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Tool Life Extension Methods for Cut-off Tools Made of High-speed Steel

Karol Vasilko[a], Zuzana Murčinková[b]*

[ab] Faculty of Manufacturing Technologies with seat in Prešov, Technical university of Košice, Bayerova1, 080 01 Prešov, Slovak Republic

Abstract

The paper presents tool life extension methods applied to cut-off tools made of high-speed steel. Despite the wide application of cutting tools made of sintered carbides, which is becoming the main cutting material, including the coated tools, there still remain the applications of high-speed steel cutting tools for low cutting speed machining (i.e. screw taps, reamers, broaching tools, cutting off tools). Therefore the improving of their cutting ability is important to be researched. The paper involves the application of selected modification methods for the increasing of the tool life in operating conditions, i.e. in manufacturing of ball bearing rings from the bar raw product. Moreover, the paper introduces and evaluates the results obtained by individual methods (tool mechanical and physical modifications) finding the reasons of longer tool-lives for example by analysing the metallographic microsections of chip formation process.

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Keywords: machining; cutting off; high-speed steel; tool life; tool modification

1. Introduction

In present, the sintered carbides are very frequently used materials for cutting tools. It becomes the main cutting material including the coated tools. Nevertheless, there still remain the applications of high-speed steel cutting tools for low/lower cutting speeds of machining. Such cutting tools are screw taps, reamers, broaching tools, cutting off tools. [1-4]

In terms of reliability and tool life, the cut-off tools belong among the critical ones regarding their application conditions that are following (according to [5-9]):

- The cutting-off tools operate in considerably changing cutting speed from $v_c = \pi D n / 1000$ on outer workpiece diameter D up to zero on the workpiece axis.
- They have limited space for chip flow. The side-wall limitation of the chip flow causes the rise of friction against machined sides of manufactured groove resulting in tool damage.
- Small width of the cut-off tool generates the local heating of its cutting section and thus early degradation.

These unfavorable operating conditions lead to the fact that the cut-off tool is the critical element of cutting off and its tool life is significantly shorter comparing with other cutting off tools. The producers of tools solve the problem by finding the suitable cut-off tool geometry (i.e. the increase of tool height, the improvement of tool face shape, the decrease of cut-off tool width). There are also other possibilities of physical and structural adjustment of cut-off tools which are highly mechanically and thermally stressed. [4, 10-12]

The proposed modifications cut-off tools regarding their tool life were verified in production of rolling bearings in cutting off the ring of the ball bearing in Fig. 1.

* Corresponding author. Tel.: +421 55 602 63 22 ; fax:-.
E-mail address: zuzana.murcinkova@tuke.sk

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In case of cutting off by tool of flat tool face showed in Fig. 1, the statistically average tool life was 480 cut-offs.

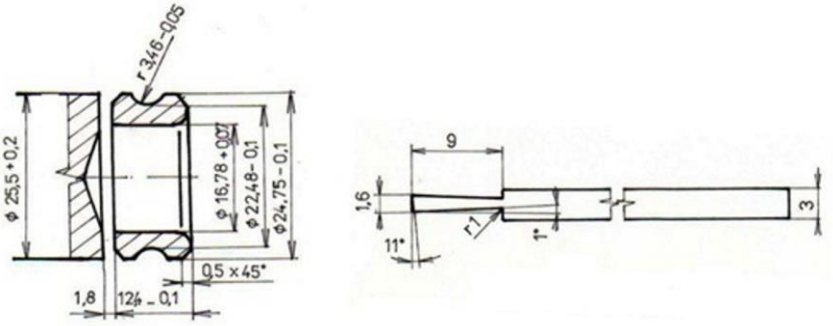

Fig. 1 (a) Dimensions of bearing ring; (b) cut-off tool geometry.
Workpiece: 100CrMn6, tool: HS 12-1-4

Nomenclature

D Workpiece diameter (mm)
n Revolutions (min^{-1})
VB_k Allowable flank wear (mm)
v_c Cutting speed (m/min)
γ_n Rake angle (°)

2. Mechanical and physical cut-off tool life extension methods

2.1. Tool modification by alternating electromagnetic field

The aim is to eliminate the residual stress in a new cut-off tool caused by heat processing and sharpening. The device involves the coil which provides induction 125 A/m and is connected to the source 220 V, 50 Hz. The coil emits the impulse waves of magnetic energy which are absorbed by the cut-off tool placed in the coil. The tool vibrates and the residual stress is removed during vibration in 45 s. The experimental tests of machining with adjusted tool were performed. The results of their tool life are in Table 1.

Table 1. Tool life of modified cut-off tools.

Tool number	1	2	3	4	5	6	7	8	9	10	Average tool life
Number of cut-offs till wear-out	900	1720	950	820	950	1250	720	420	600	880	941

2.2. Electro-spark hardening of cutting parts of cut-off tools

Ten cut-off tools were hardened by electro-spark cutter. In group I and II, the flank surface and the face surface were hardened. Both the flank and the face surfaces were hardened in group III. The results of machining are presented in Table 2 as the number of cut-offs till the allowable flank wear $VB_k = 0.5$ mm is achieved.

As Table 2 shown, it is decisive to harden the flank surface because the tool wear is preferably on the cut-off tool flank. In all groups, the significant tool life improvement is obtained.

Table 2. Tool life of hardened cut-off tools

Group	Tool number	Number of cut-offs	Average tool life
	1	1240	
	2	1840	
I	3	1650	
	4	1320	1486
	5	1380	