THERMO-MECHANICAL ANALYSIS OF BLISTER DAMAGE IN EB-PVD TBC SYSTEM: EXPERIMENTS AND MODELING

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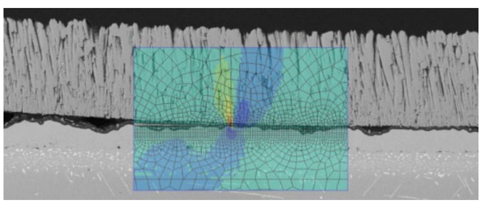
To improve high-pressure turbine blades or vanes efficiency, thermal barrier coating optimization should now integrate both sounded thermo-mechanical characterization and robust modeling for design purpose. This paper aims at demonstrating the benefit of processing interfacial defect to get large improvement in damage monitoring possibilities. This is achieved by the use of laser adhesion test method detailed in the sequel as LASAT, yielding a blister known in size and location. Modelling of the blister in anisothermal condition yields new understanding of TBC damage related to the so-called rumpling mechanism.



The LASAT consists in the use of a *ns* LASER, to provide a laser shock, yielding a compressive wave in a solid, which after reflection on a free surface becomes tensile. For LASER energy above a given threshold, it is possible to induce cracking, and in a multilayer material this could be an interfacial crack when interface toughness is lower than bulk materials' toughness [1]. This interfacial crack could be used as a pre-defect to monitor damage associated to the crack tip under any applied loading. In the case of EB-PVD TBC systems, it has been shown that with this technique, measurement of damage under thermal cycling [2] or for burner rig facility [3] was possible using interrupted tests. Non destructive measurements of blister geometry evolution and interfacial delamination were achieved respectively by optical profilometer and infra-red thermography. Recently, thermo-mechanical fatigue tests, for in- and out-of-phase conditions have also shown the possibility to measure damage from this blister for severe loading condition. These aspects will be commented into a large extent in this paper.

On the other hand, finite element analysis (FEA) of the TBC could now consider details of morphology and behavior (see figure). Again, the artificial blister processed by LASAT helps in defining robust model by sensitivity analysis. Indeed, the blister has been modelled accounting for several driving forces known to impact TBC systems: the blister geometry, which is quiet large (height > 20 µm, width > 2 mm), the interfacial roughness, of a lower scale length (amplitude < 10 µm), the top-coat (TC), thermal grown oxide (TGO), bond-coat (BC) and substrate layers. Finally, by modelling elasticity for TC, TGO and substrate, viscoplasticicity for BC [4], and strain growth within the oxide [5], the correlation between rumpling and increase of blister height in the course of thermal cycling has been proven. This constitutes an additional proof of the link between oxide growth kinetic and interfacial damage in TBC systems.

Bibliography

[1] Berthe, Laurent, et al. "State-of-the-art laser adhesion test (LASAT)." Nondestructive Testing and Evaluation 26.3-4 (2011): 303-317.
[2] Maurel, Vincent, et al. "Thermal cycling damage monitoring of thermal barrier coating assisted with LASAT (LAser Shock Adhesion Test)." Surface and Coatings Technology 380 (2019): 125048.
[3] Maurel, Vincent, et al. "Recent progress in local characterization of damage evolution in thermal barrier coating under thermal cycling." Superalloys 2020 (2020): 813-823.
[4] Texier, Damien, et al. "High temperature micromechanical behavior of a pt-modified nickel aluminide bond-coating and of its interdiffusion zone with the superalloy substrate." Metallurgical and Materials Transactions A 51.4 (2020): 1475-1480.
[5] Frachon, Julien. Multiscale approach to predict the lifetime of EB-PVD thermal barrier coatings. Diss. École Nationale Supérieure des Mines de Paris, 2009.