ABSTRACT – Ph.D. Thesis Contest

Recyclability of cemented carbide powder: optimization of milling and sintering parameters

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Cemented carbides are widely used in many relevant industries, such as mining (drill bits, road headers), cutting tools (turning, milling, drilling inserts) for machining of metal or wood components, or as wear parts in wire drawing dies or punch tools. Their excellent combination of hardness and fracture toughness, provided by the use of a cobalt binder, makes them interesting alternatives to conventional cutting tools such as high-speed steels or diamond-based materials.

However, the use of cobalt as metallic binder has raised many concerns during the last decades. Cobalt is indeed listed by the European Commission as “critical raw material” since 2011 due to its economic important and its supply risk. The world resource of cobalt is mainly located in Africa (50% in Republic Democratic of the Congo and Zambia). Moreover, the intensive use of cobalt for batteries of electric vehicles induces large fluctuations in its price. Finaly, cobalt has many health and ethical issues.

The substitution of cobalt by other materials is possible but the alternatives do not reach the same level of mechanical properties than cobalt-based cemented carbides. The recycling of end-of-life cutting tools is thus a solid option to get rid of the dependence of the European Union on Chinese or African markets, respectively for tungsten and cobalt.

The thesis studied the processing of a recycled WC-Co powder, obtained by the Coldstream process. Optimisations of ball milling and sintering have been achieved to reach the standards in terms of structure and mechanical properties, that would make it possible to reuse the material. During the thesis, different routes have been investigated: (i) direct sintering of the as-recycled powder, (ii) unconventional sintering of the as-recycled powder with SPS and GE-HIP, (iii) ball milling of the as-recycled powder, (iv) addition of small quantities of cobalt powder, (v) addition of boron as sintering aid, and (vi) mixing recycled and noble WC-Co powders.

The results show that the different parts can be separated into three categories: (i) parts sintered by spark plasma sintering with high hardness and moderate fracture toughness that could be used as simple geometry cutting tools, (ii) parts with moderate hardness and high fracture toughness (parts containing 15 wt.% CoB as binder) which could be use as low operating temperature cutting tools or wear parts, and (iii) parts with low fracture toughness that could be used as wear parts not subjected to impact loads.