Original scientific paper
Received:06.07.2019
Accepted:17.12.2020
UDK:674.057.17

DETERMINATION OF PERFORMANCE INDICATORS AND QUALITY OF TCT KNIVES WHEN SHARPENED WITH PCD GRINDING WHEELS

Zhivko Gochev, Pavlin Vitchev, Georgi Vukov

University of Forestry, Faculty of Forest Industry, Sofia, Bulgaria
e-mail: zhivkog@ltu.bg; p_vitchev@ltu.bg; givukov@ltu.bg

ABSTRACT

This article presents experimental results in respect of planer knives sharpening made of TCT, type K40 and K20 according to ISO grade classifications with abrasive tools from Polycrystalline Diamond (PCD). The specific consumptions of PCD abrasive were defined. The grits of PCD abrasive were with common heightened durability, anti-stick properties and organic binder. Some qualitative indices when sharpen planer knives were studied.

Key words: planer knives, cutter head, sharpening, abrasive tools, polycrystalline diamond, tungsten carbide tools

1. INTRODUCTION

An important stage in production and use of planer knives for longitudinal milling of wood and wood-based materials is their sharpening. Planer knives that have been used and show signs of wearing off, as well as newly delivered knives, have to be sharpened. Sharpening is done on the back side of the knives until the knife edge is restored. Of particular importance is correct choice of the abrasive tool and of the adequate sharpening mode [2, 3].

The aim of the present work is to perform comparative experimental tests for determination of the specific consumption of diamonds of abrasive tools with an organic binder and a combined metal / organic binder produced in Bulgaria, as well as some qualitative indicators for normal and forced sharpening of planer knives with TC edges, type K40 and K20. The planer knives are part of assembled cutter head.

2. MATERIAL AND METHOD OF WORK

Experimental research was carried out using cutter head with HM insert knives for preliminary and fine planing of solid wood and wood composed materials on four-side processing machines (fig. 1).

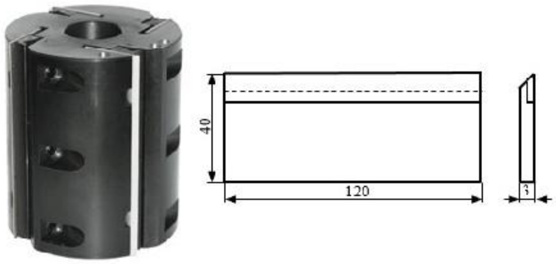


Figure 1. *Assembled cutter head with HM insert knives, type K40*

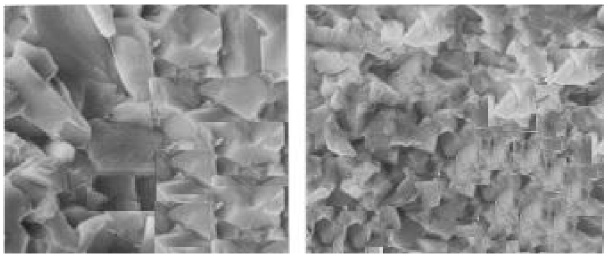
The basic parameters of the cutter head and the removable knives are given in Table 1. The planer knives are with tungsten carbide tipped edges, type K40, K20 and heat treated to hardness HRC 89.

Table 1. *Basic parameters of the cutter head and knives*

***D*, mm**	***d*, mm**	***L*, mm**	***B*, mm**	***s*, mm**	***z*, mm**	**$,^{0}$**	**Type**
123	32	120	40	3	4	45	T.C.T.

The indications in Table 1 correspond to:
D – Diameter of the cutter head;
d – Bore size;
L – Length of the knife;
B – Width of the knife;
s – Thickness of the knife;
z – Number of knives;
β – Angle of sharpening.
T.C.T. – tungsten carbide teeth.

These cutter heads have been designed for shapers machine, spindle moulder machine. The cutting plates consist of sintered materials composed of metal carbides and metallic binders: WC – 92% and Co – 8%) with medium grain of WC – 1,0 - 2,0 µm (fig. 2 A) and those from K20 with micro grain of WC up to 1,0 µm (fig. 2 B) [6].



A **B**

Figure 2. *Fracture of a standard tungsten carbide: A - Medium Grain 1,0-2,0 µm; B - Micro Grain up to 1,0 µm*

The abrasive PCD grinding wheel (fig. 3) has 12A2 45^0 shape (conical cup - CC) and works with its front surface (manufactured in ZAI JSC - Bulgaria).

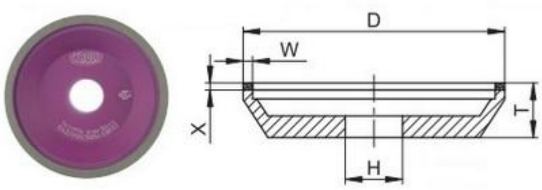


Figure 3. *Abrasive grinding wheel shape 12A2 45^0 (conical cup)*

The characteristics of the experimental abrasive wheels are given in Table 2.

Table 2. *Characteristics of the experimental wheels*

Shape and dimensions	**Abrasive type**	**Mesh Size**	**Bond Type**	**Concentration, %**
12A2 45^0 125x5x3x32	SD (Synthetic Diamond)	125/100	B8/A	100
12A2 45^0 125x5x3x32	SD (Synthetic Diamond)	125/100	BM/A	100

Experimental diamond wheels SD are made of synthetic diamond with ordinary durability.

B8/A is an organic bond based on a phenol-formaldehyde resin with added filler of barium sulphate and talc and with addition of anti-friction agents, in order to control its wear resistance, heat resistance, grit retention and lubrication.

BM/A is a metal-organic bond made of phenol-formaldehyde resin, metallic powders of copper and potassium, and zirconium dioxide to increase the bond rigidity.

The studies were performed under the following sharpening modes:

- cutting speed (V) – 18 m/s;
- longitudinal feed speed (V_l) – 1,0 m/min;
- cross feed speed (V_{dm}) – from 0,03 to 0,23 mm/double motion.

The studies were carried out according to the scheme of Table 3, with cross-feed being performed before each gradual movement of the longitudinal feed.

Table 3. *Scheme of the test carried out*

Abrasive wheel	**TCT**	**Cooling**	**Cross feed speed, mm/double motion**							
			0,03	**0,05**	**0,08**	**0,10**	**0,12**	**0,15**	**0,18**	**0,20**
SD 12A2 45^0 125x5x3x32 125/100 B8/A 100	K40	-		+		+				
	K40	+		+		+		+		+
SD 12A2 45^0 125x5x3x32 125/100 BM/A 100	K20	-		+		+				
	K20	+		+		+		+		+

Legend: + with cooling; - without cooling

Two studies were also carried out in forced sharpening with greater direct and reverse cross feed in the following modes:

- cutting speed (V) – 18 m/s;
- longitudinal feed speed (V_l) – 1,0 m/min;
- cross feed speed:

i. V_{dm}= 0,20 mm/double motion; $\overline{V}_{dm}$ = 0,15 mm – direct motion; $\overline{V}_{rm}$= 0,05 mm – reverse motion.

ii. V_{dm}= 0,23 mm/double motion; $\overline{V}_{dm}$ = 0,15 mm – direct motion; $\overline{V}_{rm}$= 0,08 mm – reverse motion.

The quality indicators of the treated surfaces were defined:

A. Grinding surface roughness (Ra):

The measurements were performed with the digital profilomer, model „Surftest SJ-210“ (Mitutoyo, Japan). The applied methodology is in accordance with BDS EN ISO 4287 and is described in details (Gochev 2005). For each knife, six measurements were made: four parallel to the cutting edge and two diagonals.

B. Micro indentations of the cutting edge

The maximum breakage deposits (H_i, µm) of the cutting edge were measured (Fig. 3). For that purpose a microscope with eyepiece-micrometer, model „Technival 2“ (Germany) was used. The measuring numbers were analogous with the index of roughness.

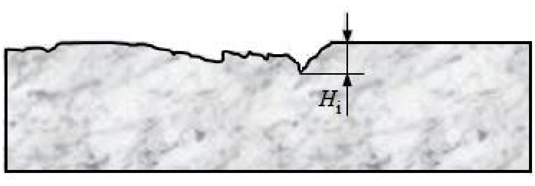


Figure 4. *Maximum breakage deposits (H_i) of the cutting edge*

C. Width of the cutting edge (B_i):

It was measured by analogy to the micro- indentations of the cutting edge in the narrowest and the widest parts.

D. *Availability of cracks, micro cracks, burns, blue in the face and some other defects in the cutting edge area:*

These indices were located by visual observation and by means of a magnifying lens in the process of knives sharpening or after already sharpened knives. They were also perceived as limiting conditions.

The following restrictive requirements have been imposed to the quality of sharpened TC knives:
- roughness of surfaces, R_a = 0,32-0,63 µm;
- micro indentations of the cutting edge, H_i = 18-25 µm;
- width of the cutting edge, B_i = 5-15 µm;
- is allowed in the close of knife edge: availability of burns, blue, change of the surface structure etc.

The specific consumption of PCD (Q_s, ct/mm^3) is a basic indicator of abrasion resistance of the abrasive tool [4, 5]. It is defined as attitude of the mass of the consumed PCD (m_a, ct) to the volume of the take down material (V_m, mm^3), i.e.:

$$Q_s = \frac{m_a}{V_m} \quad (1)$$

The relative consumption of PCD (Q_r, *ct/g*) is defined as attitude of the mass of consumed PCD to the mass of take down material (m_m, g):

$$Q_r = \frac{m_a}{m_m} \quad (2)$$

The consumption of PCD is defined to the weight method or by measuring the linear wearing out of the PCD layer.

The weight method is related to accurate weighing of the abrasive disk before and after carrying out a certain amount of work. The main disadvantage is the inaccuracy of weighing as a result of the materials in the lubricant-cooling liquid. The weight of the removed metal layer was determined for each of the knives by means of an electronic scale model „Sartorius"-type 610-D (Germany).

These disadvantages are largely overcome by using the linear wear measurement method of the PCD layer. This was done immediately before and after work, using a stereo microscope, over the width of the radial sections of the diamond layer.

The relative spending on PCD is specified according to the weight method:

$$Q_r = \frac{W_a}{m_m}\alpha_a \quad (3)$$

Where W_a is the wear of the PKD layer at each test, mg;
- α_a – a coefficient that measures the bond density and concentration of PKD in the layer.

The same index determined by the linear wear method of the diamond layer in a disk operating on its face is determined by the following formula:

$$Q_r = \frac{h_a.200.m_a}{X.m_m} \quad (4)$$

Where h_a is the wear of the wheel in the thickness of PCD layer during the tests, µm;
- X – the thickness of PCD layer before the tests, µm;

In order to obtain the volumetric specific consumption of diamond, it is necessary to multiply (Q_r) with the density of the treated material γ_m (g/cm^3), i.e. $Q_s = Q_r.\gamma_m$

The studies were carried out with the help of an automatic high productivity grinding machine for flat knives, model HMS I of a firm „Vollmer" (Germany) and lubricant cooling fluid - 1~2% an aqueous solution of calcined soda (Na_2CO_3).

The studies were carried out using an automatic, high-performance sharpening machine for planer knives, model „HMS I" of a firm „Vollmer" (Germany) and a lubricating-cooling liquid - 1~2% aqueous solution of calcined soda (Na_2CO_3).

The knives of the cutter head were mounted on the table of the sharpening machine on the step plate (Figure 5) to ensure simultaneous sharpening [3].

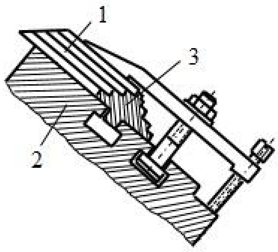


Figure 5. *Mounting of knives on the table of a sharpening machine on the step plate: 1 - knife; 2 - table; 3 – step plate*

3. RESULTS AND DISCUSSION

The results of the research were processed by the variation statistics methods with the software products QstatLab5 and Microsoft Excel. All results of the studies on sharpening planer knives at different values of the cross feed are presented in graphical form (fig. 6-9), including forced sharpening with greater direct and reverse cross feed.

Table 4 shows comparison of qualitative indicators for sharpening TC planer knives BK8 and BK8M with PCD abrasive wheels with and without cooling.

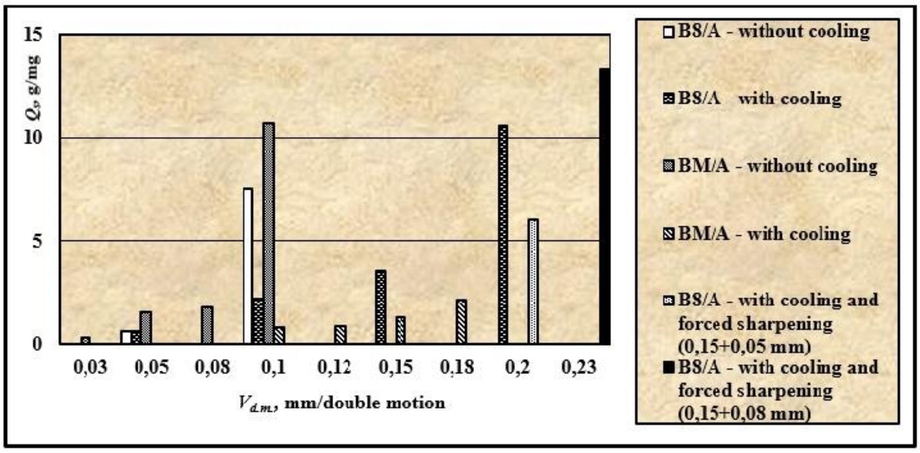


Figure 6 . *Dependence between specific consumption of PCD (Q_s) and the rate of the cross feed ($V_{дв.х.}$)*

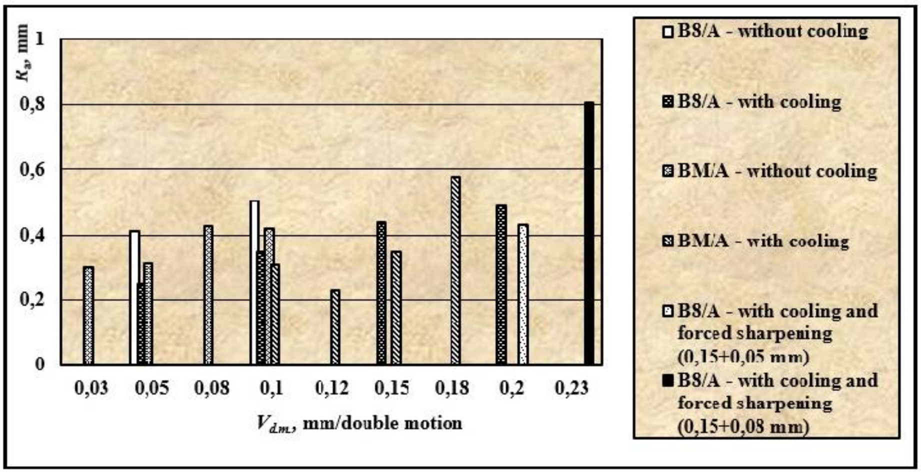


Figure 7. *Dependence between the rate of the cross feed ($V_{дв.х.}$) and the roughness index (R_a)*

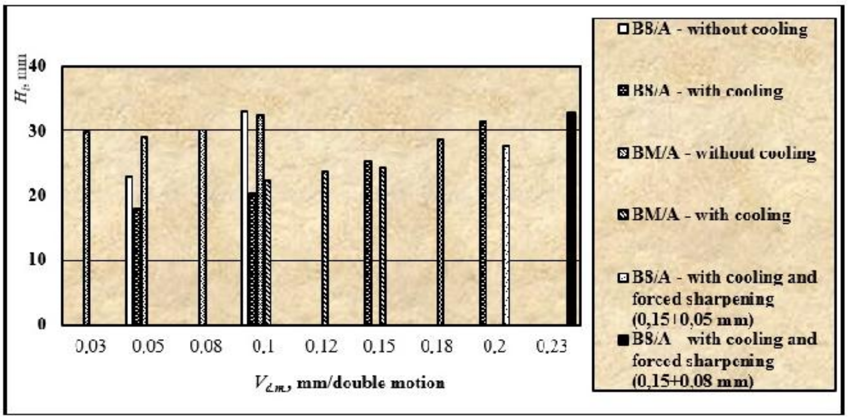


Figure 8. *Dependence between the rate of the cross feed ($V_{дв.х.}$) and H_i index*

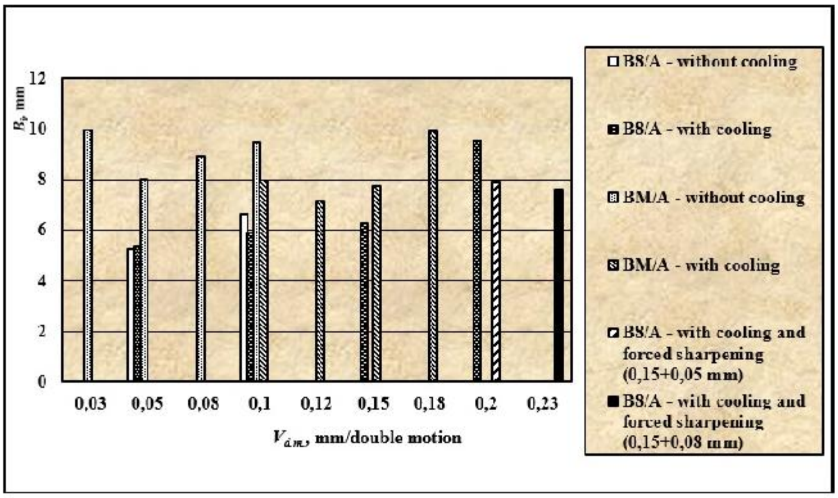


Figure 9. *Dependence between the rate of the cross feed ($V_{дв.х.}$) and the width of the cutting edge (B_i)*

Table 4. *Comparative table of qualitative Indicators for sharpening of TC planer knives with diamond abrasive wheels*

Bond	***V***	**Cooling**	**Quality Indicators of sharpening**			**Existence of defects**
			***R_a*, μm**	***H_i*, μm**	***B_i*, μm**	
B8/A	0,05	-	0,41	22,9	5,26	
		+	0,25	17,8	5,37	
	0,10	-	0,51	33,1	6,61	burning
		+	0,35	20,4	5,89	
	0,15	+	0,44	25,4	6,25	
	0,20	+	0,49	31,3	9,56	highly cracked line
	0,20 (0,15+0,05)	+	0,43	27,6	7,91	
	0,23 (0,15+0,08)	+	0,81	32,8	7,61	lack of straight line, highly cracked line
BM/A	0,03	-	0,30	29,8	9,98	
	0,05	-	0,31	29,2	8,04	
	0,08	-	0,43	30,2	8,96	light burning
	0,10	-	0,42	32,5	9,50	burning at the end
		+	0,31	22,4	7,98	
	0,12	+	0,23	23,7	7,17	
	0,15	+	0,35	24,3	7,75	
	0,20	+	0,58	28,7	9,95	breaking at the end

It can be seen from Figures 6-9 and Table 4 that:

1. Abrasive wheel with B8/A bond without cooling at V_{dm} = 0,10 mm/double motion heated the sharpened TC knives, and the specific diamond consumption is Q_s = 7,54 g/mg._This is 12 times higher specific diamond consumption at V_{dm} = 0,05 mm/double motion width (Q_s = 0,64 g/mg), or that wheel can run without cooling to V_{dm} = 0,05 mm/double motion.

2. Abrasive wheel with BM/A bond without cooling at V_{dm} = 0,08-0,10 mm/double motion heated the sharpened TC knives. The specific diamond consumption increases slightly to cross feed speed V_{dm} = 0,08 mm/double motion, but at V_{dm} = 0,10 mm/double motion, the specific diamond consumption is tenfold increased (Q_s = 10,71 g/mg). It means that an abrasive wheel with BM/A bond can run without cooling to cross feed speed V_{dm} = 0,08 mm/double motion.

3. Abrasive wheel with B8/A bond with cooling works well to cross feed speed V_{dm} = 0,15 mm/double motion and specific diamond consumption Q_s = 3,59 g/mg Q_s = 3,59 g/mg – relatively high but within acceptable limits. At V_{dm} = 0,20 mm/double motion, the specific diamond consumption is increased to Q_s = 10,56 g/mg, as there are obtained edges with a highly cracked line. Therefore, an abrasive wheel with a B8/A bond with cooling can work well with cross feed speed to V_{dm} = 0,15 mm/double motion.

4. In forced sharpening with abrasive wheel with B8/A bond, with cross feed speed $V_{дв.х.}$ = 0,20 mm/double motion: $\overrightarrow{V_{dm}}$ = 0,15 mm – direct motion and $\overleftarrow{V_{rm}}$= 0,05 mm – reverse motion, performance indicators are much better than the same wheel and with direct cross feed speed $V_{дв.х.}$ = 0,20 mm/double motion. The specific diamond consumption is by 40% lower, which is significant in this large cross-feed. With cross feed speed $V_{дв.х.}$ = 0,23 mm/double motion: $\overrightarrow{V_{dm}}$ = 0,15 mm – direct motion and $\overleftarrow{V_{rm}}$= 0,08 mm – reverse motion, did not get good results because the B8/A abrasive wheel has reached its limit.

5. The abrasive wheel with BM/A bond has much better sharpening capabilities than a wheel with B8/A bond. This is confirmed by the studies, which has 2,6 times less specific diamond consumption per wheel B8/A at a cross-feed of 0,10 mm/double motion.

4. CONCLUSION

On the basis of the experimental studies conducted and the analysis made, the following conclusions can be drawn:

1. The diamond wheel with its bond, grain type, and sharpening mode, cooling, and type of TC knives have a steady effect on performance indicators and sharpening quality.

2. The roughness of the polished surfaces (R_a) in all sharpening modes is within the standard range, with a general tendency to increase the cross-feed being increased and R_a. When sharpening with cooling, the roughness of the surfaces greatly improves.

3. The size of the micro-indentations of the edge (H_i) increases with increasing the cross-feed (V_{dm}). The knives' cooling helps to reduce the micro-indentations of the cutting edge. In some heavier sharpening modes, high H_i values are obtained, which can be reduced by smoothing the edge without crosswise feeding the abrasive wheel.

4. In all studies, the width of the edge B_i of the TC knives is within the standard requirements.

5. It is recommended to use the following brands of diamond discs and sharpening modes:

- abrasive wheel SD (PCD) 12A2 45^0 125x5x3x32 125/100 B8/A 100; V = 16-18 m/s; V_l = 1,0 m/min; V_{dm} = 0,08-0,10 mm/double motion; without cooling;
- abrasive wheel SD (PCD) 12A2 45^0 125x5x3x32 125/100 BM/A 100; V = 16-18 m/s; V_l = 1,0 m/min; V_{dm} = 0,05 mm/double motion; without cooling;
- abrasive wheel SD (PCD) 12A2 45^0 125x5x3x32 125/100 BM/A 100; V = 16-18 m/s; V_l = 1,0 m/min; V_{dm} = 0,12-0,15 mm/double motion; with cooling.

6. It is recommended forced sharpening with B8/A abrasive wheel with cooling and with cross feed speed $V_{дв.х.}$ = 0,20 mm/double motion: $\overrightarrow{V_{dm}}$ = 0,15 mm – direct motion and $\overleftarrow{V_{rm}}$= 0,05 mm – reverse motion. The specific diamond consumption decreases by 40%.

REFERENCE

[1] Vuchkov I., S. Stoyanov (1986), Mathematical modeling and optimization of technological objects, Technika, Sofia, p. 341 (in Bulgarian).
[2] Gochev Zh. (2005), Manual for wood cutting and woodcutting tools, PH in UF, Sofia, p. 263, ISBN 954-332-007-1 (in Bulgarian).
[3] Gochev Zh. (2018), Cutting of wood and cutting tools, PH Avangard Prima, Sofia, p. 523, ISBN 978-619-239-047-1 (in Bulgarian).
[4] Zaharenko I, (1981) Fundamentals of diamond processing of tungsten carbide tools, Naukova dumka, Kiev, p. 229 (in Russian).
[5] Gochev Zh. (2008), Investigation on the grinding quality of planing knives made of high-speed steel (HSS) type M2 and specific consumption of cubic boron nitride (CBN), The 6th International Scientific Conference: proceedings of papers, „Chip and Chipless Woodworking Processes“: proceedings of papers, Technical University- Zvolen, 11-13.IX. Šturovo, Slovakia, pp. 89-97, ISBN 978-80-228-1913-8.
https://carbide.ultra-met.com/viewitems/iso-grades/iso-grade-classifications-tungsten-carbide

Acknowledgement: This paper is supported by the Scientific Research Sector at the University of Forestry – Sofia, Bulgaria, under contract № НИС-Б-1012/27.03.2019.