or fluorite structure are recommended to replace 8YSZ. To date, $La_2Zr_2O_7$ (LZ), $La_2Ce_2O_7$ (LC), $LaTi_2Al_9O_{19}$ (LTA) and $Sr(Zr_{0.9}Yb_{0.1})O_{2.95}$(SZYb) are of high interest.[1-3] Besides, double ceramic layer (DCL) is also applied on the bond-coats to improve the durability of TBC. Generally, the first top-coat (TC1) is made of the conventional 8YSZ as stress buffer on the bond-coats. Then, an alternative material is deposited as the second top-coat (TC2). In this study, using finite element (FE) analysis, we investigate thermal stress of the DCL typed TBC based on candidate materials when they have the same thermal insulating capacity above 1200°. As shown in fig. 1, a periodic FE model is constructed by taking both thermo-mechanical behavior and topological characteristics into account. Assuming that the turbine inlet temperature is 1500°, the surface of TC2 is heated by impinging gas of 1300° and the substrate is cooled by the internal cooling air equivalent to 700° for 3 cycles. As a result, the system having the lowest thermal stress is LC, followed by LTA, SZYb, and LZ. For all materials, the maximum stress always occurs during the heating period. Remarkably, the position and the moment where the maximum stress occurs are all different. The maximum stress is observed at the vicinity of the wavy oxide layer or TC2. But its moment is irregular such that it may occur at either the highest temperature or the room temperature. Consequently, it can be assumed that the service life is affected by not only the highest temperature but also the temperature difference during the operating cycle. Although LC is determined as the most suitable system to the given specific operation condition, there would exist the other optimal systems for different operation conditions, which can be further investigated by the proposed FE analysis in this study.

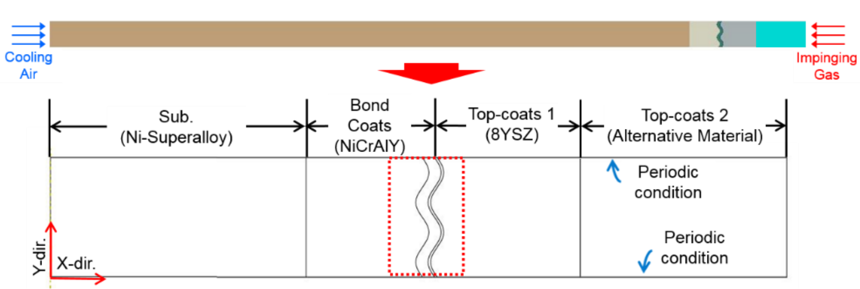

Figure 1 - An FEM model and its boundary conditions

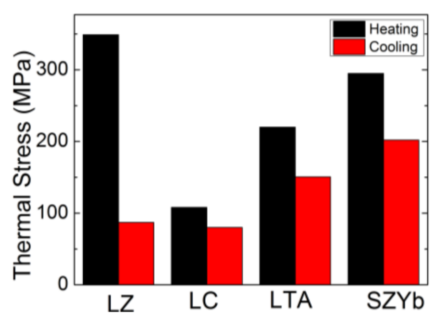

Figure 2 - Thermal Stress of DCL typed TBC based on alternative materials

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