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Hard turning of tempered DIN 100Cr6 steel with coated and no coated CBN inserts

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Abstract

Recent improvements in the machine tools technology (specially the stiffness and positioning accuracy) as well as the advent of the cubic boron nitride (CBN) ceramic cutting tools made the finishing operations for machining hardened steel parts possible, using tools with defined cutting geometry in substitution to the traditional grinding operations. The advantages presented by the hard turning are sufficiently attractive for many plants, however these are still reluctant to adopt and substitute a well known and dominated process (grinding) for other one not totally understood. Aiming to expand the knowledge of the processing effects of hard turning on the finishing of the machined workpiece, as well as the effects on the tool wear life. Series of experiments with seven different types of CBN inserts had been carried out using inserts with wiper geometry, coated with TiAlN and TiN as well as with no coated ones. The cutting parameters had been specified in such a form to cover the entire field recommended by tool suppliers. The machined part was an axle of DIN 100Cr6 steel tempered to 62 HRc. All the machining operations were carried out at a Mazak-Quick-Turn using an tool holder DCLNR-164D with insert geometry ISO CNGA120408SO1020 with edge with T preparation with 0.102 mm × 20°. The tool wear control was carried out using an optic microscope Zollern Saturn and a roughness profiler Hommelwerk T8000. Following parameters were parameters were determined: VB_{MAX}, R_a, material removal rate and the tool life determined by the Taylor's equation obtained for theoretically ideal cutting conditions. Preliminary analyses of the results compares with the literature indicating that they are significant.

Keywords: Machining; Hard turning; Steel; 100Cr6; CBN; Hard coatings

1. Introduction

This work aims to investigate the machining of hardened steels using cubic boron nitride (CBN) inserts with and without coatings as cutting tools. Typical workpiece materials suitable for hard machining operations include heat-treated materials (e.g., quenched and tempered, case hardened among others heat treatments). Due to the demands on surface finishing and dimensional accuracy, the finishing operations of those hardened workpieces are usually made by abrasive process such as grinding. However, nowadays recent improvements on machine tools technologies (specially on their stiffness and positioning accuracy) as well due to the advent of new cutting tools materials, such the ceramic ones, it became possible to perform finishing operations direct on by machining hardened steels by machining process characterized by a defined cutting edge geometry.

One of the main motivations by that the grinding processes have been used on finishing operations was due to the fact that the manufacturing technology the ceramic grinding wheels were already good stabilised since the 1970s. Machining tools with defined cutting geometry made from ceramic materials, until recent times, were characterized by a short tool life which in such way that their use were regarded as not suitable or even not viable. For the most part of the applications the grinding process presents a material removal rate lower than the machining process with tools with a defined cutting edge geometry. Thus, always when possible it would be desirable to substitute the grinding operations by hard machining processes. The advantages presented by the hard turning are much attractive for a lot of plants, however, they are still keeping some reluctance for the substitution of a well known and good stabilised process (grinding) by another not so well stabilised and dominated.

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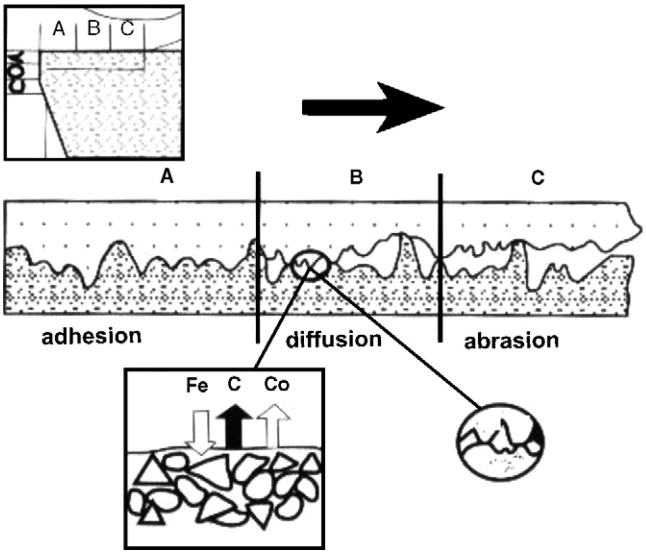

Fig. 1. Main wear mechanisms (adhesion, abrasion, diffusion) after Tchätsch [1].

Aiming to become the knowledgment of the effects of the hard turning more explicit, the present paper presents results and discussions about the hard surface finishing of the turned workpiece, as well as about the CBN insert wear.

2. Tools for the hard turning [12–15]

2.1. *Tool wear on hard turning*

The main characteristics that enable a machining tool to bear the cutting process are: hardness, mechanical strength and toughness, wear resistance and chemical stability. In general terms an increasing hardness leads to greater wear resistance, however, decreasing the toughness and impact resistance. Depending on the machining conditions and the workpiece properties different combinations of hardness and toughness will be required.

At hard machining operations arise problems with traditional tools, as the high-speed steel (HSS), which presents a lower hardness and greater toughness, typical for the usual HSS steel employed in such tools. The main reason why HSS are not more large used is due to the fact that its hardness decrease significantly above 500 °C. Even for the traditional cemented carbides (hard metals) developed to enables machining operations with higher machining speeds and viabilization of higher production rates, they can also present such problems. This kind of tools is responsible nowadays for almost 70% of the machining tools market share. With the advent of materials with increasing

Table 1
Chemical composition steel DIN 100Cr6

C (%)	0.90–1.05
Si (%)	0.15–0.35
Mn (%)	0.25–0.45
P (%)	≤0.030
S (%)	≤0.025
Cr (%)	1.35–1.65
Ni (%)	≤0.30
Others (%)	≤0.30

Table 2
Taylor equation constants vs. cutting tools conditions

Condition	*k*	*a*	*b*
1–3	2.020×10^6	−2.79	−0.75
4–8	1.140×10^9	−4.12	−1.02
9–11	2.130×10^6	−2.56	−0.42
12–16	4.670×10^6	−2.58	−0.04
17–19	3.560×10^6	−2.45	0.20

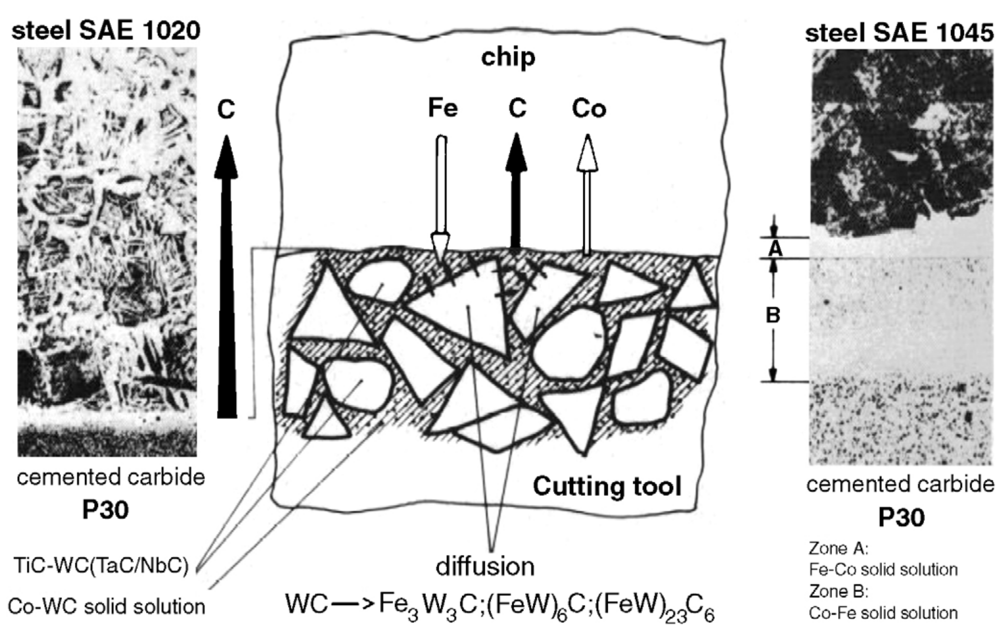

Fig. 2. Material difusion at the interface tool–workpiece (chip); after Tchätsch [1].