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Sintering, microstructure and properties of WC-FeAl-B and WC-Ni3Al-B composite materials

Mehdi Ahmadian-Najafabadi
University of Wollongong

Sintering, Microstructure and Properties of

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Mehdi Ahmadian-Najafabadi

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Candidate's Certificate

I declare that the work presented in this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Mechanical, Materials and Mechatronic, University of Wollongong; and is wholly my own work and original except where otherwise referenced or acknowledged. The document has not been submitted at any other academic institution for a higher degree.

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Mehdi Ahmadian-Najafabad

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Abbreviations

APB	Antiphase grain boundary
APIM	Atom probe ion microscopy
EDS	Electron dispersive x-ray spectrometry
Fig.	Figure
GBs	Grain boundaries
VH	Vickers hardness
IMCs	Intermetallic matrix composites
K_{IC}	Fracture toughness
MPa.m	Mega Pascal-meter
No.	Number
SAD	Selected area diffraction
SEM	Scanning electron microscopy
t	Time
T	Temperature
TEM	Transmission electron microscopy
SISFs	Superlattice intrinsic stacking faults
XRD	X-ray radiation diffraction
YS	Yield strength
YSA	Yield strength anomaly

Publications

1. M. Ahmadian, D. Wexler, A. Calka and T. Chandra, "Liquid Phase Sintering of WC-FeAl and WC-Ni_3Al Composites With and Without Boron", Materials Science Forum (2003) 426-432(3): p. 1951-1956.

2. M. Ahmadian, D. Wexler, T. Chandra and A. Calka, "Abrasive Wear of WC-FeAl-B and WC-Ni_3Al-B Composites" International Journal of Refractory Metals and Hard Materials 23 (2005) 155-159.

3. M. Ahmadian, D. Wexler, A. Calka and T. Chandra, "The Effects of Boron on the Hardness and Fracture toughness of WC-FeAl-B and WC-Ni_3Al-B Composites", Accepted for presentation at THERMEC' 2006, International Conference on Processing and Manufacturing of Advanced Materials, Vancouver, Canada, 4-8 July 2006.

Abstract

The effect of boron on microstructure and mechanical properties of the intermetallic matrix composites (WC-FeAl-B and WC-Ni_3Al-B) were investigated. The results were compared with those obtained from WC-Co composite which had same binder volume fraction and fabricated under identical sintering conditions. Boron doped FeAl ($Fe_{60}Al_{40}$) and Ni_3Al alloys were selected as potential new alternative binders in place of cobalt for WC composites due to their particular combination of mechanical properties.

Sub micron WC-40vol%(FeAl-B), WC-40vol%(Ni_3Al-B) and WC-40vol%Co composites were synthesized by powder processing followed by uniaxial hot-pressing at the optimized temperature of 1500 °C under a pressure of 20 MPa in argon atmosphere. Doped aluminide binders, with boron levels ranging from 0 to 0.1 wt%, were prepared in ultrafine form using controlled atmosphere arc melting and then ring-grinding under argon atmosphere. Hardness and indentation fracture tests were performed on composite specimens and the microstructures were characterized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Phase and compositional characterization were studied by XRD, TEM-EDS and electron diffraction. Abrasive wear performance was evaluated using a pin-on-drum apparatus and the worn surfaces studied by SEM.

The results showed that WC sufficiently wet by the boron doped aluminide binders which resulted in sintered composites with near full densities. WC is also relatively stable in WC-40vol%(FeAl-B) and WC-40vol%(Ni_3Al-B) systems up to 0.1wt% B, with no new phases observed at sintering temperature of 1500 °C. The microstructures exhibited faceted WC grains with no significant grain growth, with continuous aluminide binders and similar morphology to WC-Co. Increasing the amount of boron in the aluminide binders up to 0.1 wt% resulted in more faceting in WC particles and increasing amount of dissolved W in the aluminide binders. Furthermore, the WC contiguity (WC/WC contact) and grain sizes of aluminide binders decreased with increasing the amount of boron in the aluminide binders.

Hardness of WC-FeAl was found to be higher than that of WC-Ni_3Al but the WC-Co had lowest hardness. WC-FeAl showed the highest wear resistance and lowest fracture toughness compared to those of WC-Ni_3Al and WC-Co. Fracture toughness and wear resistance of WC-Ni_3Al were found to be comparable to those for WC-Co. Boron addition up to 0.1wt% in both WC-FeAl-B and WC-Ni_3Al-B had no significant effect on the hardness but the boron addition showed significant enhancement in their fracture toughness (42% for WC-FeAl-B and 38% for WC-Ni_3Al-B) and better wear resistance (24% for WC-FeAl-B and 14% for WC-Ni_3Al-B) which were found to be higher than those of WC-Co. Increasing boron content also resulted in decreasing of surface abrasion during abrasive wear testing by brittle processes such as pull out of particular phases and cracking of carbide particles. The improvement of the fracture toughness and wear resistance with addition of boron could be due to combination of factors including increasing WC solubility in the aluminide binders and reduction in WC contiguity as well as aluminide binder's grain sizes. This in turn could lead to improve the strength of WC/aluminides interfaces and wettability of WC with aluminides.

Finally, the boron doped FeAl and Ni_3Al alloys is proposed as alternative binders to replace Co in conventional WC-Co composites and it is envisaged that WC-FeAl-B and WC-Ni_3Al-B composites could be considered as potential candidates in some specific applications.

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