THERMEC'2023 - International Conference on Processing & Manufacturing of advanced Materials 2 – 7 July, 2023 VIENNA, AUSTRIA
THERMEC'2023 – Abstract Book http://www.thermec2023.tugraz.at (page 36)

KEYNOTE LECTURE

Thermal residual stresses and fracture in metal-matrix composites: Experimental evaluation and modeling based on the actual microstructure

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Abstract

Processing-induced thermal residual stresses are one of the key issues in metal-matrix composites (MMCs) as they may trigger unexpected failure of structural elements. In the first part, the lecture will address the effect of material microstructure on thermal residual stresses in bulk composites reinforced with alumina particles or porous alumina preforms. By applying two processing techniques (sintering vs. infiltration), different metallic or intermetallic matrices (Cr, NiAl, AlSi12) and particle sizes, a variety of composite microstructures were obtained for which thermal residual stresses of type II were measured using neutron diffraction, X-ray diffraction, and optical techniques. Anomalous size effects in residual stresses were noticed experimentally and explained with the help of numerical simulations based on the actual material microstructure reconstructed from micro-CT images (micro-CT based finite element models). Thermal residual stresses were evaluated also in graded composites (FGMs) emphasizing the role of composition gradient in reducing the residual stresses. In the second part of the talk the influence of microstructure on the mechanical strength and fracture modes of the composites under investigation will be presented. Results from the in-situ micromechanical bending tests conducted under SEM will be discussed. Numerical simulations performed using a micro-CT based FEM model enabled determination of the interfacial failure properties (cohesive strength and fracture energy) at the matrix/reinforcement interface. The actual force-displacement behavior and the crack propagation paths were also reproduced with a good accuracy. Finally, some conclusions will be formulated regarding the relationship between the microstructure, residual stresses and fracture in the investigated MMCs.