ELECTRODISCHARGE AND ELECTROCHEMICAL DRESSING OF SUPERHARD GRINDING WHEELS

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Abstract: *In the paper the electrodischarge and electrochemical dressing method of super hard grinding wheels using segmental tool electrode and low concentration of electrolytes has been presented. Also the investigation stand for dressing has been depicted. The experimental results concerned forming of cutting surface of grinding wheels (CSGW) in two different processes: electrodischarge profiling and electrochemical dressing. The obtained results confirmed usefulness of both of these processes in forming macro- and microgeometry of CSGW, reduction of geometrical deviations and form dressing of super hard grinding wheels with metal bond. Potential application of electrochemical and electrodischarge methods using diluted solutions of electrolytes for dressing of grinding wheels has been presented. The hybrid system of electrodischarge and electrochemical grinding wheels dressing has been proposed.*

Keywords: SUPER HARD GRINDING WHEEL, ELECTROCHEMICAL AND ELECTROCHEMICAL DRESSING, CSGW, CD, CBN

1. Introduction

Grinding wheels made of super hard abrasives (such as: natural diamond CD, synthetic diamond SD or cubic boron nitride CBN) bonded are nowadays very modern abrasive tools. They are referred to below as super hard grinding wheels. These super hard grinding wheels have attractive operational properties, especially: a very good cutting abilities, long life, good tear strength, and high quality of grinding [1,2,8,11,12]. Super hard grinding wheels are generally used in the machining of hard – to – grind materials, e.g. cemented carbide, ceramics and glass, high – speed steel, tungsten carbide, titanium alloys. Rational exploiting of their attractive mechanical properties is determined by the accurate formation of working profile and macro- and micro-geometry (topography) of grinding wheel cutting surface CSGW [2,3,8,10].

Dressing of superabrasive grinding wheels comprises 3 principal operations: profiling, sharpening and fining (cleaning). Profiling of grinding wheel aims at formation of the macro-geometry of working profile of grinding wheel, being one of the factors responsible for deviations in shape and size of ground workpieces. Sharpening of grinding wheel consists in formation of micro-geometry of CSGW, comprising among others: the number, shape and distribution of static and kinematic cutting edges on the working surface of CSGW. These cutting edges decide of the cutting performance of grinding wheel and determine the course and results of grinding. The goals of fining of grinding wheel are removal of grinding products, deposited on CSGW, and regeneration of cutting performance of grinding wheel. Realization of these operations, which are crucial for mechanical characteristics of superabrasive grinding wheels is a difficult task both for the manufacturers of grinding wheels and for their users, because of their specific physicochemical properties (e.g. very high hardness of abrasive materials, high durability of metal bond) [3,7,9,13]. Therefore the conventional methods such as dressing by using the single-point diamond dressers, rotating dressers, hard rollers or abrasive whetstones, corundum or soft steel block dressing etc. are neither useful nor effective. The most predisposed for dressing of superabrasive grinding wheels were found to be certain unconventional dressing methods, mainly erosive ones [5-12].

The method of electrochemical super hard grinding wheels dressing using alternating current, referred to as the ECD–AC method, was developed in the Lodz University of Technology [4÷7]. Electroerosion dressing methods EDD are particularly useful for profiling of super hard grinding wheels, especially for multilayer grinding wheels with distinct cutting profile shape CPS. It is to note that the thermal character of CPS formation by using these approaches has a negative impact on cutting performance of the dressed grinding wheels. Therefore in many cases they have to be additionally sharpened on completion of electroerosion dressing [6,10,12]. Hybrid dressing methods rank among the promising and intensively developing techniques of formation of mechanical properties of superabrasive grinding wheels. They are mainly based on coupled, electro-erosive and electrochemical processes. These systems take advantage of both types of erosive dressing approaches and facilitate simultaneous profiling and sharpening of a grinding wheel within one operation.

Analysis of the usefulness of erosive methods of super hard grinding wheels dressing indicates that electrodischarge and electrochemical methods are the most suitable of them. The first methods are particularly useful for grinding wheels profiling, and the latter ones for their sharpening. These two dressing manners are realized in two separate operations, which require application of different appliances. That considerably limits their use for dressing of multilayer grinding wheels. In the paper, authors propose a electrodischarge and electrochemical dressing system, using segmental tool electrode and diluted solutions of electrolytes. The principle of operation of this system, stand for its realization and experimental results concerning dressing of super hard grinding wheels have been reported.

2. Method of hybrid elctrodischarge and electrochemical dressing system

Analysis of the usefulness of erosive methods of super hard grinding wheels dressing indicates that electrodischarge and electrochemical methods are most predisposed of them [4,6]. The first ectrodischarge methods are particularly useful for grinding wheels forming, and the latter ones electrochemical methods for their sharpening.

The scheme of this hybrid dressing process is presented in Fig. 1, however the scheme of a stand for hybrid electrodischarge and electrochemical form dressing system of super hard grinding wheels is shown in Fig. 2 .

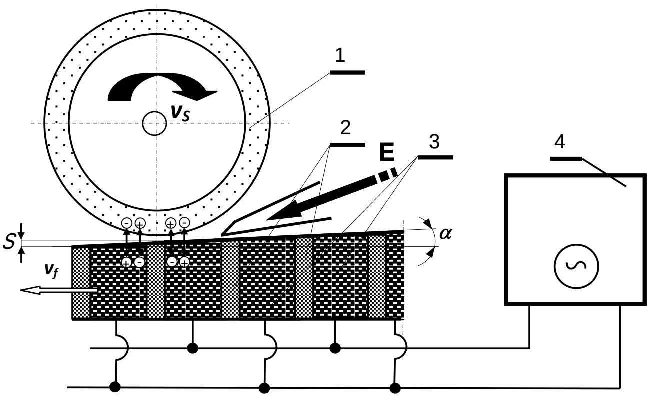

Fig.1. *Schematic diagram of hybrid electrodischarge and electrochemical dressing system: 1 – grinding wheel, 2 – diluted solutions of electrolytes supply, 3 – slat electrode, 4 – impulse generator, 5, – AC power unit, S – inter electrode gap, a – angle of working tool electrode inclination.*

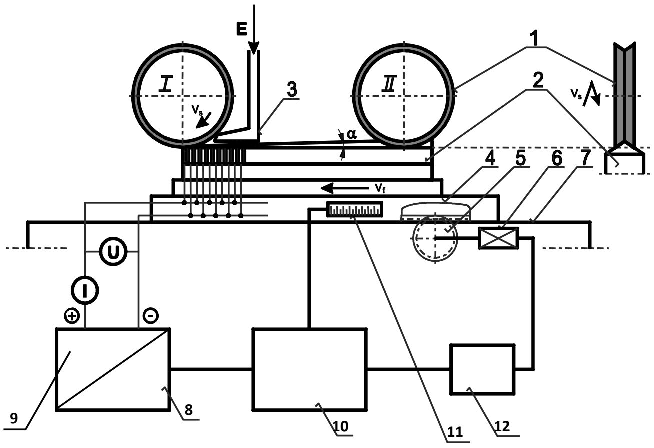

Fig. 2: *The scheme of a stand for hybrid electrodischarge and electrochemical form dressing system of super hard grinding wheels: 1 – grinding wheel, 2 – working tool electrode, 3 – electrolyte supply jet, 4 – grinder table, 5 – toothed gear for transmission of the grinder table feed, 6 – electric motor, 7 – grinder body, 8 – impulse generator, 9 – AC power unit, 10 – control system, 11 – optical device, 12 – motor programmer,* v_s *– grinding wheel speed,* α *– angle of working tool- electrode inclination, E – electrolyte solution, I and II – initial and final position of the grinding wheel during CSGW forming.*

These two dressing manners are realized in two separate operations, which require application of different appliances. The view of working zone and segmental tool-electrode is presented in Fig. 3. That considerably limits their use for form dressing of multilayer grinding wheels. Our investigations point at the possibility of combining the advantages of both the dressing methods, and their realization in a single dressing operation, by means of a hybrid system of grinding wheels dressing. The proposed dressing system is based on application of coupled electrodischarge and electrochemical processes. The first of these processes has substantial effect on the grinding wheel profile forming, and the second on the CSGW sharpening. The system principle is based on application of both a segment tool-electrode (Fig. 3b), providing non-contact voltage supply to a grinding wheel, and specially selected, diluted solutions of electrolytes.

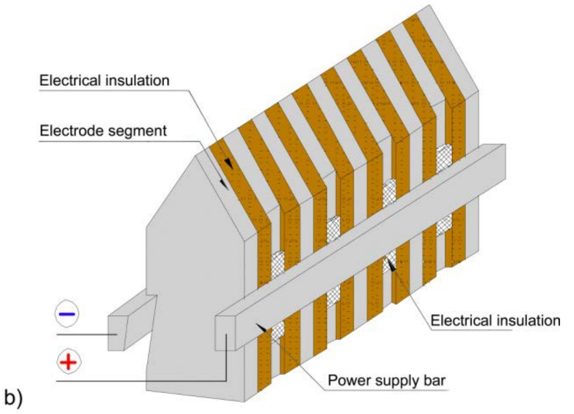

Fig. 3. *The view of working zone (a) and segmental tool-electrode (b).*

Dressing process (Fig. 2) of grinding wheels using this system proceeds in two permanents. First of them realizes electrodischarge forming of the grinding wheel, second realizes electrochemical dressing of it with ECD–AC method. During electrodischarge dressing of grinding wheel the segment tool electrode is connected with impulse generator – 8, which initiates spark discharge between the metal bond and segments of tool-electrode. During electrochemical dressing process the tool-electrode is connected with AC power unit – 9. The feed of tool-electrode to grinding wheel is realized by its inclination – α and low longitudinal feed of table of the grinder. To realization of presented dressing system of grinding wheels, the test stand which base is the proper adapted electrochemical grinding machine type ECTB-8 was constructed.

3. Results and discussion

The tests of the stand including among other things: control of proper function of its assembles, measurement of electric parameters of impulse generator and recording of courses of impulses of voltage and intensity of electric current during electrodischarge dressing process were performed. Electrical parameters of electro-erosive grinding wheels dressing were determined on the basis of results of preliminary experiments of dressing of diamond and CBN grinding wheels. To determine the suitable electrical parameters of the pulse generator, the voltage and current intensity of spark discharges occurring in an inter-electrode gap (between grinding wheel and working electrode) were recorded, and the basic parameters characterizing the effectiveness of grinding wheel dressing process were estimated. They were as follows: the volume of abrasive material removed through erosive process and the relative wear of working electrode [6]. Representative records of effective passes of spark discharges during electro-erosive dressing of (D125/100 M75) grinding wheel are displayed in Fig. 3. Presented variations in voltage and intensity of electric current in the inter-electrode gap provide evidence of generation of the plasma channel and spark discharges, which are essential for effective removal of metal bonds of grinding wheels subjected to this treatment. Analyze of courses of impulses (Fig. 4) indicates that there are conditions for come into being plasma channel and spark discharge which is necessary for removal of metal bond of grinding wheel during dressing process. It confirms that impulses in this process are the spark machining with relatively uniformly energy of discharge. The investigations connected settlement of electric parameters of generator providing obtaining the best indexes of effectiveness of electrodischarge dressing process of grinding wheels have been continued.

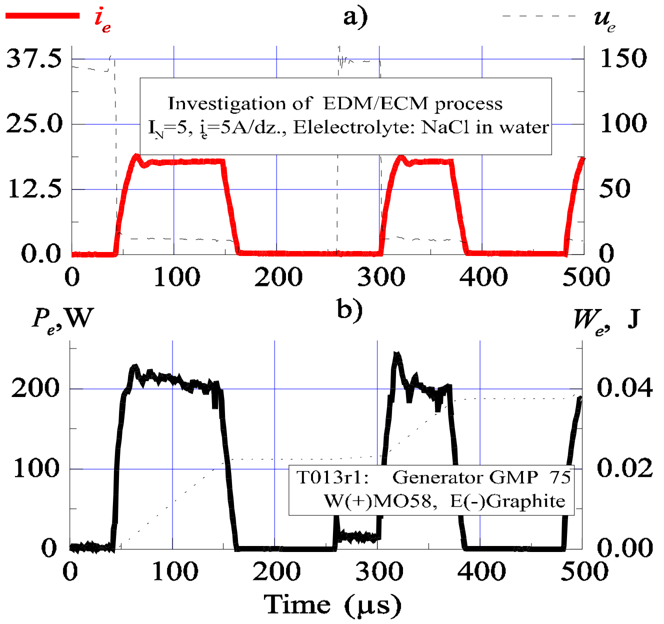

Fig. 4. *Example courses of impulses of electric current: a) intensity of electric current –* i_e*, and decrease in voltage –* U_e*, b) course of power –* P_e *and energy of impulses of electric current –* W_e*.*

Effects of electrical parameters of pulse generator on effectiveness of electrodischarge dressing of grinding wheels are shown in Table 1. These results were achieved during relatively long (approximately 180-200 min) electrodischarge dressing of grinding wheels, carried out for 3 different ranges of electrical parameters of pulse generator (referred to as: P1, P2, and P3 in Table 1).

Table 1: *Effect of electrical parameters of electric pulse generator on results of dressing of grinding wheels.*

Type of dressing	Type of grinding wheel	Type of electrode material	Electrical parameters	Capacity of grinding wheel ΔV_s [mm^3]	Relative wear of tool electrode $\mathrm{v} = \frac{\Delta V_e}{\Delta V_s} \times 100\%$
Traverse pass	SD 125/100 M75	Cu/C	P_1	162,5	59,8
			P_2	270,3	39,7
			P_3	Z	Z
		Ti/Ti	P_1	153,4	65,5
			P_2	279,8	41,5
			P_3	290,4	55,4
		Ti/C	P_1	127,4	75,3
			P_2	205,2	62,3
			P_3	240,8	72,5
Longitudinal pass	SD 125/100 M75	Cu/C	P_1	78,4	45,3
			P_2	140,4	33,2
			P_3	Z	Z
		Ti/Ti	P_1	88,0	53,2
			P_2	166,7	31,1
			P_3	170,3	51,1
		Ti/C	P_1	73,4	69,2
			P_2	122,3	68,5
			P_3	Z	Z
	RBN 125/100 M75	Cu/C	P_1	84,1	52,3
			P_2	145,8	35,0
			P_3	154,3	62,1
		Ti/Ti	P_1	79,9	45,6
			P_2	136,7	44,6
			P_3	138,5	51,2
		Ti/C	P_1	58,5	45,1
			P_2	108,3	44,0
			P_3	Z	Z

P_1: U=100V, I=25A, t_i=16μs, t_p=125μs
P_2: U=250V, I=50A, t_i=125μs, t_p=320μs
P_3: U=300V, I=75A, t_i=250μs, t_p=1000μs
Z – short circuit of electrode

Analysis of these results indicates that increments in power supplied by pulse generator resulted in larger volumes of removed abrasive material and the greater relative wear of working electrode. It is to note that for the maximum power of the pulse generator (referred to as P3) the negative phenomenon, termed "the short circuit of electrode" occurred in many experimental trials. Due to this phenomenon the continuation of EDD process was impossible. Results of these experiments indicate that the spark channel, which provides the relatively uniform energy of spark discharges, was generated over the following ranges of pulse generator parameters: working voltage 250 V, current intensity 25-50 A, pulse duration 125-250 μs, pulse pause 250-500 μs.

Profiling of grinding wheel by electrodicharge dressing of grinding wheels using a slat-tool electrode a with an apical angle of 90°, and the α angle of inclination with respect to its longitudinal feed (Figure 1). The following quantities were determined: the accuracy of CSGW patterning after the profile of tool electrode and the relative wear of tool electrode. Representative results of studies are shown in Fig. 5. The applied electrical parameters of pulse generator were determined earlier and are referred to as P2 in Table 1. Results of these studies proved that CSGW could be patterned after the profile of tool electrode. However, the accuracy of this operation depends on the relative wear of working electrode. This dependence indicates that the wear of tool electrode should be taken into consideration within the step of its designing because approaching the target depth of the CSGW profile requires application of the electrode with a significantly larger working cutting length.

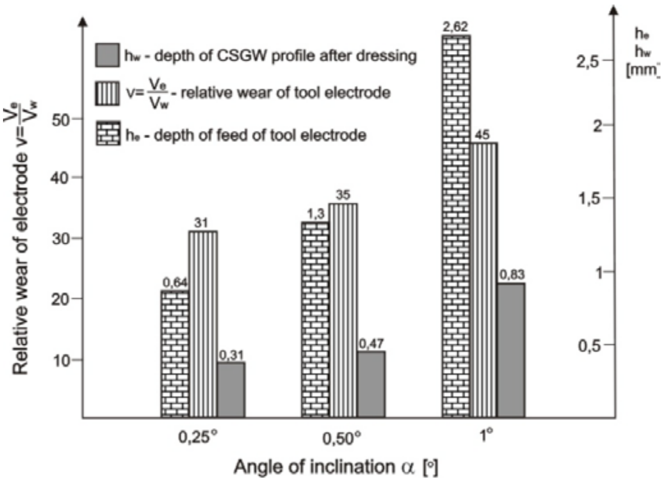

Fig. 5. *The influence of the angle of the working tool electrode inclination on the relative efficiency of dressing and the wear of electrode; grinding wheel D125/100 M75, feed of electrode - 0.4 mm/min.*

Example investigation results concerned the assessment of effectiveness of electrodischarge and electrochemical dressing process on the shaping of micro-and macrogeometry of the CSGW are presented in Fig. 6-8. Comparative studies on macro- and microgeometry (topography) of CSGW formed through electroabrasive and electrochemical processes were conducted.

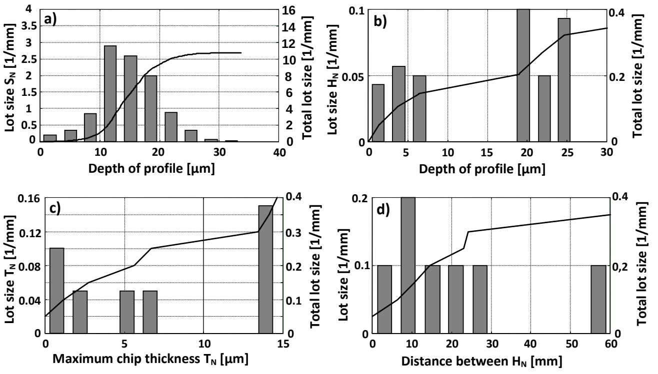

Fig. 6. *Streometrical parameters of the CSGW after electrodischarge dressing of the grinding wheel D125/100 M75: (a) S_N – static cutting edges, (b) H_N – kinematics cutting edges, (c) T_N – maximum chip thickness, (d) L_N – distance between kinematics cutting edges; grinding wheel D125/100 M75, wheel speed = 25m/s, table speed =5m /min, depth of cut =0,02 mm*

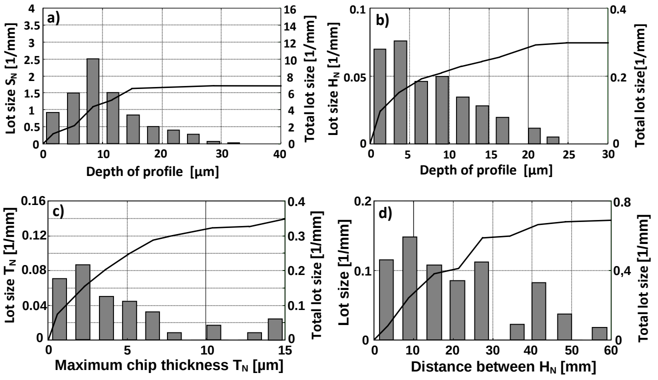

Fig. 7. Streometrical parameters of the CSGW after electrochemical dressing of the grinding wheel D125/100 M75: (a) S_N – static cutting edges, (b) H_N - kinematics cutting edges, (c) T_N – maximum chip thickness, (d) L_N – distance between kinematics cutting edges; grinding wheel D125/100 M75, wheel speed = 25m/s, table speed =5m /min, dept of cut =0,02 mm.

The effectiveness of electrodischarge and electrochemical dressing processes in the forming of the CSGW macro- and microgeometry was assessed on the basis of the stereometric parameters, such as numbers of static cutting edges (S_N) and kinematic cutting edges (H_N), and the average maximum thickness of a chip (T_N). They were determined using the computer analysis of circumferential representation of the CSGW profile and simulation of the grinding process [1,5,7].

In Fig. 6-7 the comparison of stereometrical parameters of the CSGW (static cutting edges, kinematical cutting edges, maximum chip thickness and distance between kinematical cutting edges after electrodischarge dressing process and electrochemical dressing has been depicted. Application of electrodischarge dressing process causes approximately a 100% increase of number of static edges (S_N), almost 70% increase of depth of deposition of the static edges, 40% decrease of number of kinematic edges (H_N), about 60% increase of depth of deposition of the kinematic edges, approximately 65% increase of number of average thickness of chips (T_N) and about a 100% increase of distance between cutting edges (L_N).

The differences in CSGW morphology correspond with results obtained using SEM method. The SEM pictures of CSGW are presented in Fig. 8.

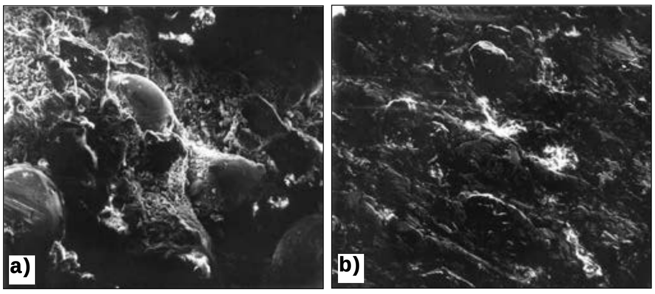

Fig. 8. *SEM images of the grinding wheel D125/100 M75 after dressing: (a) electrodischarge dressing, (b) electrochemical dressing.*

The comparison of the CSGW images (Fig. 8 a) confirms that a result of the thermal effect of spark discharges on the CSGW is a curvature of grinding grain edges brought about by their partial graphitization. These unfavorable processes are not observed after electrochemical dressing (Fig. 8b). This phenomenon indicates that electrodischarge dressing process has to be followed by electrochemical sharpening dressing operation.

Analysis of stereometrical parameters of the CSGW after electrodischarge (Fig. 6) and electrochemical dressing process (Fig. 7) indicates essential differences in forming of macro- and microgeometry. The electrochemicall dressing process causes a decrease of number of static edges (S_N) and kinematic edges (H_N), their proper concentration in the nominal surface of CSGW and increase in the average thickness of chips (T_N) and in the distance between cutting edges (L_N). These favorable changes of stereomtical parameters of CSGW improve cutting ability of the grinding wheel.

4. Conclusion

Presented studies confirmed the usefulness of the coupled, electrodischarge and electrochemical system of grinding wheels dressing for forming the functional qualities of metal-bonded superabrasive grinding wheels. This two-step system is particularly suitable for: correction of geometrical deviations of grinding wheels, CSGW patterning after the profile of tool electrode, and formation of the required macro- and microgeometry (topography) of CSGW. The principal advantage of this system is simultaneous realization of two operations, i.e. electrodischarge profiling and electrochemical sharpening of superabrasive grinding wheels.

5. References

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