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Mechanical Properties of Ultra-fine WC-TiC-Co Cemented Carbides

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1. Introduction

Cemented carbides, consisting of WC grains bound by the Co phase, have been used as cutting tools, rock drill tips and other wear resistant components during the decades. In recent days, nanocrystalline WC-Co cemented carbides have been developed by thermochemical and thermomechanical process named as spray conversion process. Recent studies of mechanical properties of nanocrystalline WC-Co cemented carbides proposed different mechanisms for fracture and deformation of nanocrystalline WC-Co cemented carbides according to the microstructure and chemical composition. WC-TiC-Co cemented carbides, which have better hardness and wear resistance than WC-Co cemented carbides, have been introduced to improve mechanical performance for wider applications of cemented carbides. However, researches on ultra-fine or nanocrystalline WC-TiC-Co cemented carbides have not been carried out.

In this study, the mechanical properties were analyzed by varying the WC grain size between ultra-fine and conventional grade in various TiC content in order to investigate the effect of WC grain size refinement in WC-TiC-Co cemented carbides.

2. Experimental Procedure

The starting materials are 99.8% WC of 4.06 μm, 1.33 μm and 0.57 μm from TaeguTec. Ltd., 99.0 % TiC of 0.8 μm from H. C. Starck and 99.0% Co of 2 μm from Aldrich. The composition of cemented carbides is (90-x)WC-xTiC-10Co where x varies from 0 to 20. The powders with desired compositions were wet-mixed in Hexane containing 1.0 mass% organic binder referred to the total mass of each charge in plastic bottle with WC-13Co% ball of 2 mm by ball-milling for 24 hours. The ball-milled powders were dried in a vacuum oven for 10 hours at 80℃. The dried powders were pressed under a pressure of 350 MPa by uniaxial press at room temperature. The cold-pressed compacts were de-waxed at 350℃ for 2 hours in vacuum and then hot-isostatically pressed under a pressure ranging from 180-200 MPa at the temperature of 1375℃ for 1 hour. The hardness and fracture toughness of sintered cemented carbides were measured by Vickers hardness tester under load of 1kg. The transverse rupture strength of sintered cemented carbides were measured according to ASTM B528.

3. Results and Discussion

The hardness of cemented carbides sintered with full densification sinter-HIP process increases with increasing the TiC content. In case of given composition, the hardness of WC-TiC-10Co cemented carbides increased with decreasing the WC grain size ranged from 0.4 to 4.0 μm. The hardness of WC-10Co cemented carbides satisfied the Hall-Petch type relation with the WC grain size. However, the hardness of ultra-fine WC-TiC-10Co cemented carbides had variation from tendency of Hall-Petch relation of conventional ones.

The fracture toughness of WC-TiC-10Co cemented carbides decreased with increasing TiC content and refining WC grain size. In WC-10Co cemented carbides, the grain size

refinement improves hardness while fracture toughness decreases very sensitively. However, in WC-TiC-10Co cemented carbides, the grain size refinements improves hardness without decreasing the fracture toughness as constant low grade.

The transverse rupture strength of WC-TiC-10Co cemented carbides showed two tendency by TiC content with varying WC grain size. In WC-10Co cemented carbides, the transverse rupture strength decreased with decreasing the WC grain size. However, the transverse rupture strength of WC-TiC-10Co cemented carbides increased with refining WC grain size.

The WC grain size refinement had an effect on mechanical properties of WC-TiC-Co cemented carbides, better hardness and transverse rupture strength with constant fracture toughness level.

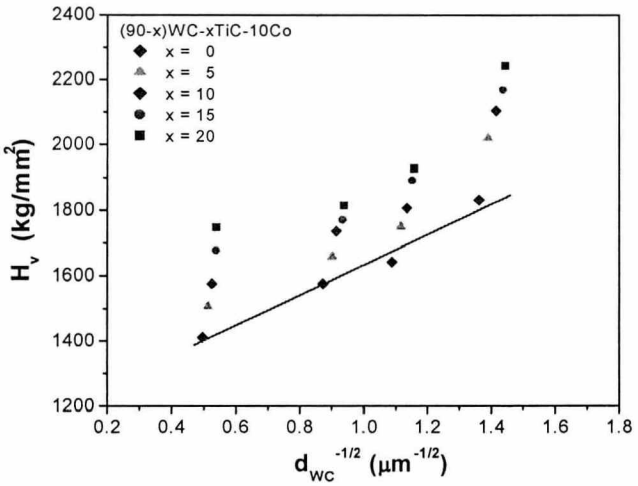

Fig. 1. Hardness of WC-TiC-10Co cemented carbides with varying the WC grain size and TiC content

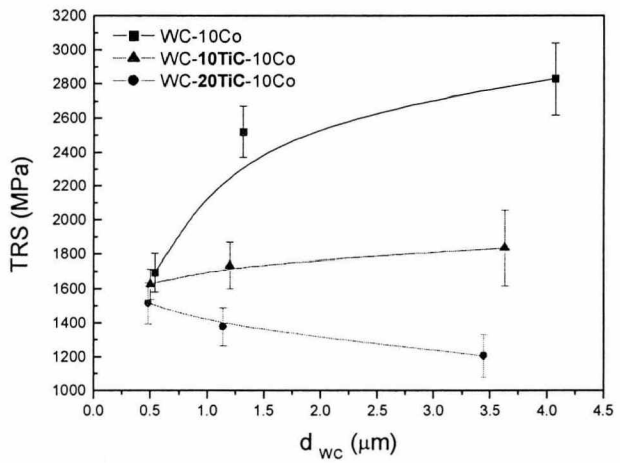

Fig. 2. Transverse rupture strength of WC-TiC-10Co cemented carbides with varying the WC grain size and TiC content.