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Potentials of niobium carbide (NbC) as cutting tools and for wear protection

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Abstract

Apart by vacancies, the different pseudo-cubic phases NbC, Nb_4C_3 and Nb_6C_5, can accommodate any stoichiometry of NbC_x ($0.75 \leq x \leq 1.0$) in the binary phase diagram and enable a large process window. Properties, like micro-hardness, hot hardness, sliding wear resistance, elastic modulus and toughness can be tailored by the C/Nb ratio, the addition of secondary carbides and the type of binder. SPS sintered and cobalt bonded ($NbC_{0.88}$-12Co SPS). NbC and Nb_2O_5 have so far no REACH classifications related to human toxicology and are not listed as substances of very high concern contrary to Co_3O_4. The NiMo-bonded stoichiometric $NbC_{1.0}$ grades enable the substitution of cobalt by nickel, SPS by conventional sintering and $NbC_{0.88}$ by $NbC_{1.0}$ in view of functional properties. Nickel bonded NbC grades have improved toughness versus cobalt bonded NbC grades, but loosed in hardness. NiMo and $NiMo_2C$ bonded $NbC_{1.0}$ grades in combination with secondary carbides compensated the loss in hardness while keeping the toughness. The tool lifes of uncoated $NbC_{1.0}$-12Ni4Mo4VC and $NbC_{0.88}$-12Co under dry turning of 42CrMo4 and C45E were between +30% to +200% higher and up compared to WC-6Co (extra fine grain). Niobium is today largely available as resource. NbC grades displayed lower dry sliding friction over WC grades. The softer Ni- and NiMo-bonded $NbC_{1.0}$-grades have a higher dry abrasive wear resistance (ASTM G65), even with lower toughnesses, as the tougher WC-Co grades.

Keywords
Niobium carbide, friction, wear, NbC, hard metal, machining, nickel

1. Introduction

In 2016, tungsten carbide (WC) had its 90th anniversary. WC dominates since then the attribute of "wear protection" since 90 years, either under abrasive conditions or especially for tool materials. Even known since the same time, surprisingly little attention has been paid to niobium carbide (NbC), although it was deeply investigated in the sixties and seventies. Nevertheless, niobium carbide has been occasionally used as secondary carbide phase in hardmetals and cermets, castings and tool steels. In these applications, it serves either as grain refiner or as hard phase helping to enhance wear resistance, limit grain growth and improve the hot hardness.

It was recently shown, that pure NbC as well as metal bonded NbC have a pronounced wear resistance under dry sliding conditions versus other monolithic ceramics and carbides [1,2] and also increased tool lifes [3,4,5], when compared to WC-Co.

Cobalt and tungsten carbide gave rise to a spectrum of risks and health issues [6,7,8,9], which engaged more and more stringent labellings. Tungsten carbide (WC), niobium carbide (NbC) or bulk cobalt metal have not been restricted by any critical classifications so far. Tungsten trioxide (WO_3) and