RECYCLING OF TUNGSTEN CARBIDE-BASED SCRAP METAL: SELECTIVE DISSOLUTION OF THE COBALT BINDER PHASE AND RECOVERY OF VALUABLE CONSTITUENTS USING A COMPLEXING AGENT-AIDED ACID LEACH PROCESS

Alan Shemi

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Abstract

Cemented tungsten carbides provide a pre-mined and easily accessible secondary source of tungsten and cobalt critical metals. The ability of acidic media to leach and collect metallic species from the cemented carbide composite material is based on one mechanism: metallic binder dissolution. However, members of the iron group, namely, Fe, Ni and Co, when used as binders in cemented carbide, wet the grains of tungsten carbide (WC) making it very difficult to remove them from between the grains during reclamation.

This research project explored the possibility of designing a technique wherein the Co binder phase is selectively extracted whilst leaving the WC hard phase intact. It is this possibility wherein the properties of cemented carbide were investigated so as to understand the possibilities and limitations of the approach. The properties of cemented tungsten carbide were evaluated using a Field Emission Scanning Electron Microscope (FESEM), a Rockwell Hardness Tester and a GX50 inverted metallurgical microscope.

Preliminary tests in 1M sulphuric acid showed that an acidic oxidative environment enabled Co binder dissolution to extraction levels where selective dissolution of the cobalt binder metal is guaranteed. Initial tests gave a Co extraction of 8.7% in 6 h. Further tests gave a Co extraction of up to 99.6% in 10.5 days. The dissolution process and recovery of constituents was studied using various techniques including a statistical Design of Experiments (DOE) for modeling optimum leaching conditions, factor range finding tests for analysis of influence of process parameters, reagent selection tests for finding a suitable lixiviant and a conceptual kinetic model for describing Co dissolution from the binder matrix. Leaching, precipitation, solvent extraction and electrorecovery techniques were used for leach liquor purification and resource recovery of WC and Co constituents. Co dissolution followed kinetic models, $x = kt$ and $1- (1-x)^{1/3} = kt$ and activation energies: $56.70 kJmol^{-1}$ and $21.07 kJmol^{-1}$ suggesting chemical reaction and thin film diffusion control. Co dissolution exhibited a strong dependence on temperature, leaching time and acid concentration. The DOE regression model predicted a maximum Co extraction rate of 25.0% at optimal leaching conditions of 82°C, 2M H_2SO_4 and 10 h leaching time. The Co extraction rate found experimentally was 24.1%. Using optimal conditions and increased leaching time gave 97.6% Co extraction in 4.2 days. An increase in temperature from 82 to 92°C yielded 98.2% Co extraction in 1.5 days. Factor

perturbation plot revealed temperature as the key driver of the Co dissolution process. A dosage of 5% (v/v) lactic acid strongly impacted Co extraction in the first 1 h but waned with increasing leaching time due to poor mass transfer in the inner core of the button. The recovered WC powder exhibited well faceted fine particles; the electro-recovered Co metal showed morphological integrity and the economic factors indicated economic process viability, thus presenting a possible practical application of the cemented tungsten carbide recycling process.