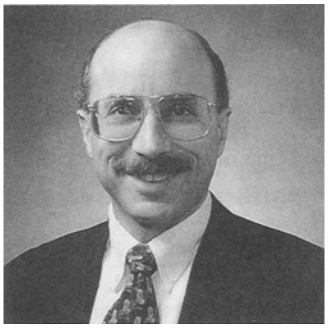
Editorial



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Thermal Barrier Coatings

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If you've flown in a turbine-powered aircraft recently, you almost certainly flew in a plane that used thermal barrier coatings (TBCs) in the engines. What's more, if the plane you rode in used current generation turbine engines, the TBCs were included as a part of the initial engine design. This represents a significant change from relatively recent thinking, when TBCs were considered a "Band-Aid" solution to thermal management problems in turbines. The vast change in attitude is the result of one overriding factor: TBCs work.

TBCs are simply a method of insulating a component from the high temperatures that exist in a hot engine. Current production TBCs insulate well enough to achieve an average reduction in the metal temperature for aircraft engine turbine blades of 50 to 80 °C (Ref 1, 2) and reductions in blade hot-spot temperatures of up to 139 °C (Ref 3). But even this significant temperature reduction is only a fraction of the capability of TBCs, estimated at 170 °C or more (Ref 1). There are no other technologies that will be available in the near-term or even midterm that offer the high potential of TBCs. The real current thermal benefit combined with the phenomenal potential benefit is the reason that TBCs are included in the turbine design of every advanced gas turbine engine on the commercial transport market and are being designed into the next generation engines (Ref 4).

The high potential is also the reason why TBCs are in use and under intense scrutiny for increased use in land-based turbines and diesel engines. In land-based turbines, TBCs have been under study for nearly 20 years and in use in combustors for 10 years. While initial development followed aircraft turbine development closely, it is expected that TBC development for turbine blades of land-based turbines will diverge from that for aircraft. This is due to the significantly different and very challenging conditions to which land-based turbine coatings will be exposed, the chief difference being much longer times at high temperatures (Ref 5, 6). TBC modeling and actual testing to date has demonstrated the high potential benefits for TBC use in land-based turbines (Ref 6-8).

TBCs for diesel engines were initially pursued following reports of greatly increased fuel efficiency for a low heat rejection (adiabatic) engine (Ref 4, 9-11). Companies working in the area had first to develop a coating that was sufficiently durable in order to determine experimentally if coatings could actually increase fuel efficiency. Research and development led from aircraft-style abradable outer air seals (thick, graded TBCs), to the development of graded coatings that are highly effective in a diesel engine (Ref 10-12). The development of durable graded TBCs enabled meaningful testing of TBCs in heavily instrumented test engines. The result was that fuel efficiencies were increased, but not as high as had been hoped (Ref 9, 10). While the promise of a very high-efficiency insulated engine has not been realized, efforts have turned to the dual purpose of enhancing component durability for increasingly severe thermal conditions in diesel engines while improving efficiency by a moderate amount (Ref 9). In this aspect the diesel engine TBC goals have become more similar to those for aircraft engines; that is, to maintain component durability while running at higher engine operating temperatures (Ref 9).

TBCs have already been proven to provide significant temperature reduction for heat engine applications. Currently, most of that reduction in aircraft engines is used for "component life extension." Component life extension is clearly worth the cost of adding TBCs, but the largest payoffs for TBC use are associated with increasing engine efficiency through increased operating temperatures. This big payoff is achievable if the primary issues of durability, reliability, and insulation can be adequately addressed (Ref 4, 13). The wide range of topics related to these primary issues includes TBC failure mechanisms as a function of operating conditions (in aircraft, land-based turbines, and diesel engines) (Ref 1, 2, 4, 11, 14, 15), determination of mechanical and physical properties most relevant to durability and reliability (Ref 4, 12, 16-18), development of test methods to determine the properties for these unique materials (Ref 19, 20), determination and control of thermal properties of TBCs, especially the heat transfer through the coating (Ref 13, 21, 22), design philosophy for a specific application and design of new TBCs (Ref 13), life prediction (Ref 15), and mechanical modeling (Ref 12, 14), time-dependent properties (Ref 16, 17, 20, 22), processing development and process repeatability (Ref 11, 23, 24), and others.

The papers contained in this special issue of *JTST* were presented at the TBC Workshop, held in Cleveland, OH, in March 1995. The Workshop was sponsored by NASA, DOE, and NIST. The intent was to foster open discussion on the existing knowledge about the extremely broad range of TBC issues. These papers, now thoroughly reviewed and edited according to *JTST* guidelines, provide the overall viewpoint that TBCs do indeed work well in current life-extending applications, but that there is a significant amount to learn about TBCs before we can thoroughly understand them. In understanding TBCs, we can then hope to tap their full potential.

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