THERMAL SCIENCE

International Scientific Journal

Ion V. Ion, Anibal Portinha, Jorge Martins, Vasco Teixeira, Joaquim Carneiro

ANALYSIS OF THE ENERGETIC/ENVIRONMENTAL PERFORMANCES OF GAS TURBINE PLANT

ABSTRACT

Zirconia stabilized with 8 wt.% Y_2O_3 is the most common material to be applied in thermal barrier coatings owing to its excellent properties: low thermal conductivity, high toughness and thermal expansion coefficient as ceramic material. Calculation has been made to evaluate the gains of thermal barrier coatings applied on gas turbine blades. The study considers a top ceramic coating Zirconia stabilized with 8 wt.% Y_2O_3 on a NiCoCrAlY bond coat and Inconel 738LC as substrate. For different thickness and different cooling air flow rates, a thermodynamic analysis has been performed and pollutants emissions (CO, NOx) have been estimated to analyse the effect of rising the gas inlet temperature. The effect of thickness and thermal conductivity of top coating and the mass flow rate of cooling air have been analysed. The model for heat transfer analysis gives the temperature reduction through the wall blade for the considered conditions and the results presented in this contribution are restricted to a two considered limits: (1) maximum allowable temperature for top layer (1200 °C) and (2) for blade material (1000 °C). The model can be used to analyze other materials that support higher temperatures helping in the development of new materials for thermal barrier coatings.

KEYWORDS

thermal barrier coatings, zirconia, gas turbine, heat transfer, thermal and exergetic efficiency, irreversibility, pollutant emissions

PAPER SUBMITTED: 2008-02-22

PAPER REVISED: 2008-09-12

PAPER ACCEPTED: 2008-12-08

DOI REFERENCE: TSCI0901147I

CITATION EXPORT: view in browser or download as text file

THERMAL SCIENCE YEAR 2009, VOLUME 13, ISSUE 1, PAGES [147 - 164]

REFERENCES [view full list]

1. Bejan, A., Advanced Engineering Thermodynamics, 2nd ed., John Wiley & Sons, New York, USA, 1997

2. Teixeira, V., et al., Effects of Deposition Temperature and Thermal Cycling on Residual Stress State in Zirconia-Based Thermal Barrier Coating, Surface and Coatings Technology, 120-121 (1999), Nov., pp. 103-111.
3. DeMasi-Marcin, J. T., Gupta, D. K., Protective Coatings in the Gas Turbine Engine, Surface and Coatings Technology, 68-69 (1994), Dec., pp. 1-9
4. Johner, G., Schweitzer, K. K. J., Flame Rig Testing of Thermal Barrier Coatings and Correlation with Engine Results, Journal of Vacuum Science & Technology, A: Vaccum, Surfaces, and Films, 3 (1985), 6, pp. 2516-2524
5. Cernuschi, F., et al., Thermal Diffusivity/Microstructure Relationship in Y-PSZ Thermal Barrier Coatings, Journal of Thermal Spray Technology, 8 (1999), 1, pp. 102-109
6. Risk, N. K., Mongia, H. C., Semianalytical Correlations for NOx, CO and UHC Emissions, Journal of Engineering for Gas Turbine and Power, 115 (1993), 3, pp. 612-619
7. Clyne, T. W., Gill, S. C., Residual Stresses in Thermal Spray Coatings and Their Effect on Interfacial Adhesion: A Review of Recent Work, Journal of Thermal Spray Technology, 5 (1996), 4, pp. 401-418
8. Teixeira, V., et al., Failure in PVD-Plasma Spraying Thermal Barrier Coatings During Thermal Cycling, Proceedings (Ed. C. Berndt), 8th National Thermal Spray Conference, Houston, Tex., USA, 1995, pp. 515-520
9. Chang, G., Phucharoen, W., Miller, R., Behavior of Thermal Barrier Coatings for Advanced Gas Turbine Blades, Surface and Coatings Technology, 30 (1987), 1, pp. 13-28
10. Evans, A. G., He, M. Y., Hutchinson, J. W., Mechanics-Based Scaling Laws for the Durability of Thermal Barrier Coatings, Progress in Materials Science, 46 (2001), 3-4, pp. 249-271
11. Evans, A. G., et al., Mechanisms Controlling the Durability of Thermal Barrier Coatings, Progress in Materials Science, 46 (2001), 5, pp. 505-553
12. Thompson, J. A., Clyne, T. W., The Effect of Heat Treatment on the Stiffness of Zirconia Top Coats in Plasma-Sprayed TBCs, Acta Materialia, 49 (2001), 9, pp. 1565-1575
13. Vassen, R., et al., New Materials for Advanced Thermal Barrier Coatings, Proceedings (Eds. J. Lecomte-Beckers, F. Schuber, P. J. Ennis), 6th Liége Conference on Materials for Advanced Power Engineering, Liége, Belgium, 1998, pp. 1627-1635
14. Vassen, R., Stöver, D., Functional Gradient Materials and Surface Layers Prepared by Fine Particles Technology, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2001, pp. 199-216
15. Portinha, A., et al., Characterization of Thermal Barrier Coatings with a Gradient in Porosity, Surface and Coatings Technology, 195, (2005), 2-3, pp. 245-251
16. Portinha, A., et al., Stabilization of ZrO2 PVD Coatings with Gd2O3, Surface and Coatings Technology, 188-189 (2004), Nov.-Dec., pp. 107-115
17. Raghavan, S., et al., Thermal Properties of Zirconia Co-Doped with Trivalent and Pentavalent Oxides, Acta Materialia, 49 (2001), 1, pp. 169-179
18. Nicholls, J. R., et al., Methods to Reduce the Thermal Conductivity of EB-PVD TBCs, Surface and Coatings Technology, 151-152 (2002), Mar., pp. 383-391
19. Stöver, D., Funke, C., Directions of Developments, of Thermal Barrier Coatings in Energy Applications, Journal of Materials Processing Technology, 92-93 (1999), pp.195-202
20. Siegel, R., Spuckler, C. M., Analysis of Thermal Radiation Effects on Temperatures in Turbine Engine Thermal Barrier Coatings, Materials Science and Engineering: A, 245 (1998), 2, pp. 150-159
21. Campagnoli, E., Ruscica, G., Factors Affecting the Application of Coatings on Superalloys, High Temperatures - High Pressures, 31 (1999), 3, pp. 321-329
22. Valero, A., et al., CGAM Problem: Definition and Conventional Solution, Energy, 19 (1994), 3, pp. 279-286
23. Yunus, A. C., Michael, A. B., Thermodynamics: An Engineering Approach, 3rd ed., McGraw-Hill, New York, USA, 1998

24. Cohen, H., Rogers, G. F. C., Saravanamuttoo, H. I. H., Gas Turbine Theory, 4th ed., Longman Group Ltd., UK, 1996
25. Kotas, T. J., The Exergy Method of Thermal Plant Analysis, Butterworths, Academic Press, London, 1985
26. Lazzaretto, A., Toffolo, A., Energy, Economy and Environment as Objectives in Multi-Criterion Optimization of Thermal Systems Design, Energy, 29 (2004), 8, pp. 1139-1157
27. Aydin, O., et al., Theoretical Analysis of Heat Transfer through an Idealized Gas Turbine Blade Model with Thermal Barrier Coating, International Journal of Rotating Machinery, 8 (2002), 2, pp. 81-86
28. Lefebvre, A. H., Gas Turbine Combustion, 2nd ed., CRC Press, Boca Ration, Fla., USA, 1998
29. Bejan, A., Kraus A. D., Heat Transfer Handbook, John Wiley & Sons Inc., Hoboken, N. J., USA, 2003

PDF VERSION [DOWNLOAD]

ANALYSIS OF THE ENERGETIC/ENVIRONMENTAL PERFORMANCES OF GAS TURBINE PLANT