Nondestructive Characterization of Plasma Spray Coatings—Some Recent Industry/University Work*

A. Abbate, W. Russell, and P. Kotidis, Textron Systems and C.C. Bemdt, SUNY at Stony Brook

Introduction

A nondestructive laser-ultrasonic technique and instrumentation for simultaneously measuring the thickness and the elastic properties of ceramic plasma sprayed thermal barrier coatings (TBCs) is currently being developed by Textron Systems, Inc. in collaboration with the Center for Thermal Spray Research of SUNY at Stony Brook. Tests have been performed on TBC samples ranging in thickness from 100 to 700 μm. These coatings were manufactured from yttria-stabilized zirconia (YSZ) feedstocks of identical chemistry, yet different particle size distributions, to investigate processing effects on coating material

***This is a "work in progress," and readers are invited to contact the authors and submit any comments. Other authors are invited to present short notes concerning current research that should be rapidly communicated.**

properties that could result in coatings with different mechanical properties.

Background

Plasma sprayed coatings are widely used to protect parts from aggressive environments. In applications such as land-based gas turbines, TBCs are used to protect the turbine components from very high operating or firing temperatures. The TBCs are commonly applied by the standard air plasma spray process, which is an open-loop operation with no feedback about the coating conditions during deposition (Ref 1). It is very important to be able to assess the properties of the coating layer and its thickness as it is deposited, since on-line variations of the spray conditions, such as continuous wearing of the torch hardware, can adversely affect the coating quality and create significant part-to-part variations. Unfortunately, the standard method of evaluating coatings is destructive in nature; hence these tests cannot be performed on each produced part (Ref 2). As a result, coated parts may not have the consistent quality and durability needed for many applications (Ref 3).

Laser ultrasonics is based on the generation and detection of ultrasonic waves using lasers, thus avoiding any contact to the part (Ref 4). A short laser pulse, typically 10 to 15 ns in duration, is used to generate a thermoelastic stress wave of small amplitude by local heating of the sample. This ultrasonic stress wave has the typical shape of a spike (Ref 5). A second laser beam, located at a fixed distance from the generation point, is used for detection. In a uniform material, such as an uncoated part, the detected ultrasonic signal resembles the laser pulse delayed by the time necessary for the wave to travel from the generation point to the detection point.

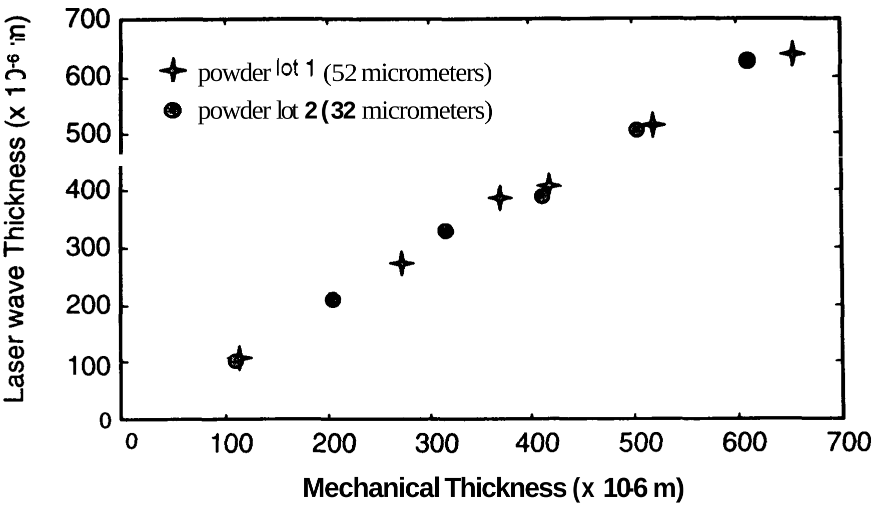

Fig. 1 **Comparison between average mechanical thickness obtained using a micrometer and the thickness measured using the laser ultrasonic technique.**

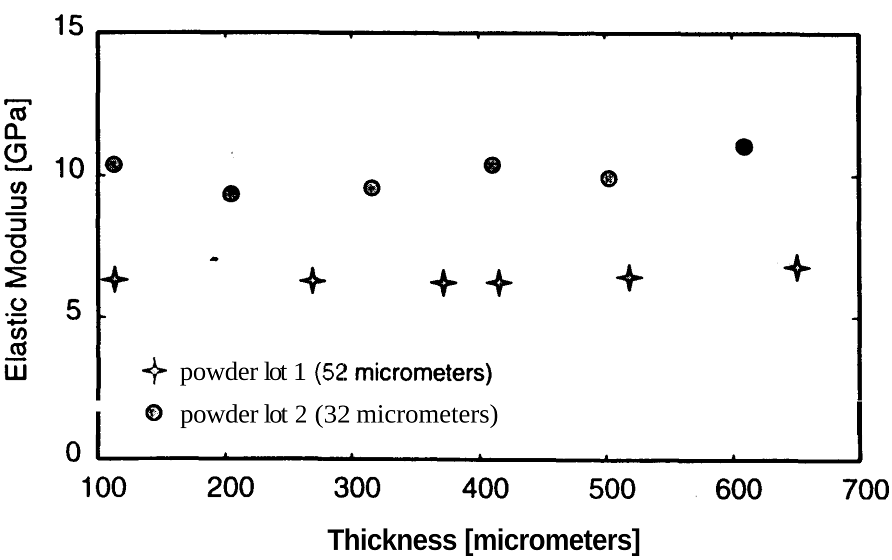

Fig. 2 **Plot of the elastic modulus measured using the laser ultrasonic technique.**

Results and Summary

The mean powder sizes used in this experiment were 52 and 32 pm, for feedstock lots 1 and 2, respectively. The corresponding densities were measured to be 5.16 and 5.3 **g/cm^3**, with relative porosities of 12.0 and 11.7%.

By comparison and fit of the experimental signals and the theoretical prediction models of dispersion, the elastic modulus and the thickness of the TBC can be simultaneously obtained. For example, by using the information contained in the signal and the dispersion curve, the elastic modulus and the thickness of the TBC were measured to be 6.7 ± 0.4 **GPa** and 638 ± 20 pm, respectively. By comparison, the thickness of the coating was estimated to be 621 **µm** by mechanically measuring the sample before and after the deposition process. The estimated error for the micrometer is about **10 µm.**

Thickness readings have been compared to conventional micrometer measurements, and an accuracy of **15 µm** for the ultrasonic measurement was established (Fig. I). This measurement procedure is currently being incorporated into standard **LaserWave** Analyzer equipment, which will allow real-time control of the plasma process **with** increased efficiency in deposition.

Figure 2 indicates the nondestructive determination of the modulus for a variety of TBC coatings manufactured from the two feedstocks. These results indicate that the TBC manufactured from the finer powder exhibits the greater modulus, ~10 **GPa** compared to 5 **GPa** for the TBCs manufactured from the 52 µm feedstock. It is important to note that whereas the overall porosities of the two types of coating were approximately equivalent (~12%), the porosity distributions (not reported here) indicated that the coarse powder (52 pm) exhibited larger void sizes. These modulus values arc lower than destructive measurcmcnts rcportcd in thc litcraturc. Thcrcforc, it is thought that thc lascr ultrasonic mcthod allows a dircct mcasurcmcnt of splat-to-splat intimacy, and that thc numerical mcasurcmcnts obtaincd in this work bcttcr dcscribc thc naturc of thc structurc/propcrty rclationships of thcrmal spraycd matcrials.

Contact: A. Abbatc, Tcxtron Systcms, 201 Lowcll St., Wilmington, MA 01887-2941; tcl: 978/657-1910; fax 978/657-6770; c-mail: aabbatc@systcms.tcxtron.com; or C.C. Bcrndt, SUNY at Stony Brook, Stony Brook, NY 11794-2275; tel: 516/632-8507; fax: 516/632-8525; c-mail: cbcrndt@ ccmail.sunysb.cdu.

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