Thermal Residual Stresses Effect in Functionally Graded Metal Matrix Composite – Experiment and Simulation

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In ceramic-metal composites thermal residual stresses (TRS) of type II are inherently present at the microscale mainly due to different coefficients of thermal expansion of the phase materials. Such stresses may trigger microcrack nucleation and growth, especially in the ceramic phase or along matrix-reinforcement interfaces. Therefore, the determination of TRS is of continuing research interest both in experimental mechanics and materials modelling [1, 2]. One of the remedies to reduce the TRS is to use graded composites with varying volume fractions of metal and ceramic phases.

Functionally graded materials (FGMs) have been the subject of intensive research both in materials science and mechanics for several decades. The concept of FGM to obtain a gradual change of the macroscopic material properties or reduce TRS is appealing from the application point of view. However, it poses a real technological challenge for materials manufacturers and is quite demanding in characterization and modeling due to complex microstructure and morphology of FGMs.

In this paper an aluminum alloy (AlSi12) matrix composite reinforced with alumina particles (Al_2O_3) with a step-wise gradient in the alumina content (10, 20, 30 vol.%) was manufactured by powder metallurgy route comprising powder mixing in a planetary ball mill and consolidation by hot pressing (HP). The TRS in the single composite layers and the FGM compacts were measured by neutron diffraction at PSI (Villigen, Switzerland).

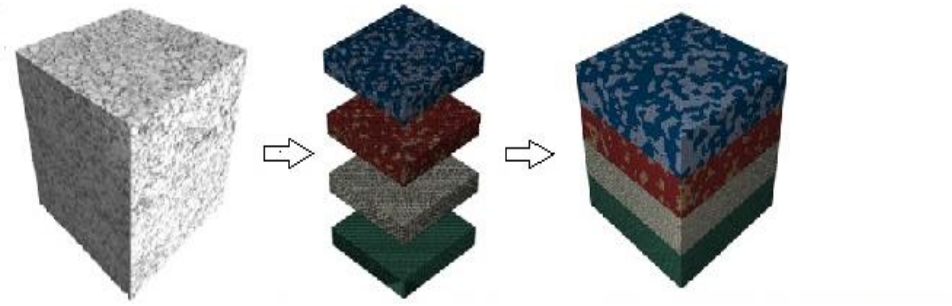

Figure 1. Micro-CT-based FEM modelling methodology

To verify the hypothesis that a graded structure can help minimize the TRS, the results of neutron diffraction experiments were compared with the numerical simulations performed using a FE model based on the real microstructure obtained from micro-CT scanning (Fig. 1). The processing-induced thermal residual stresses (TRS) were measured in the AlSi12 matrix and the alumina phase of the composite and the FGM samples. A good agreement between the micro-CT FEM results and the experimental data was obtained.

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References

[1] J. Maj, M. Basista, W. Węglewski, K. Bochenek, A. Strojny-Nędza, K. Naplocha, T. Panzner, M. Tatarková, F. Fiori, Effect of microstructure on mechanical properties and residual stresses in interpenetrating aluminum-alumina composites fabricated by squeeze casting, Materials Science and Engineering: A, 715 (2018) 154-162

[2] M. Basista, W. Węglewski, K. Bochenek, Z. Poniżnik, Z. Nowak, Micro-CT Finite Element Analysis of Thermal Residual Stresses and Fracture in Metal-Ceramic Composites, Adv. Eng. Mat., 19, 1600725, 2017