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Cutting performance of nanostructured WC (nWC) inserts without cobalt bonds

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Abstract
The paper presents novel patented material denoted WolCar based on nanostructured tungsten carbide WC. It performs enhanced wear resistance and is feasible for the waterjet nozzles and the tools cutting high hardness steel. Unlike most WC-based and TiC-based tool materials, WolCar does not contain cobalt. Typically, cobalt addition is used in order to increase strength and to decrease sintering temperature of the cutting insert composite. However, when the temperature during machining rises up to 800 or 1000 °C, cobalt causes rapid decrease of both hardness and wear resistance. In WolCar, absence of cobalt overcame this demerit, but the initial strength is kept. In the experimental researches, the machining of the TiC/Fe material with 45 vol% of TiC and 55 vol% of Fe was performed. WolCar inserts provided fine surface of roughness *Ra* 1.2, corresponding with grinding effect. In the similar cutting conditions, WC – 6 wt%Co insert provided roughness *Ra* 4.8. Thus, the novel material was proved to be advantageous for precision machining cutting tools.

Keywords: cutting tool, wear, tungsten carbide, precision, machining

1. Introduction

Tungsten carbide (WC) is one of the hardest materials used in many industrial applications. It is an inorganic compound with equal parts of tungsten (W) and carbon (C) with cobalt (Co) as a binder phase, and sometimes other carbide particles like titanium or tantalum carbide are alloyed in a small quantity [1]. Conventional manufacturing of WC-Co composite involves a liqud phase suntering process [2]. Obtained combination of hardness and toughness provides strength, high wear resistance, toughness, and hot hardness property. However, in High Speed Cutting applications (HSC), temperatures in the cutting area reach 800 and even 1000 °C, and the durability of WC-Co cutting inserts drops down due to the presence of cobalt.

There are reports on the submicron binderless compaction of pure WC of about 200 nm grain size with high relative density, high hardness and high fracture toughness [3]. In the present study, durability of patented binderless WC-based material WolCar [4] in cutting tools application is examined.

2. Materials and methods

The samples of cutting inserts were made out of the patented material WolCar. It consisted almost purely of binderless tungsten carbide with no additions of cobalt. Samples were prepared using the electroconsolidation method with directly applied current [5].

The as prepared inserts had smaller radius of cutting edge than that of WC-Co ones, namely, the cutting edge radius was 12 µm, 43% of the typical edge of the WC – 6 wt%Co insert, where it was 28 µm, as shown in Figure 1. The latter ones, denoted BK6, are available in the marked and were used in the researches for the comparative analysis.

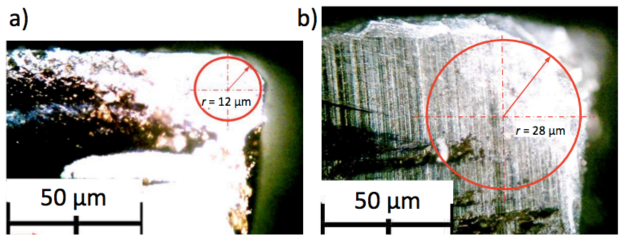

Figure 1. Cutting edges of tested inserts: a) binderless nanostructured WC material WolCar, b) WC – 6 wt%Co material BK6

The machined material was a TiC/Fe composite, widely used due to its significant advantages, such as low density, high hardness and excellent chemical stability [6]. The composition of machined samples was vol.% 45 TiC and vol.% 55 Fe with ferrite-pearlite or nickel-martensite grains.

During experiments, the cutting parameters were following: cutting speed v_c = 70 m/min and feed rate S_n = 0.05 mm/rev.

3. Results and discussion

Preparation of the binderless nWC cutting inserts was more simple than the similar process for WC-Co composite. First of all, the difficult homogenizating operation for the nanopowders was eliminated. In addition, without a cobalt powder, the electroconsolidation process was shortened, which further prevented appearance of the microcracks and micropores.

The experimental results of the cutting process demonstrated advantages of the binderless nanostructured WC inserts WolCar. Small radius of the cutting edge contributed to the high quality of the obtained surface, and the machined surface was free from burned areas typical for grinding process remains. Compared to the machining with BK6 inserts, surface of the machined TiC/Fe composite was better both in visual analysis, and from the perspective of the roughness measurement, illustrated in Figures 2 and 3, respectively. While *Ra* obtained by WolCar insert was 1.23 µm, the BK6 insert was able to produce *Ra* = 4.86 µm.

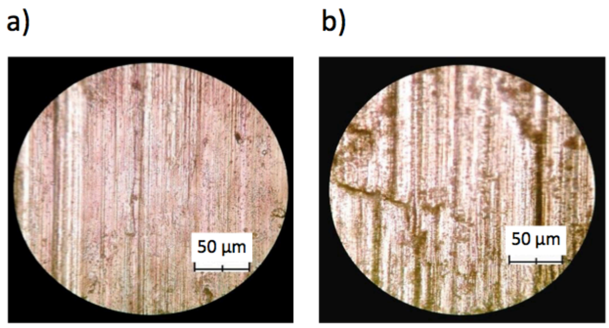

Figure 2. Quality of the TiC/Fe composite surface machined with different inserts: a) WolCar, b) BK6

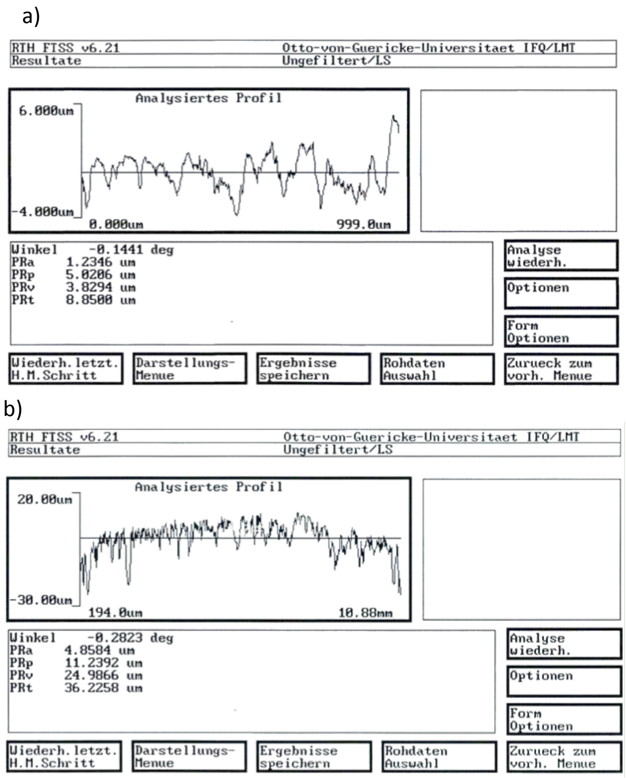

Figure 3. Roughness of the TiC/Fe composite surface machined with different inserts: a) WolCar, b) BK6

Apart from the higher surface quality, the WolCar exhibited longer durability at increased cutting speeds. In particular, when v_c = 100 m/min, the edges made out of BK6 material were able to cut for 10-12 minutes, while the WolCar inserts worked almost three times longer. This can be explained by the increased abrasive wear of BK6 material with cobalt at higher temperatures. Wear analysis of the edges and flanks suggested that among the main wear mechanisms (adhesion, abrasion, oxidation, diffusion, cracking and formation of built-up edges [7]), the abrasive wear of cobalt-free WolCar was reduced due to higher hardness kept at the increased temperatures close to 1000 °C. The worn flank surface of WolCar insert is shown in Figure 4.

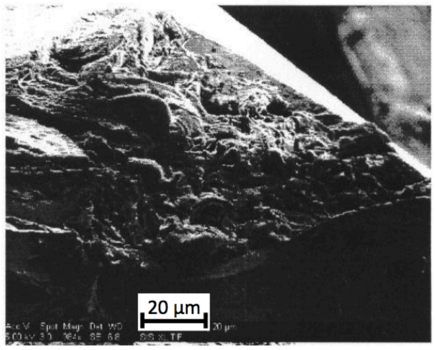

Figure 4. SEM image of the flank wear of WolCar cutting insert

It should be noted that the experiments were performed for dry cutting. In these conditions, at the cutting speed v_c = 40 m/min and higher, small-size built-up edges formation took place. Application of a coolant or lubricant caused its disappearance also at higher machining speeds.

4. Conclusions

The researches demonstrated that the binderless nWC-based cutting inserts (WolCar) have some advantages compared to the typical WC tools with 6 wt% addition of cobalt (BK6). Hot pressing technology with directly applied electric current made it possible to eliminate complicated mixing procedure and to shorten the manufacturing process of the WolCar inserts.

Next advantage of the WolCar insert was sharper cutting edge with radius ca. 50% smaller than that of BK6. As it could be expected, it was able to obtain higher quality of the machined surface. In the cutting tests of the TiC/Fe composite, WolCar tools provided *Ra* close to 1 µm, which was ca. 25% of the roughness obtained with BK6 inserts.

And, finally, when the cutting speed was increased up to v_c = 100 m/min, it was much less destructive for the WolCar inserts. The WC-Co material lost its hardness and durability, so that its working time reduced down to 30% of the WolCar time at the same conditions.

Futher researches with application of coolants and lubricating liquids may help to understand better the nature of wear mechanisms and to check wear resistance of the WolCar material.

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