Notice for the PhD Viva Voce Examination

Mr Pasupuleti Kirti Teja (Reg. No. 1670089), PhD scholar at CHRIST (Deemed to be University), will defend his PhD thesis at the public viva-voce examination on Tuesday, 29 June 2021 at 3.00 pm on the WebEx Meeting platform.

Title of the Thesis	:	**Duplex, Functionally Graded and Multilayered Thermal Barrier Coatings Based on 8% Yttria Stabilized Zirconia and Pyrochlores**
Discipline	:	**Mechanical Engineering**
External Examiner (Outside Karnataka)	:	**Dr Chakravarthy P** Associate Professor Indian Institute of Space Science and Technology Valiamala P.O., Thiruvananthapuram Kerala - 695547
External Examiner (Within Karnataka)	:	**Dr P Sampath Kumaran** Professor Department of Mechanical Engineering Sambharam Institute of Technology M S Palya, Jalahalli East Bengaluru, Karnataka - 560097
Supervisor	:	**Dr Parvati Ramaswamy** Professor Department of Mechanical and Automobile Engineering School of Engineering and Technology CHRIST (Deemed to be University) Bangalore Kengeri Campus Bengaluru - 560074
Co-Supervisor	:	**Dr S V S Narayana Murty** Scientist 'G' and Head of Materials Characterization Division (MCD), Vikram Sarabhai Space Centre Trivandrum – 695022, Kerala

The members of the Research Advisory Committee of the Scholar, the faculty members of the Department and the School, interested experts and research scholars of all the branches of research are cordially invited to attend this open viva.

Registrar

Place: Bengaluru
Date: 23 June 2021

ABSTRACT

Thermal Barrier Coatings (TBCs) protect gas turbine engine metal components while they serve in a high temperature environment (upto 1200℃). 8% Yttria-Stabilized Zirconia (8YSZ) is the current state of the art material for TBCs. Typically, 250 to 500 μm (upto 2 mm) thick TBCs can lower the metal temperature by upto 150°C than the service temperature and thereby enhance life to the components. 8YSZ TBCs however, suffer from (a) increased sinterability, (b) phase de-stabilization and (c) poor adhesion with time in service at high temperature. In order to facilitate longer engine running time, research is being directed towards finding (i) newer materials that do not possess these deficiencies or (ii) configurations that can overcome them. In order to further improve the performance efficiency of the engines, TBC materials with extended thermal fatigue life at higher than current service temperatures (>1100℃) are also being actively investigated. In the same area of research, this thesis presents the findings of work on air plasma sprayed (i) duplex, (ii) functionally graded and (iii) multilayered configurations of TBCs synthesized from commercial 8YSZ and lab synthesized pyrochlore (lanthanum zirconate, lanthanum cerate and lanthanum cerium zirconate) compositions with NiCrAlY bond coat.

Duplex i.e., 2-layered TBCs, synthesized by depositing commercial 8YSZ ceramic topcoat (METCO 204 NS) and NiCrAlY bond coat (AMDRY 962) plasma spray powders on Inconel 718 and/or stainless-steel substrates were used for benchmarking purpose (designated as conventional 8YSZ TBC). Next, TBCs were prepared by using these two powders in blended form (8YSZ+NiCrAlY) to serve as a third intermediate layer between the duplex TBC layers in functionally graded material (FGM) configurations. The role of the third intermediate layer is to minimize the thermal expansion mismatch between the ceramic and bond coat layers at elevated temperatures. 8YSZ FGM TBCs were prepared from three different blends of plasma spray powders of NiCrAlY and 8YSZ (i.e., 25%NiCrAlY +75%8YSZ, 50% NiCrAlY + 50% 8YSZ and 60% NiCrAlY + 40% 8YSZ).

The development of newer ceramic TBC materials and configurations was achieved by the synthesis of novel pyrochlores and FGM TBCs from them. The Rare-earth pyrochlores and Rare-earth zirconate pyrochlores studied were (i) Lanthanum Zirconate (La2Zr2O7), (ii) Lanthanum Cerium Zirconate (La2 (Zr0.7Ce0.3)2O7 and (iii) Lanthanum Cerate (La2Ce2O7). Plasma sprayable powders of these compositions were synthesized in the laboratory via a solid-state method. They were spray-coated by Atmospheric Plasma Spray (APS) method in duplex layers by using three different spray parameters on NiCrAlY bond coated substrates. The spray parameter that provided the best TBC for each composition was identified based on preliminary thermal fatigue tests.

FGM TBCs with (50% NiCrAlY+ 50% 8YSZ) blend as intermediary layer exhibited significantly improved thermal fatigue resistance (life) over conventional 8YSZ TBC (up to 1400℃). Hence, in the FGM pyrochlore system too, further studies were restricted to TBCs with (50%NiCrAlY+50% pyrochlore) blend layers to serve as the intermediate FGM layers.

Further studies involved the synthesis of multilayered TBCs: two types of systems have been experimented (a) FGM with commercial 8YSZ integrated with the pyrochlores - here the intermediary blend layer was (50% NiCrAlY+ 50% 8YSZ), and lab synthesized pyrochlores were the topcoats and (b) 8YSZ as an intermediary layer and pyrochlores as the topcoats.

Identical (to the extent possible) characterization methods were employed to study and evaluate all TBCs synthesized in this research work. They were (1) thermal fatigue tests between high temperature & ambient by using (a) gas flame (1200℃ & 1400℃) and (b) furnace (1150°C) (2) oxidation stability tests (at 800℃,1000℃ and 1150℃) (3) structural phase analysis (XRD) and (4) microstructure with chemical composition analysis (SEM/EDS). The work was aided by studies on adhesion strength test (ASTM C633 standard), residual stress analysis and assessment of thermal barrier effect (temperature drop across TBC) in chosen few TBCs.

TBCs fabricated from three pyrochlores exhibited significant improvements in terms of thermal fatigue resistance at 1200℃ and 1400℃. In duplex, Multilayer (ML) FGM and Multilayer (ML) configurations, La2Ce2O7 (LC) TBC performance was exemplary in all configurations studied in this research work.

XRD analysis of pyrochlores in duplex, ML-FGM and ML configurations TBCs evaluated for thermal fatigue at 1200℃ and 1400℃ (gas flame heating) exhibited no phase destabilization in the failed specimen, confirming the thermal stability of the TBC system within the coated layers. The trend of improved thermal fatigue resistance of lanthanum cerate TBCs continued when studied via high-temperature furnace heating at 1150℃ as well.

The experimental research work with details of TBC systems, processing, characterizations, and discussion based on findings and published literature to explore the prospective TBC material system and configuration with the potential to serve as an alternative to conventional 8YSZ TBC, in terms of life and thermal fatigue resistance, comprise the main contents of this thesis.

Keywords: Thermal barrier coating, functionally graded TBCs, pyrochlores, multilayered TBCs.