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The optimisation and evaluation of VC-WC-Co hardmetals.

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ABSTRACT

The use of vanadium carbide in hardmetals is not new. The original use of vanadium carbide was as a grain refiner in ultra-fine and fine-grained hardmetals in amounts up to 1wt%. These additions of VC were made to prevent discontinuous grain growth, thereby maintaining a fine carbide microstructure. In this work, the vanadium carbide is used as a substitute for the tungsten carbide. The amount of vanadium carbide used in this work, 10wt%, was meant to show that VC could be used as a partial substitute for WC. The partial replacement of WC with VC is a novel approach in producing a new type of hardmetal alloy for industrial and mining applications. This work relates to the optimisation and evaluation of this new WC-VC-Co hardmetal. The production route of the material is by powder metallurgy techniques due to the high melting points of the tungsten carbide and vanadium carbide. Critical process operations such as milling and sintering have been closely monitored and optimised. After sintering, the properties of the hardmetal were evaluated using standard hardmetal quality control procedures, as well as additional techniques, such as field emission scanning electron microscopy and transmission electron microscopy. Field testing was also undertaken to determine how this material would compare to other commercially available materials.

The materials produced possess some unique properties. The(W,V)C phase was found to contain Co and should therefore be more correctly called (W,V,Co)C. Initially, the material was prone to crack initiation from and propagation through the mixed carbide phase. This problem was overcome by using starting powders with a finer grain size or by refining the powders by extended milling times. This reduced the grain size of the (W,V,Co)C in the sintered material to less than the critical value for crack initiation and growth.

The hardness of the WC-VC-Co materials was found to be superior to conventional Nanograde (approximately 500μm) WC-Co materials with the same cobalt content. The toughness of the WC-VC-Co materials was found to be similar or greater than Nanograde WC-Co alloys with approximately the same hardness. The density of the materials produced with 10wt% Co and 10wt% VC are 2 $g.cm^{-3}$ less dense than for conventional Nanograde WC-Co grades with the same cobalt content. This would give significant weight savings in most applications.

Field testing was done at two different mines, one mining iron ore and the other silica. On the silica mine, the results were disappointing as the WC-VC-Co material was worn away quickly in

comparison to the commercial grade of carbide currently being used. It must be noted that the grade used currently has a nickel binder providing significant improvement in corrosion resistance over the WC-VC-Co with only a cobalt binder. For a fair comparison, a Ni binder should have been used for the VC alloy.

On the iron ore mine, the WC-VC-Co materials performed well and gave the same life as the grade of material currently used. Due to the worry about chipping and damaging the conveyor belt the WC-VC-Co grade had 12wt% cobalt binder, whereas the grade currently used is WC-10wt% Co without nickel as the environment does not have as low a pH as the silica mine. If a WC-VC-10wt% Co material were to be used, the wear resistance would have been superior to the grade currently used.

A brief cost analysis has also been conducted to determine whether there is any cost advantage to these WC-VC-Co materials. Since only the raw materials differ and processing is the same, the cost of production would be equal, but overall there is a slightly greater expense for the WC-VC-Co materials as the VC is of significantly higher cost than the WC.