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The influence of interface morphology on the stress distribution in double-ceramic-layer thermal barrier coatings

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Abstract

The influences of the interface morphologies upon the stress distribution in the double-ceramic-layer thermal barrier coating (DCL-TBC) have been mainly studied in our present article using the finite element method. The two important interfaces in the DCL-TBC, which are interface #1 (the interface between two ceramic layers) and interface #2 (the interface between the inside ceramic layer and the bond coat (BC)), are modeled as a sinusoidal wave with considering different values of the amplitude.Results show that the interface #1 has important influence upon the stress of the top ceramic layer. Especially, in the edge of the model, the rougher interface can relief the high stress level of the top ceramic layer caused by the edge stress concentration. Similarly, the influence of the interface #2 upon the stress of different parts of the thermal growth oxide layer has also been studied.

Keywords: Double-ceramic-layer thermal barrier coating; Interface morphology; Stress distribution; Finite element simulation

1. Introduction

Double-ceramic-layer thermal barrier coating (DCL-TBC), which includes a top ceramic layer (TC1), an inside ceramic layer (TC2), a bond coat (BC) and an alloy substrate (SUB), turns out to be an effective method to meet the demand for developing thermal barrier coatings [1–6]. The TC1 layer is made by these new ceramic materials, such as lanthanum zirconate (LZ), cerium lanthanum zirconate (LZ_7C_3), which can ensure that the coating system has good heat insulating performance. The TC2 layer is usually made by the traditional TBC materials, generally 8YSZ, which has the larger thermal expansion coefficient. The inside ceramic layer is mainly designed in the DCL-TBC as a stress buffer layer to ensure the coating system has low stress level [4].

It should be mentioned that in the case of a thermally sprayed TBC or DCL-TBC, the rough interface is initially obtained during the sand blasting step [7]. The influence of the interface morphology on the stress of the traditional TBC has been studied by lots of authors [6–14]. The rough interface in the coating system improves the adhesion and can apparently increase the lifetime of a plasma-sprayed TBC system [7–9] during the thermal cycling process due to the apparition of a compressive zone. However, many studies have shown that the maximum stress level in the TBCs always occurs at the TBC/BC interface during the thermal cycle. The rough interface in the coating system can also increase the tensile stress level or the tensile stress range in the coating system [15–18]. Once the stress level at the interface exceeds the interface strength, the material can be damaged [6–9,19–21]. However, similar study on the influence of the interface morphology in the DCL-TBC has not yet been reported. It had been presented in previous articles [4] that the DCL-TBC has a major difference comparing with traditional TBC: the DCL-TBC has two ceramic layers. Thus, there are two interfaces in the DCL-TBC: the interface between the two ceramic layers, and the interface between the TC2 layer and the TBC layer. As the thermal growth oxide (TGO) formed during the thermal cycling process and the TGO layer is rather thin, the interface between the TC2 layer and the BC layer is just the morphology of the TGO

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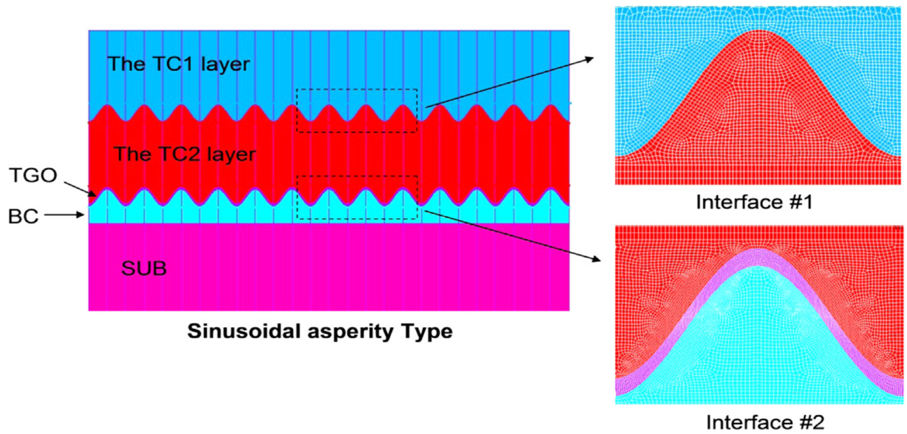

Fig. 1. The schematic view of the numerical model.

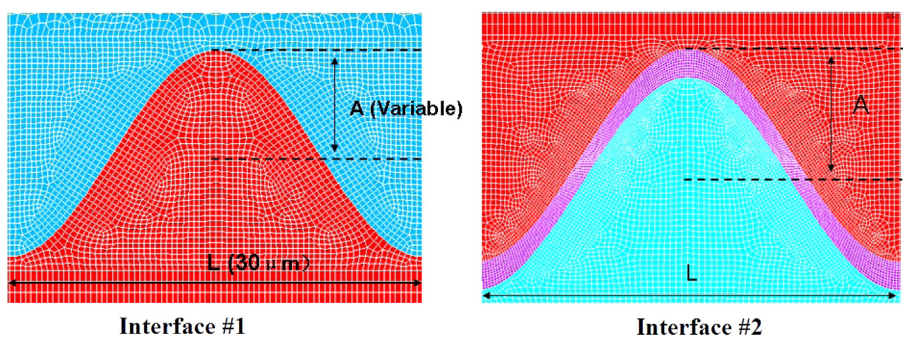

Fig. 2. The parameters of the interface wave.

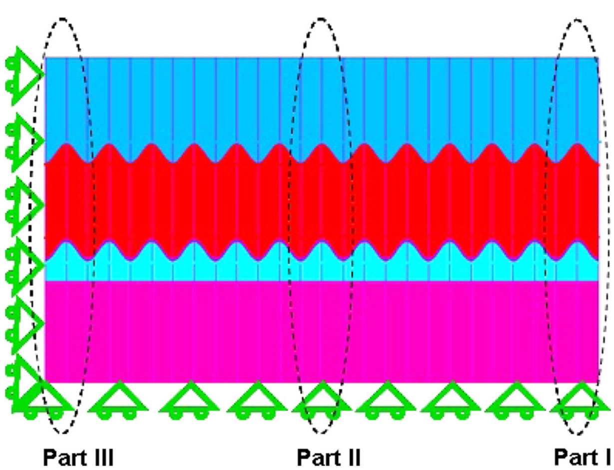

Fig. 3. The three parts in study and the boundary conditions of model .

layer. It has been discussed in previous articles that the TC1 layer and the TGO layer are deemed as two dangerous positions to constrain the life of DCL-TBC based upon previous studies [1–4]. It can be concluded that these two interfaces, which are closely next to these two dangerous positions, will have much influence upon the stress of these two layers, and finally will have much influence upon the failure behaviors and the thermal cycling performance of the DCL-TBC.

Based upon these considerations, the influences of the interface morphologies upon the stress distribution in the DCL-TBC have been mainly studied in present article using the finite element method. A numerical model, which is different from the model reported in previous articles [4] and can account for the effects of different interface parameters, has been developed to assess the thermo-mechanical behavior of the DCL-TBC system using the finite element code ANSYS. The studies detailed in present article have revealed the unique influence law of the interfaces in the DCL-TBC comparing that in the traditional TBCs. Some important and meaningful conclusions, which have important guidance significance upon studying the failure behavior and optimizing the interface roughness of the DCL-TBC, have been discussed and summarized in present article.

2. The simulation scheme

As shown in Fig. 1, the finite element model consists of two air plasma-sprayed ceramic layers, which are top ceramic layer (TC1) and inside ceramic layer (TC2), thermally grown oxide layer (TGO), bond coat (BC), substrate layer (SUB). This model is similar to the model used in previous works [4], and the major difference is that the two interfaces in present model are taken to be a sinusoidal wave, as shown in Fig. 1. Same with the model in [4],