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Hot pressed nickel aluminide materials with various dopant elements for high temperature regimes

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The nickel aluminide base composites are considered to be potentially interesting high temperature structural materials for aerospace industry due to their low density (5.9 g/cm^3), high thermal conductivity (76 W/mK) and good corrosion and oxidation resistance. However, it is well-known that the main reason limiting this material's application in aerospace industry is related to its low fracture toughness and low ductility at room temperature. Research works on this subject have been carried out by various scientists throughout the world for more than four decades now. After initially high expectations, followed by rather disappointing results reported some 15 years ago, the recent progress in processing technologies in the context of fracture toughness levels is, indeed, remarkable. However, application of this structural material in real working conditions is still to be confirmed, [1].

The composite materials investigated in this study were manufactured by powder metallurgy technique. The primary target was to obtain low density nickel aluminide bulk materials with enhanced fracture toughness, flexural strength and high oxidation resistance. The powders of NiAl were mixed in a planetary ball mill with various volume fractions of aluminum oxide, chromium and rhenium. Sintering was conducted in a hot press under the pressure of 30 MPa at 1400^{o}C. Mechanical properties, microstructure and cyclic oxidation at 900^{o}C, 1100^{o}C, 1300^{o}C were investigated. A promising improvement of flexural strength and fracture toughness were observed for each chemical composition. The highest enhancements were measured for the composite with 0.6 at.% addition of rhenium, where the flexural strength increased from the reference level of 428 MPa (pure NiAl) to 808 MPa. The oxidation tests showed predominantly high oxidation resistance due to formation of a thin oxide layer preventing significant mass losses. The oxidation experiment was limited to 150 cycles of 1 h duration, hence further tests are necessary to make the final assessment of the oxidation behavior.

The second major problem investigated in this paper were thermal residual stresses (TRS) induced in the sintered composites during cooling from high sintering temperature to room temperature, due to CTE mismatch of the constituent materials. The effects of TRS on fracture parameters and other mechanical properties (E modulus, bending strength) were examined experimentally and modelled numerically using micro-CT based FE meshes mimicking the material microstructure. Our micro-CT based FEM models reproduce the TRS measurements by neutron diffraction with good accuracy, which may be an asset for engineering applications considering the high cost of beam time at the neutron sources.

[1]. K. Bochenek, M. Basista, Advances in processing of NiAl intermetallic alloys and composites for high temperature aerospace applications, Progress in Aerospace Sciences, 79, 136-146, 2015.

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