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Cast WC-Co alloy-based tool manufacturing using a polymeric mold prepared via digital light processing 3D printing

Hakhyun Kim [a,b], Jong-Il Kim [a], Sung-Soo Ryu [a,*], Hyeondeok Jeong [a,*]

[a] Engineering Ceramic Center, Korea Institute of Ceramic Engineering and Technology, Icheon 17303, Republic of Korea
[b] Department of Materials Science and Engineering, Hanyang University, Seoul 04763, Republic of Korea

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ABSTRACT

Tungsten carbide-Cobalt (WC-Co), also known as cemented carbide, is a widely used alloy to manufacture high-performance tools for mining, drilling, cutting, and machining applications. Due to the high melting point of WC, it is challenging to cast it to manufacture products. Therefore, in this study, we investigated a method for manufacturing cutting tools from WC-Co alloy using high-precision digital light processing-based three-dimensional (3D) printing technology. The high refractive index of WC renders it difficult to directly apply it to photocurable 3D printing. Therefore, a polymer mold was fabricated via 3D printing to obtain a WC-Co slurry cast. Rheological studies were performed to optimize the slurry composition. After slurry casting and drying, a green body was formed, which was sintered at 1400 °C to obtain a defect-free sample with a shape identical to that of the 3D model. The cast sample exhibited identical characteristics (microstructure, hardness, and fracture toughness) to those of conventional press-molded sample. The results of this study confirm that complex cutting tool manufacturing is possible without using expensive metal molds. The presented approach is expected to significantly reduce the cost and time incurred during the product development stage involving multiple designs.

1. Introduction

Tungsten carbide-Cobalt (WC-Co) cemented carbide alloy is widely used for manufacturing cutting tools such as drills and inserts. As casting of WC is difficult due to its high melting point of 2870 °C, WC-based products are typically manufactured using powder metallurgy, which involves press molding, sintering, and addition of Co as a sintering aid. However, press molding has practical limitations in terms of product shapes that can be manufactured. Additionally, manufacturing a press mold is highly time-consuming and expensive, with products often requiring post-processing operations. Particularly, it is inefficient during the product development stage, where testing of products of various designs requires fabrication of separate molds for each design.

To address these issues, several studies have attempted to mold WC-Co alloy using three-dimensional (3D) printing to directly produce complex-shaped products. Typical methods include powder bed fusion (PBF) [1,2], material extrusion (ME) [3,4], and binder jetting (BJ) [5,6]. However, laser PBF, also referred to as selective laser melting, generates residual stress in the printed material, whereas ME and BJ can cause poor shape resolution. Photocuring methods, such as digital light processing (DLP) and stereolithography, are difficult to use with WC because of its high refractive index, which causes ultraviolet scattering of the particles and generates an extremely low curing depth for the slurry [7].

In this study, a polymeric material-based mold was printed by the DLP 3D-printing method to facilitate the shaping of complex designs for the production of WC-CO. The high solid loading slurry of WC-Co was cast in the polymeric mold and the mixing ratio of solid content and dispersant in the slurry was optimized based on the rheological analysis. The WC-Co alloy-based product fabricated using the polymeric mold was evaluated in terms of mechanical properties such as hardness and fracture toughness.

2. Materials and methods

Raw WC-Co powder (10 wt% Co added, D50 = 0.5 μm; UF-100, TaeguTec, Korea), dispersant (BYK-111, BYK, Germany), isopropyl alcohol (IPA, Merck, Germany), and N-methyl-2-pyrrolidone (NMP, Merck, Germany) were used in this study. The raw WC-Co powder particles were coated with the dispersant using a three-roll mill. This was done to prepare a slurry for casting with a high solid loading. We added 5, 10, 15, and 20 vol% of dispersants to the powder. The mixtures

* Corresponding authors.
E-mail addresses: ssryu@kicet.re.kr (S.-S. Ryu), jhd526@kicet.re.kr (H. Jeong).

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