The microstructure, mechanical properties and oxidation resistance of nickel aluminide based composites with various dopant elements for high temperature aerospace applications

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Abstract:

Intermetallic compounds such as NiAl manifest an attractive combination of mechanical and physical properties – low density (5.9g/cm^3), high melting point (1676°C), high thermal stability along with good oxidation and corrosion resistance. This has resulted in their numerous non-structural applications such as thermal barrier coatings, but no successful structural application of NiAl has been reported yet. This is caused by its low ductility and poor fracture toughness (<5MPa$\sqrt{m}$) at room temperature along with an insufficient impact resistance. There has been a lot of work done already in order to improve NiAl properties and implement this material in aero engines. The results are very promising, but till now there has been no reported successful application of NiAl-based bulk materials in real in-service conditions [1-2].

In order to overcome this problem we propose the powder metallurgy technique to obtain nickel aluminide composites with enhanced properties – fracture toughness, flexural strength with retained low density and high oxidation resistance. The powders with various content of nickel aluminide, aluminum oxide, chromium and rhenium were mixed in planetary ball mill and sintered at 1450°C under 30MPa pressure. Mechanical properties, microstructure and cyclic oxidation at 900°, 1100°, 1300°C of sintered materials were investigated.

From the investigated chemical compositions as the most promising material we have identified the NiAl with 0.6 at.% of rhenium. With this composition an improvement in flexural strength from 505 MPa (pure NiAl) up to 935 MPa (NiAl with 0.6 at% Re) was achieved. The performed oxidation tests showed in most cases a high oxidation resistance due to formation of a thin oxide layer preventing significant mass losses. However, the oxidation experiment was limited only to 150 cycles of 1 h duration, and needs to be continued to make the final assessment of oxidation behavior possible.

The selected route for manufacturing of nickel aluminide based materials leads to the conclusion that we are able to obtain materials with enhanced properties and high homogeneity, along with short time of production in comparison with methods such as directional solidification, which are mostly related with a long-time annealing post processing.

References

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

2. R. Darolia, NiAl alloys for high-temperature structural applications, JOM, 43 (3) (1991), pp. 44–49

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