Development of Nondestructive Evaluation Methods for Ceramic Coatings

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Introduction

Nondestructive evaluation (NDE) methods are being developed for use with ceramic coatings for components in the hot-gas path of advanced gas-fired turbine engines with low emissions. The main coatings studied are thermal barrier coatings (TBCs), for vanes, blades, and combustor liners to allow hotter gas-path temperatures. The NDE methods will be used to a) provide data to assess the reliability of new coating application processes, b) identify defective components that could cause unscheduled outages, c) track growth rates of delaminations and defects during use in engines, and d) provide data for reaching rational decisions for replace/repair/re-use of components.

Thermal Barrier Coatings

Advances in thermal barrier coatings (TBCs), using two deposition methods, electron beam–physical vapor deposition (EB-PVD) and air plasma spraying (APS), are allowing higher temperatures in the hot-gas path of gas turbines including syn-gas fired turbines(1-3). However, as TBCs become "prime reliant," it becomes important to know the condition of the TBCs at scheduled or unscheduled outages. Work at Argonne National Laboratory (ANL) is underway to develop NDE methods to assess the condition of the TBC primarily from the point of view of detecting pre-spall conditions. Prior to spallation of EB-PVD coatings, it has been shown, see Fig. 1, that the interface topography between the thermally grown oxide layer (TGO) and the substrate, changes as a function of the number of thermal cycles (4). The growth and change in topography for APS coatings is less clear at the present time. However, if an NDE method could be developed that would allow interrogation of this interface for either EB-PVD or APS coatings, , it would seem possible to begin to develop pre-spall prediction. One such NDE method under development utilizes polarized laser light in a back-scattering mode , see Fig. 2. This method is based on a modification of the reflectometry method (5) and a description of this method was presented previously (6). Laser scatter data for an entire test sample are acquired by raster scanning the sample under computer control. During this past year, several sets of TBC samples were examined that were produced using both EB-PVD and APS methods. The results reported here are for the APS samples. These were 25 mm diameter button shaped samples produced using CMSX-4 substrate. The bond coat, also applied by APS, was an MCrAlY and the TBC was a 7 wt % YSZ. The YSZ composition was changed for each of the two sample sets. These samples were thermally treated by using an isothermal furnace using a one-hour cycle time. The laser back scatter data were acquired prior to thermal cycling and again after, 233 and 326 cycles. Then sample set A was examined after 374 cycles and sample set B after 399 cycles. By using digital image processing, the coefficient of variation from the collected laser back scatter could be obtained after each set of thermal treatments. The coefficient of variation for each sample was then plotted as a function of the number of thermal cycles as shown in Fig. 3. Clearly, as the samples approach spallation, the coefficient of variation changes significantly. These samples spalled after another 30 cycles.

References

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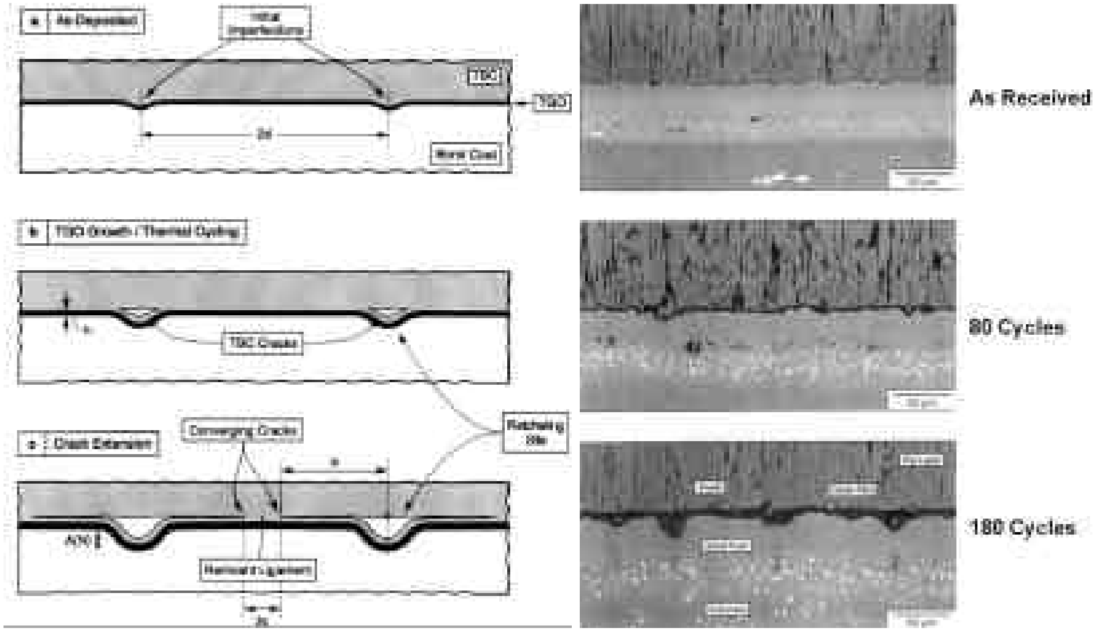

Fig 1. Schematic diagram and optical photomicrographs showing changes in topography between TGO and substrate for EB-PVD TBC (based on Ref. 4)

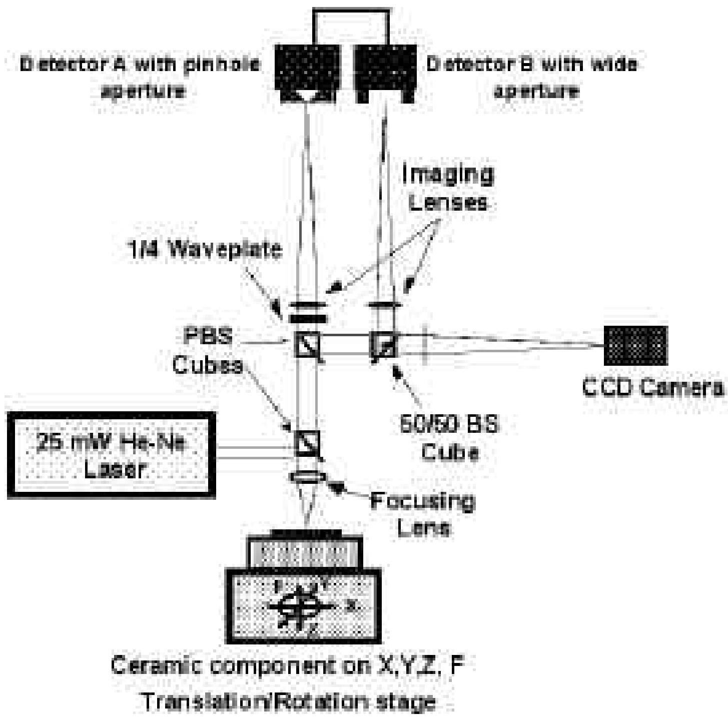

Fig 2. Schematic diagram of the polarized laser back-scatter NDE method for studying the topography of the TGO-substrate interface.

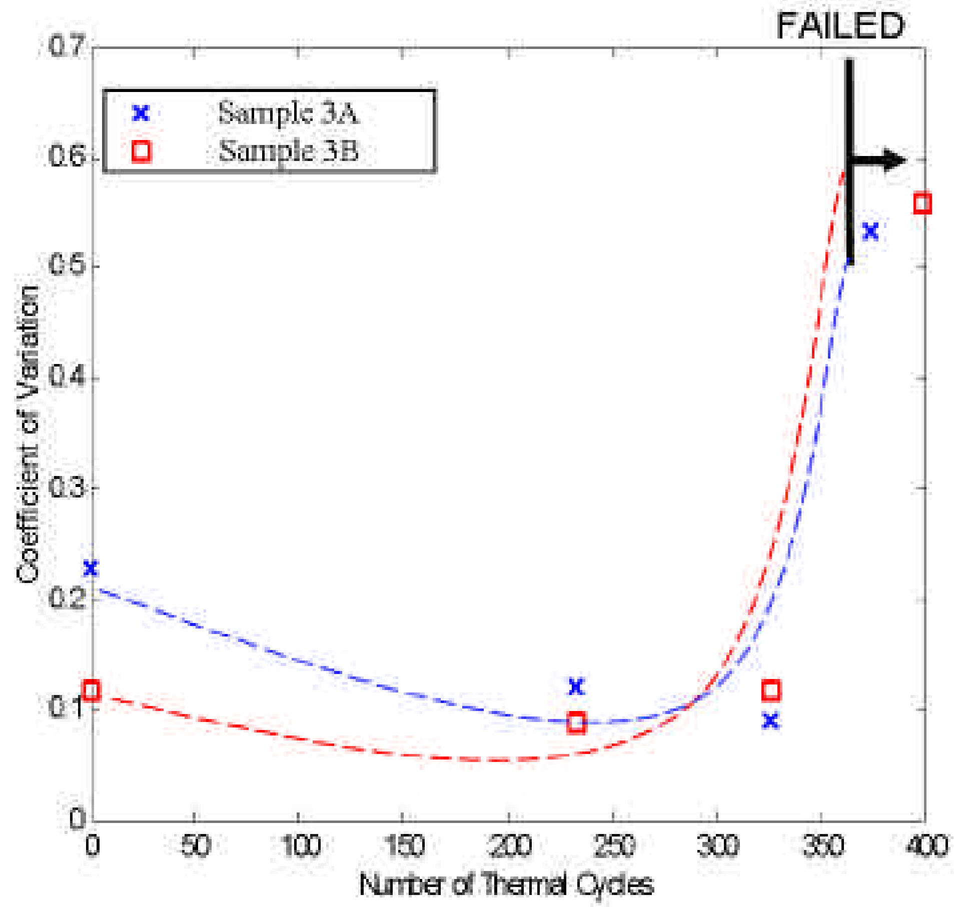

Fig 3. Change in Coefficient of variation as a function of number of thermal cycles for laser scatter data from APS TBCs