International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 36 No. 1 December 2022, pp. 396-401

An Influence Of The Pulsed Magnetic Field Processing On The Cemented Carbide Cutting Tools Wear

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Abstract – An influence of pulsed field processing technology on the cutting performance of cemented carbide cutting tools has been evaluated in this study. The magnetic pulsed field interacts with the metal-cutting tool material, changing its thermal and electromagnetic properties and improving its structure and performance. Improved properties in metal-cutting tools are achieved by directing the free electrons of the material by an external field, resulting in an increase in the thermal and electrical conductivity of the material. For processing of small parts the inductor is established on a horizontal dielectric diamagnetic surface. The products are placed in the middle of the inductor and a processing session lasting 120 s is carried out. Cutting tests when machining hardened steels were performed. Processed parts used for experiments allowed to conduct intermittent machining. This set of tests was conducted to assess the performance of cemented carbide cutting tools processed via pulsed magnetic field method and compare their ability to withstand to intermittent loads during machining of hardened steel. Such type of tests was utilized because the main supposed effect of pulsed magnetic field processing (PMFP) is an increase of bending strength of the material and declination of variance of their mechanical properties. Experimental study of two grades of cemented carbide indexable inserts showed that, other things being equal, processed by PMF method cutting tools demonstrate higher resistance to abrasive wear and higher strength of the cutting edges.

Keywords – cemented carbides; cutting tool; pulsed magnetic field processing; wear; machining

I. INTRODUCTION

An important task is to improve cutting tools for high-precision productive machining of difficult-to-machine materials by applying the latest tool strengthening methods [1-5]. An analysis of different methods for enhancing the physical and mechanical properties of hard-alloy tool materials showed that the best combination of cost and production efficiency was observed with the pulsed magnetic field processing method [6-7]. This is particularly relevant for hard-alloy cutting tools. It is well known that hard alloys have, on the one hand, a high heat resistance, which allows cutting tools to operate at high cutting speeds. On the other hand, hard alloys have a low bending strength, which limits their ability to work in previous, roughening operations, where the tool is subjected to shock loads, which are generated by workpieces made by casting or forging methods, abrasive dust, unevenness of assumptions, etc.

The essence of PMFP is that the metal-cutting tool before machining is placed in a cavity of a magnet connected to a pulsed generator. Under magnetic influence the metal changes its physical and mechanical properties. The magnetic pulsed field interacts with the metal-cutting tool material, changing its thermal and electromagnetic properties and improving its structure and performance [8-10]. Improved properties in metal-cutting tools are achieved by directing the free electrons of the material by an external field, resulting in an increase in the thermal and electrical conductivity of the material. The main advantages of PMFP are: strengthening of metal-cutting tools of any design, simplicity of technological tooling and absence of consumables, environmental friendliness, low cost.

In this study, was investigated the effect of PMFP on the wear of the cemented carbide indexable inserts during the processing of hardened steels.

II. METHODOLOGY

At the Department of Computerized Mechatronic Systems, Instruments and Technologies of Donbas State Machine-Building Academy, pulsed magnetic field (PMFP) processing of carbide cutting inserts is carried out at an installation consisting of a pulse generator, power supply and inductor.

For processing of small parts the inductor is established on a horizontal dielectric diamagnetic surface (plastic, a tree, rubber, etc.), the axis of the inductor has to be vertical. The products are placed in the middle of the inductor and a processing session lasting 120 s is carried out. Technical characteristics of the generator and inductors are given in table. 1. The technological parameter of the unit control is the operating voltage of the installation (capacitor discharge voltage, magnetic field pulse generation circuits), displayed on the front panel of the generator unit (Fig. 1, a). Various designs of the magnetic inductor are developed for realization of processing (fig. 1, b). The analysis of the geometry of solenoids for magnetic inductors in terms of their optimality and ability to provide the required values of magnetic field strength and pulse frequency. As the length of the solenoid increases, there is a weakening of the magnetic field in the working gap.

TABLE I. BRIEF TECHNICAL CHARACTERISTICS OF THE COMPLEX FOR PMFP

Complex parameter	**Parameter value**
Magnetic field strength range, A/m	0.2·105–2.2·105
Operating voltage	100–900V
Inductor inductance	225 mkH
Pulse frequency, Hz	1–10
Impulse time, ms	60

a)

b)

c)

Fig. 1 – Experimental setup for generating a pulsed magnetic field: a - generator unit b, c - design of the magnetic inductor

The magnetic field strength in the center of the inductor is determined by the formula: $H = \mu_0 I_0 \frac{W}{l}$,

where I_0 is the current in turn, A;

W - number of turns;

l is the length of the winding, mm;

μ_0 is the magnetic constant (for vacuum $\mu_0 = 4\pi 10^{-7}$ H/m).

TABLE II. BRIEF TECHNICAL CHARACTERISTICS OF INDUCTORS

Parameters	**Parameter value**	
	Inductor 1	**Inductor 2**
Inductance, μH	220	220
Length, mm	90	70
Number of turns, mm	90	103
Conductor diameter, mm	3	3
Internal diameter of the inductor, mm	40	32

This set of tests was conducted to assess the performance of cemented carbide cutting tools processed via pulsed magnetic field method and compare their ability to withstand to intermittent loads during machining of hardened steel. Such type of tests was utilized because the main supposed effect of PMFP is an increase of bending strength of the material and declination of variance of their mechanical properties. Thus, as a result of PMFP processing tool life and resistance to impact loads must increase. Two types of cemented carbide materials (Table III) and three sets of indexable inserts (Table IV) for each type of materials were used. Processing was performed at two modes: Mode1 and Mode2. Cutting inserts of both types have CVD protective, which significantly improves performance and wear resistance of the cutting tools [10-12].

TABLE III. TESTED CUTTING TOOLS

	Supplier	**Grade**	**Application group ISO**	**Shape ISO**	**Chemi1cal content**
1	ZCC	YBC251	P10-P-30	CNMG120408-DM	WC-TiC-Co
2	ZCC	YBD152	K05-K25	CNMG120408	WC-Co

TABLE IV. CONDITIONS OF INDEXABLE CUTTING INSERTS

Set1		Set2		Set3	
Non processed		Processed Mode 1		Processed Mode 2	
YBC251	YBD152	YBC251	YBD152	YBC251	YBD152

Processed materials: AISI52100 HRC62 and AISI52100 HRC58-60 were used as the materials of processed workpieces. The utilization of workpieces of high hardness allows to insure high contact loads and to realize the express tests in standard cutting conditions and machine tool without application of high feed rates and depth of cut and special equipment for heavy turning. Six longitudinal grooves were performed on the workpieces to make machining process intermittent. Conditions of cutting tests are shown in the Table V.

TABLE V. CONDITIONS OF THE CUTTING TESTS

Material	Cutting speed, v m/min	Feed rate, f mm/rev	Depth of cut, t mm	Time of macining
AISI52100 HRC62	35	0.12	0.2	30 sec
AISI52100 HRC58-60	35	0.12	0.2	3 min

The experiments are carried out on FT11 lathe with a maximal power of 11 kw and a maximal spindle rotation speed of 1600 r/min. Toolholder type, used for indexable inserts: MCBNR2525M12.

III. RESULTS AND DISCUSSION

Table VI shows the examples of the wear patterns of the YBC251 tools' cutting edges after hardened steels machining. No significant impact of PMFP can be seen. However it should be noted that this type of cutting tool material - the cemented carbide of ISO P grade in general is not intended for processing of high hardness materials. And, as can be seen, PMFP cannot substantially improve strength or hardness of YBC251 cutting tools to make them applicable in such conditions. All tested samples were destructed by brittle fracture accompanied with abrasive wear.

Table VI shows the examples of the wear patterns of the YBD152 tools' cutting edges after hardened steels machining. As in a previous case when processing HRC 62 steel, full breakage of the cutting edges is observed for all sets of cutting inserts. In contrast to this, when machining workpiece of lower hardness wear pattern is characterized by flank wear land formation.

After 3 minutes of machining of workpiece with hardness 58-60 HRC, keeping all other machining conditions equal to previous case, original inserts have wear land width VB = 0.35-0.8 mm. Wear land morphology, shown at fig. Table VII is typical for cases, when fracture of cutting edge with subsequent intensive abrasive wear of new surfaces, which are not protected by thick CVD coating, is taking place. Processed indexable inserts in the same conditions of machining keep integrity of the tooltip. Without brittle destruction of the cutting edges gradual flank wear land formation is observed. At the same time inserts processed according to Mode1 conditions have VB = 0.14-0.17mm, while Mode2 inserts shows even lower wear: VB = 0.10-0.14mm. Significant difference in width of wear lands between processed and original inserts can be explained by bulk strengthening of cemented carbide material by PMFP. That prevents initial microdestruction by brittle fracture of the material at the areas adjacent to the cutting edges of the tool. Thus, protective coatings is not destructed and declines wear intensity of the carbide substrate. Also it can be noted that processing Mode2 shows better results in wear tests.

TABLE VI . WEAR OF YBC251 INSERTS

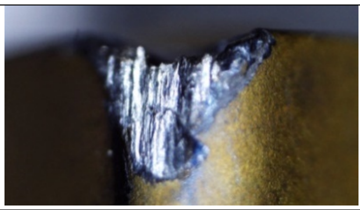
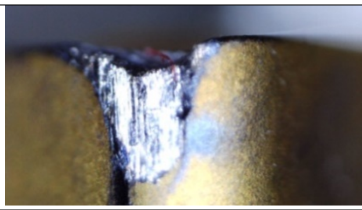
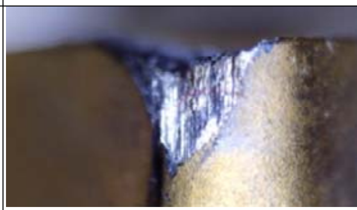
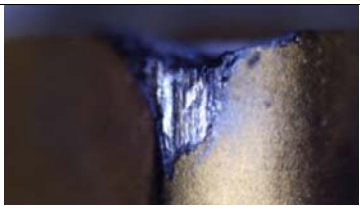
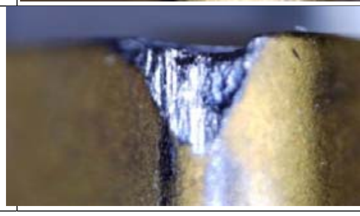
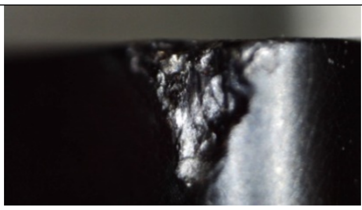
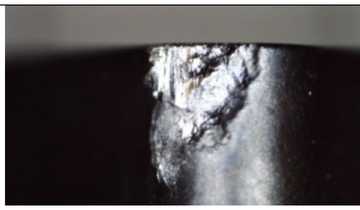
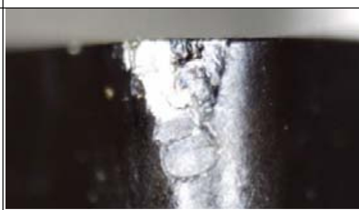
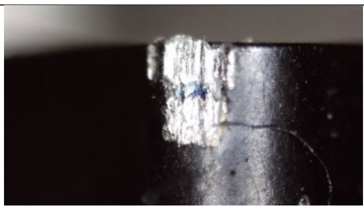
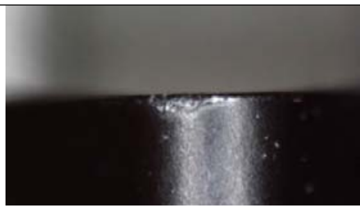
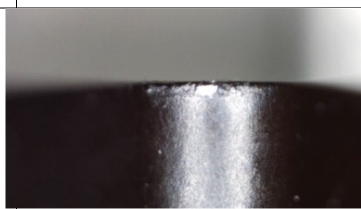
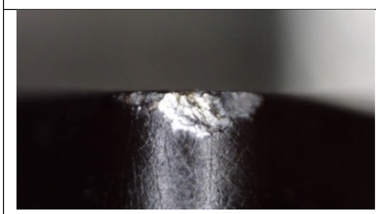
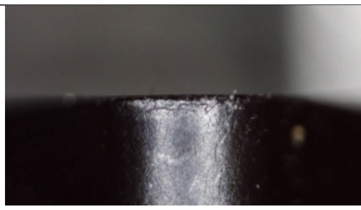
YBC251			
	Non processed	**Processed Mode 1**	**Processed Mode 2**
HRC 60			
HRC 56-58			

Table VII. WEAR OF YBD152 INSERTS

YBD152			
	Non processed	**Processed Mode 1**	**Processed Mode 2**
HRC 62			
HRC 58-60			
	VB=0.82 mm	VB=0.17 mm	VB=0.14 mm
			
	VB=0.35 mm	VB=0.14 mm	VB=011 mm

IV. CONCLUSIONS

1. The effect of volumetric strengthening of cemented carbide cutting tools by processing with a pulsed magnetic field leads to improvement of performance of the cutting tool when processing in hard-to-machine conditions.

2. Tests of cemented carbide ISO K-grade samples during short-time interrupted machining of hardened steel parts with gaps were conducted. It was estimated that original inserts have wear land width VB = 0.35-0.8 mm, while processed according to Mode 1 conditions inserts in the same conditions of machining have VB = 0.14-0.17 mm, whereas Mode 2 inserts show even lower wear: VB = 0.10-0.14 mm.

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