X-ray micro-computed tomography based model of thermal residual stress in functionally graded aluminum-matrix composites

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ABSTRACT

In aluminum matrix composites reinforced with ceramic particles (e.g. SiC, Al_2O_3), such as those used in the automotive industry as structural materials for the modern brake discs, the large difference between the thermal expansion coefficients of the matrix and the reinforcement can lead to fabrication-induced thermal residual stresses (TRS) at the microscale. Such residual stresses can locally exceed the material strength and cause microcracking which often leads to uncontrolled cracking of the component under service conditions.

In this presentation, we investigated the TRS in hot pressed (HP) three-layered composite materials (FGM) made of AlSi12 alloy matrix and Al_2O_3 and SiC reinforcement with 10, 20, and 30% volume content. The main objective of the work was to develop a numerical model to predict the TRS in the metal matrix and ceramic phase of the fabricated FGMs, and to validate it experimentally using the neutron diffraction method.

Finite element method meshes were generated using micro-XCT scans of the real microstructure of the composite layers and the three-layer FGMs. These micro-XCT based meshes were used to build the FEM models to calculate the TRS.

In the experimental part of this research, the process induced TRS were measured in the AlSi12 matrix and the ceramic phase. Finally, the TRS obtained from the micro-XCT FEM simulations were compared with the neutron diffraction measurements. A good agreement between the micro-XCT FEM results and the experimental data was obtained.

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