Effect of Secondary Carbide Addition on Properties of $Ti(C_{0.7}N_{0.3})$-Ni Cermets

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Abstract

The effect of WC or NbC addition on various properties of Ti(C0.7N0.3)-Ni cermets was investigated. The microstructure of Ti(C0.7N0.3)-xWC-20Ni showed a typical core/rim structure, irrespective of the WC content, whereas the structure of Ti(C0.7N0.3)-xNbC-20Ni was different and was dependent on the NbC content. The hardness (HV) and the fracture toughness (KIC) had a tendency to increase marginally, while the coercive force (HC) and the magnetic saturation ($4\pi\sigma$) decreased gradually with an increase in WC or NbC content in the systems studied. In addition, increasing WC content in Ti(C0.7N0.3)-xWC-20Ni system, decarburization was retarded, while denitrification was accelerated

Keywords : Ti(CN), cermets, secondary carbide, microstructure

1. Introduction

Recently, with the introduction of advanced sintering techniques, which permit the surface properties of cermets, as cutting tools, the performance of Ti(CN)-based cermets have improved considerably [1]. Thus, applications that were formerly limited to finishing cuts of work pieces have extended to intermediate cutting [2]. However, for stable applications in an interrupted cutting situation, a high toughness is essential, which requires a good understanding of the properties of solid solution rims, which interact directly with the workpiece. Specifically, attention must be focused on the influence of various factors on the rim structure in terms of microstructure and composition. Among these issues, the effect of the amount and type of added carbides on microstructure and rim composition has been systematically studied in our previous reports [3-5]. In an extension of our previous studies, the effect of the addition of a secondary carbide on the microstructure and various properties of $Ti(C_{0.7}N_{0.3})$-xWC(or xNbC)-Ni systems was investigated.

2. Experimental and Results

Specimens were prepared using commercial process. Weighed quantities of powders were attrition milled with 5mm ϕ WC-Co balls in a WC coated stainless jar in ethanol for 15h. The drying and granulation of the mixed slurry was achieved by spray drying to improve the green density and compact efficiency. The granule powders were pressed in an automatic die at a uniaxial pressure of 200MPa. The dimension of the compacts was 12.7mm x 12.7mm x 4.76mm(t). The compact specimens were sintered at 1450°C for 1hr in a vacuum. For the analysis of the microstructure and mechanical properties, the specimens were sectioned and polished with diamond paste up to 1μm and examined by scanning electron microscopy (SEM) in the back scattered electron (BSE) mode and Vickers indentation measurements were made. For sintered specimens, the coercive force (H_C) (SJ-CM-2000, SUKJIN, KOREA) and magnetic saturation ($4\pi\sigma$) (C60-25, SETARAM, FRANCE) was analyzed, to understand the properties of the binder. In addition, the amount of carbon and nitrogen were determined using a carbon analyzer (WC200, LECO, USA) and a nitrogen analyzer (TC300, LECO, USA), respectively.

Microstructure

The effects of WC and NbC content on the microstructure of the $Ti(C_{0.7}N_{0.3})$-Ni system were quite different. The influence of WC content in a $Ti(C_{0.7}N_{0.3})$-Ni system on microstructure was found to be insignificant. As a result, with an increase in WC content, the size and thickness of the rim remained nearly constant and all $Ti(C_{0.7}N_{0.3})$-xWC-Ni systems exhibited a typical core/rim structure. On ther other hand, in the case of the $Ti(C_{0.7}N_{0.3})$-xNbC-Ni system, the influence of NbC content on microstructure was quite dramatic. The thickness of the rim decreased with increasing NbC content and partially rimless Ti(CN) cores began to appear. With a high content of NbC, the microstructures showed rimless Ti(CN) particles and Nb-rich cores. As reported in previous studies [3-5], such differences in the two systems containing WC and NbC might be due to the misfit strain between the cores and solid solution rim phase.

Mechanical properties

With an increase in WC or NbC content in the $Ti(C_{0.7}N_{0.3})$-Ni systems, the hardness (H_V) and fracture toughness (K_{IC}) had a tendency to increase marginally. These observations indicate an increase in resistance to plastic deformation and crack propagation, attributed to the grain refinment and toughening which is triggered by forming the solid solution rims with respect to WC and NbC content in $Ti(C_{0.7}N_{0.3})$-Ni systems.

Concerning the change in hardness (H_V), the addition of NbC appears to be more effective, compared to WC in the $Ti(C_{0.7}N_{0.3})$-Ni systems. However, WC has much more pronounced influence on the toughness. This is due to th e difference in the mechanical properties of (Ti,Nb)(C N) and (Ti,W)(CN), which are present as major phases in the two systems.

Magnetic properties

With an increase of WC and NbC content, the coercive force (H_C) and magnetic saturation ($4\pi\sigma$) decrease gradually. It is well known that coercive force (H_C) and magnetic saturation ($4\pi\sigma$) are affected by the grain size and the purity of the metal binder, respectively [6, 7]. Thus, the drop in the coercive force (H_C) and magnetic saturation ($4\pi\sigma$) can be attributed to the apparent grain refinment by rim formation and the increase in the W or Nb solute in the Ni binder, respectively.

Irrespective of the amount of secondary carbide (WC or NbC), the coercive force (H_C) and magnetic saturation of the $Ti(C_{0.7}N_{0.3})$-xNbC-Ni system is higher than that for the $Ti(C_{0.7}N_{0.3})$-xWC-Ni system. Such an observation suggests that WC addition on grain refinemet is more effective than NbC and also indicates that WC has a higher solubility limit in the Ni binder, compared with NbC at a given condition.

Chemical properties

The extent of decarburization appears to be different in the two systems. Irrespective of NbC content in the $Ti(C_{0.7}N_{0.3})$-xNbC-Ni system, the amount of decarburization shows a marginal change. However, the extent of decarburization for the $Ti(C_{0.7}N_{0.3})$-xWC-Ni system decreases considerably with increasing WC content and appears to be zero at 25wt% WC.

Unlike the decarburization behavior in the $Ti(C_{0.7}N_{0.3})$-xWC-Ni systems, the extent of denitrification tends to increase with WC content. In the case of $Ti(C_{0.7}N_{0.3})$-xNbC-Ni systems, the denitrification, on the other hand, is not sensitive to the NbC content. The difference between the carbon and nitrogen behavior in two systems with respect to WC and NbC content may be related to the affinity between W or Nb and N or C [8, 9].

3. Summary

The following conclusions can be drawn from this study.

i) Irrespective of WC content, the microstructure of $Ti(C_{0.7}N_{0.3})$-xWC-20Ni system exhibited a typical core/rim structure, while that for the $Ti(C_{0.7}N_{0.3})$-xNbC-20Ni system changed with respect to NbC content. The difference in the microstructure of both systems was due to the effect of strain between Ti(CN) core and the solid solution rim.

ii) With an increase in WC or NbC content in the $Ti(C_{0.7}N_{0.3})$-xWC or xNbC-Ni systems, the mechanical properties (H_V and K_{IC}) had a tendency to increase marginally. This can attributed to the grain refinment and toughening, triggered by the formation of solid solution rims with the WC and NbC content in $Ti(C_{0.7}N_{0.3})$-Ni systems.

iii) With an increase in WC or NbC content in the $Ti(C_{0.7}N_{0.3})$-xWC or xNbC-Ni systems, the coercive force (H_C) and the magnetic saturation ($4\pi\sigma$) showed a gradual decrease. The decrease in coercive force (H_C) and magnetic saturation ($4\pi\sigma$) can be attributed to grain refinment by rim formation and an increase in W or Nb solute in the Ni binder, respectively.

iv) With an increase in WC content in the $Ti(C_{0.7}N_{0.3})$-xWC-20Ni system, decarburization was retarded, while denitrification was promoted. The carbon and nitrogen behavior with respect to WC content is related to the affinity between W and N or C.

4. References

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