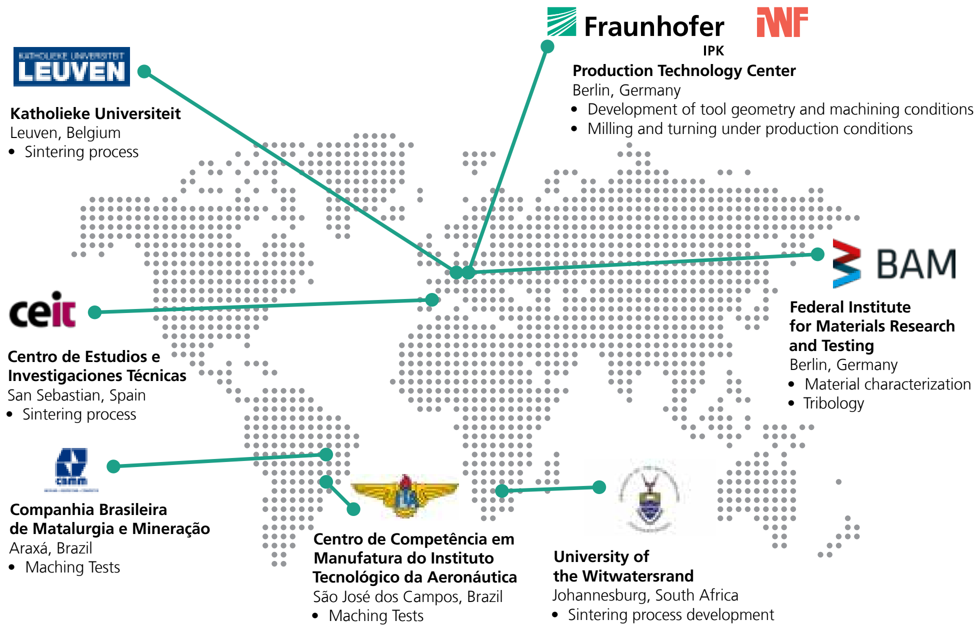
International R&D

A Promising Alternative

Niobium Carbide as Cutting Tool Material

Niobium carbide (NbC) shows promising results as an alternative cutting tool material to industrially used tungsten carbide (WC) for the machining of iron-based materials. In order to investigate a possible substitution of the conventional cutting tool material WC, the IWF of the Technische Universität Berlin and Fraunhofer IPK collaborate internationally in investigating the suitability of NbC for use as a cutting tool in dry cylindrical longitudinal turning processes. Unlike WC tools, NbC substrates show constant material removal at increased cutting speeds combined with higher process reliability for the specific experimental setup and the chosen iron-based workpiece materials.



International collaboration for the development of NbC cutting tools

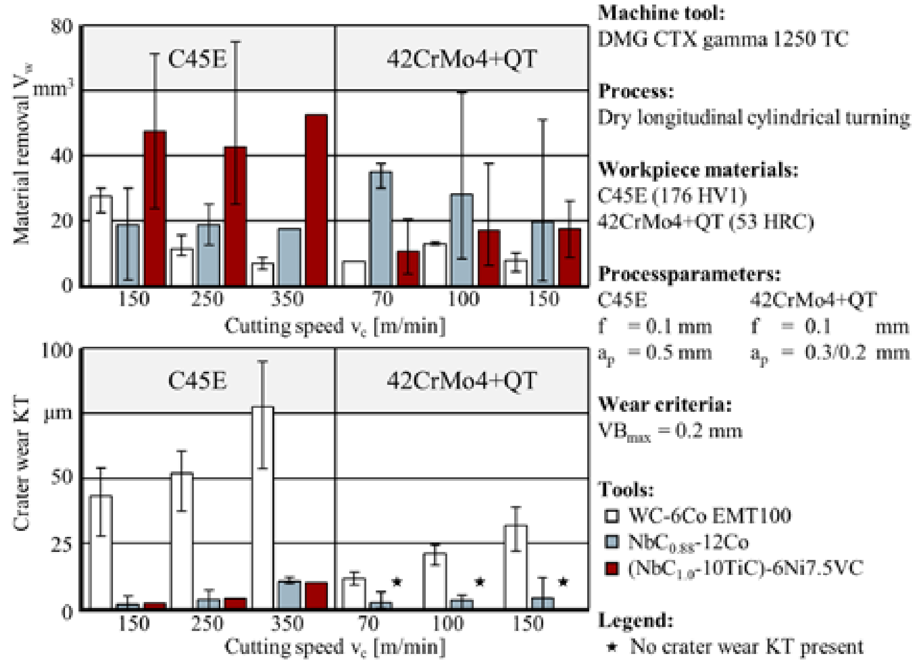
► A Critical Resource

With a market share of approximately 53 percent of distributed cutting materials, WC now dominates the commercial use of hard metal tools. In combination with a wear resistant tool coating, WC is applied to different machining operations such as turning, milling and drilling for a variety of workpiece materials. With regard to this industrial standard, NbC inherits a series of beneficial properties for machining operations such as comparable hardness, toughness, as well as heat and wear resistance. Although WC tools currently provide efficient and reliable industrial manufacturing processes, the recent quest for an alternative cutting material is focused on NbC-based cutting tools. By substituting the WC hard metal phase in its spectrum of technical applications, the continuous optimization of NbC cutting tool material aims to adapt to increasingly complex machining operations in, for instance, high speed cutting (HSC) or high performance cutting (HPC) conditions.

Since 80 percent of raw tungsten is located in China, a guaranteed supply for global consumption is subject to Chinese economic policies. Thus, WC is classified as a critical resource. The latest basic research has identified the cutting tool market as a possible new technological field of application for NbC, alongside its current uses in the aerospace, electronics and medical industries and its use as a grain growth inhibitor and microalloying element for increased strength and ductility. The long term objective to establish NbC as a reliable cutting tool material offers beneficial economic impacts in terms of price stability and material supply for manufacturing industries. Along the entire tool manufacturing process chain, the international collaboration network covers the mining and processing of NbC bulk material in Brazil by the Companhia Brasileira de Metalurgia e Mineração (CBMM), powder metallurgical manufacturing and material characterization by KU Leuven, Belgium, and the German Federal Institute for Materials Research and Testing (BAM), as well as its application as a cutting tool by the Instituto Tecnológico de Aeronáutica (ITA), Brazil, the University of Witwatersrand, South Africa and the IWF in association with Fraunhofer IPK, Germany.

► Cutting Materials in the Test

Based on the lower solubility of binderless NbC in solid chrome, nickel, cobalt and iron as compared to WC, reduced chemical wear on the rake face of the cutting tool has been certified. Due to the higher melting point of NbC at 3520 °C linked with its lower solubility in alloys, a reduction of adhesion with the workpiece during machining has also been attested. The tribological profile of NbC displays the properties required for machining iron-based workpiece materials based on a lower wear rate caused by friction at elevated speeds combined with a higher hot hardness as of 800 °C.

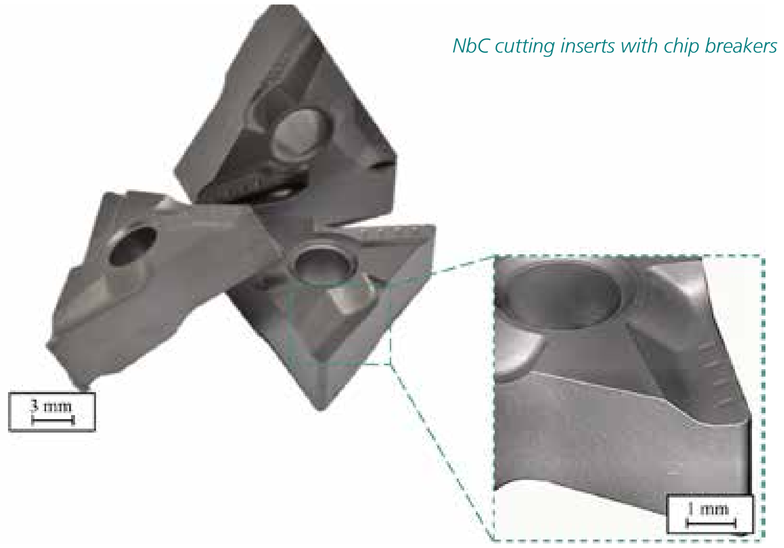


Material removal Vw and crater wear KT when machining C45E and 42CrMo4+QT in dependence on cutting tool material and cutting speed vc

In order to underline the promising tribological behavior of different NbC substrate materials that differ in binder composition and thus in mechanical properties, dry cylindrical turning trials were performed at Fraunhofer IPK. The experimental NbC tool compositions used in this wear investigation are defined as substochiometric $NbC_{0.88}$-12Co and stoichiometric $(NbC_{1.0}$-TiC)-6Ni7.5VC, and are manufactured by the Catholic University of Leuven, Belgium. Commercially available WC tools with a 6 percent cobalt binder manufactured by EXTRAMET AG, Plaffeien, Switzerland, denominated as WC-6Co (submicron grain), serve as the industrial reference commonly used in production.

► The Experimental Setup

The turning tests were performed on a DMG MORI AG, Bielefeld, Germany machining center CTX gamma 1250 TC. Assessment of the cutting materials was carried out via dry longitudinal cylindrical turning. In compliance with ISO 3685, a maximum wear width of 0.2 mm and crater wear depth are used for quantitative wear evaluation. A variation in cutting speed was performed for the two different workpiece materials carbon steel C45E (SAE 1050) as well as quenched and tempered tensile steel 42CrMo4+QT (AISI 4140). In each case, three machining trials for all combinations of cutting material, workpiece material and cutting speed were performed.



NbC cutting inserts with chip breakers

► Excellent Results

Machining trials with carbon steel C45E and hardened, quenched and tempered tensile steel 42CrMo4+QT show the potential of NbC as a capable cutting material substitute for WC. The promising material properties of NbC that profile its competitive mechanical characteristics vis-à-vis conventionally used WC have focused interest on NbC as a powerful cutting tool material. Based on present dry turning operations, the following conclusions for the NbC compositions investigated and future scientific work may be drawn: First, NbC-based cutting materials achieve a higher average material removal rate than WC-6Co with regard to the iron-based alloys C45E and 42CrMo4+QT. Improvement of process reliability at higher cutting speeds in the $(NbC_{1.0}$-TiC)-6Ni7.5VC substrate is based on the above mentioned lower wear rate at elevated speeds. Secondly, the lower diffusion wear, i.e. crater wear, of NbC substrates compared to the reference WC-6Co cutting tool materials is based on the lower solubility of iron-based workpiece materials in NbC substrates. Further investigations will include the optimization of cutting tool geometry for best possible engagement conditions, adaptation of a tool coating to increase wear resistance as well as extension towards varying machining processes such as milling. ■

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