

ECONOMICAL ASPECT OF ASSESSMENT OF ELECTROCHEMICAL DRESSING OF SUPER HARD GRINDING WHEELS

Prof. D.Sc. Ph.D. Eng. Golabczak A.¹, D.Sc. Ph.D. Eng. Golabczak M.²

Department of Production Engineering, Lodz University of Technology, Lodz, Poland ¹

Institute of Machine Tools and Production Engineering, Lodz University of Technology, Lodz, Poland ²

andrzej.golabczak@p.lodz.pl; marcin.golabczak@p.lodz.pl

Abstract: Rational exploitation of super hard grinding wheels with metal bond requires estimation of constituent costs of grinding process and dressing of grinding wheels. In the article the method of electrochemical dressing of super hard grinding wheels and economical analysis of electrochemical dressing of these kind of grinding wheels consisted in assessment of selected costs of this process has been presented. Also analysis of costs of the grinding process has been depicted. Obtained relationships allowed us to estimate contribution of respective component of costs of grinding process using super hard grinding wheels and are basis for their optimization.

Keywords: SUPER HARD GRINDING WHEEL, ELECTROCHEMICAL DRESSING, COSTS OF GRINDING, DIAMOND, CBN

1. Introduction

Grinding wheels made of super hard abrasives (such as: natural diamond CD, synthetic diamond SD or cubic boron nitride CBN) bonded by means of metal bond are among the most 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 [1,2,6,7].

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. However, the range of use of super hard grinding wheels is limited by the difficulty in forming macro- and microgeometry of the cutting surface of a grinding wheel (CSGW) in the dressing process [1,2,4,7].

Both grinding wheels manufactures – during the original formation of the CSGW, and their users – during regeneration of grinding wheels face the problem of the dressing of grinding wheels. The difficulty in dressing of super hard grinding wheels largely resulted from their specific physical and mechanical properties, i.e. a high hardness of the abrasive and a good strength of the metal bond. Thus, the use of conventional dressing method (e.g. dressing with single – and multi – grain diamond dressers, rotating diamond dressers, grinding with Al_2O_3 or SiC grinding wheels, grinding 'soft steel', crush dressing with a hard rollers, etc.) is ineffective and uneconomical [2,4,6,10]. Neither can these difficulties be eliminated by means of unconventional dressing methods, such as jet sharpening or electro contact discharge dressing due to the disadvantages of these methods [2,3,4,10].

The analysis different dressing methods of super hard grinding wheels and the studies carried out at the Lodz University of Technology resulted in the development of electrochemical dressing technology with using alternating current (AC). This method is subsequently marked as the ECD-AC method [4,5]. Thus major advantages of this method are as follows; contactless supply of voltage to the grinding wheel being dressed, cathodic activation of the grinding wheel, lower cost of the power supply, and the possibility of using electrolytes of a low concentration of chemical compounds. These electrolyte solutions are characterized by insignificant noxiousness for the surroundings and the natural environment.

In the electrochemical dressing of superhard grinding wheels (ECD-AC) and the economical aspects of exploitation of super hard grinding wheels with metal bond have been presented. Also relationship which allows for determination of constituent costs of grinding operation using super hard grinding wheels and includes machine costs, grinding costs, dressing costs and wear of grinding wheel has been elaborated.

Basing on investigation results, the exemplary calculations of constituent costs of realized grinding operation of sintered carbides have been presented.

2. Method of electrochemical dressing

Dressing of super hard grinding wheels using ECD-AC method is a heterogeneous anodic process of digestion (solid substance/solution) of metal bond and gumming up products of CSGW. The scheme of dressing of super hard grinding wheels (cup grinding wheels) using ECD-AC method has been presented in Fig. 1, however a scheme a set-up constructed in order to carry out dressing is shown in Fig. 2. This is made up of a grinder, equipment with an additional electrochemical unit and a monitoring-measuring system.

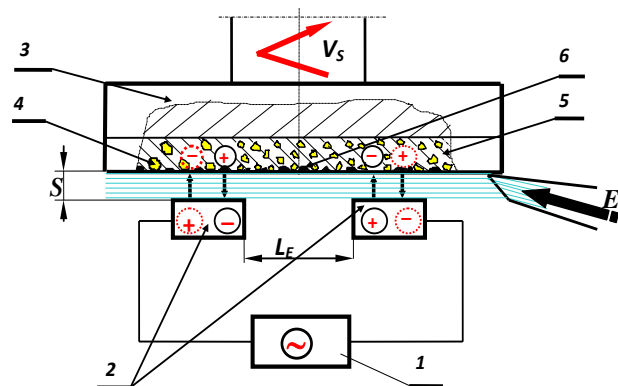


Fig. 1. The scheme of super hard cup grinding wheels dressing using the ECD-AC method: 1 – alternating current power pack, 2 – working electrode, 3 – grinding wheel body, 4 – abrasive, 5 – metal bond, 6 – products of loading in the CSGW.

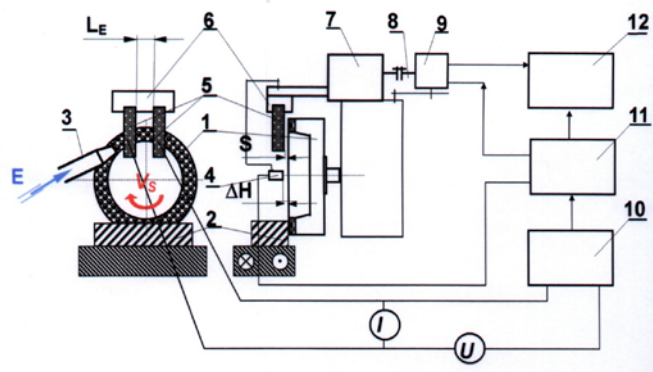


Fig. 2. The scheme of a stand for grinding wheels dressing using the ECD-AC method: 1 – grinding wheel, 2 – workpiece, 3 – electrolyte supplying nozzle, 4 – inductive sensor, 5 – tool-electrode, 6 – electrode holder, 7 – tool-electrode feed unit, 8 – guide-screw, 9 – stepping motor, 10 – AC power unit, 11 – LC generator, 12 – computer, L_E – spacing of electrodes, E – electrolyte solution, S – inter-electrode gap, ΔH – the linear grinding wheel decrement.

The dressing of a grinding wheel (3) consist in the anodic dissolution of a metal bond (5) and products loading the CSGW (6) in the inter – electrode gap (S), to which a electrolyte solution (E) of specially selected chemical compounds is supplied (containing up 5% sodium – potassium salts). An alternating current voltage is supplied to the grinding wheel by two carbon electrodes (2) connected with the power supply (1).

The dressing process consists in the cyclic dissolution of components of the grinding wheel, which alternately acts as anode or a cathode, corresponding to the frequency of changes in alternating current (Fig. 3).

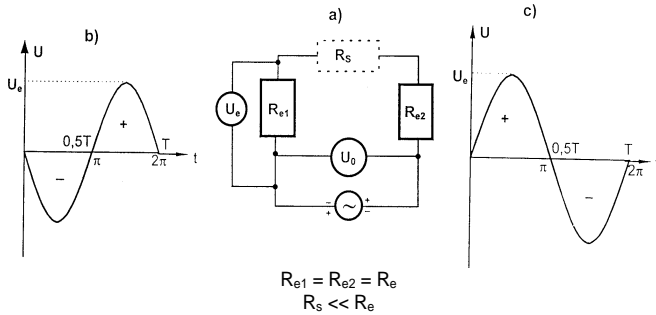


Fig. 3. A diagram of the equivalent electrical circuit of the ECD – AC method (a), and a course of voltage in the grinding wheel (b), and (c), R_e – electric resistance of inter-electrode gap, R_s – electric resistance of grinding wheel.

The anodic digestion of the grinding wheel compounds takes place in periodic of positive polarization of the grinding wheel (when it acts as an anode). In periods of negative polarization of the grinding wheel (when it is a cathode), the digestion of the passive layer (metal oxides and solid salts formed on the CSGW in the anodic process) mainly occurs. The removal of the passive layer from the CSGW is a favorable process, considering an increase in the digestion rate and the efficiency of the dressing process [4,5]. The application of two electrodes allowed an automatic change in the grinding wheel polarity and elimination of breaks in the dressing process in periods of negative polarization of the grinding wheel (Fig. 3b and 3c).

To investigate the process of dressing superhard grinding wheel by the ECD–AC method in the test send (Fig.2). Working voltage application to the grinding wheel (1) subjected to dressing, is executed with two carbon electrodes (5) fixed in an isolated casing (6), and connected to an alternating current supply power unit (10). In order to measure a grinding wheel linear decrement (ΔH), a contactless inductive sensor (4) cooperating with a LC generator (11) was applied. The stabilization of the inter electrode feed, is accomplished with a microcomputer (12), which by means of a stepping motors (9) and a guide screw (8), feed in the set of electrodes to the grinding wheel (1) subjected to dressing. To control the dressing process and to record its basic parameters, the special software.

3. Results and discussion

The investigations results presented concern the assessment of usefulness of the dressing method ECD–AC in shaping of macro- and micro geometry of the CSGW and regeneration of functional qualities of super hard grinding wheels [4,5].

Example investigation results confirming the possibility of the removed layer of the grinding wheel ΔH a face of a grinding wheel S3012 175x6x3x50 D125/100 M100 in the ECD–AC process is shown in Fig. 4. The investigations carried out have also showed the good conformity the theoretical calculations with the experimental investigations.

Economical usage of attractive operational properties of super hard grinding wheels points to necessity of analyze of all constituent costs of grinding operation. Significantly higher costs of super hard grinding wheels comparing to the wheels made of

conventional materials (i.e. with ceramic and resin bond) justify usage of aforementioned analysis.

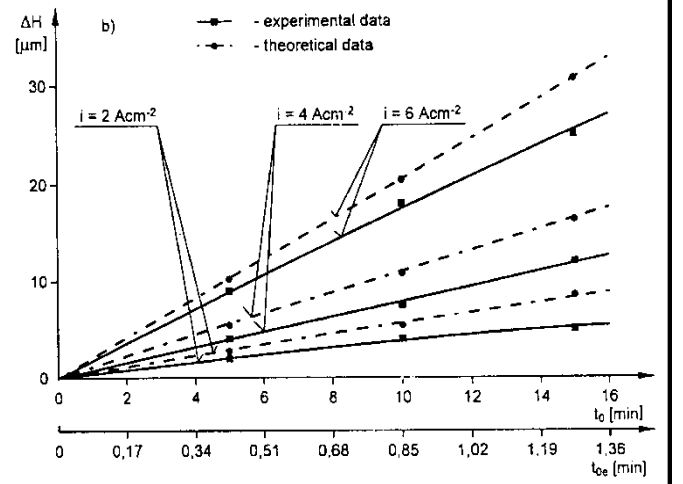


Fig. 4. A comparison of the theoretical calculations and the results of the experimental investigations of the grinding wheel (S3012 175x6x3x50 D 125/100 M100) layer ΔH removed in the ECD–AC dressing process.

Because of this in costs analysis of grinding operation it is necessary to consider: machine-hour cost of grinder – C_m , which amounts during grinding time – $C_{m gr}$ and during dressing time – $C_{m dr}$ and cost of wear of grinding wheel (super hard grinding layer) during grinding operation – $C_{gr m}$ and during electrochemical dressing time – $C_{gr dr}$. Taking into consideration all these costs components it is possible to evaluate total cost of grinding operation – C as the relationship (1):

$$C = C_{m gr} + C_{m dr} + C_{gr m} + C_{gr dr} \tag{1}$$

Entering a period of durability of grinding wheel (economical time) – T_e , time of grinding operation – t_m and time of dressing of grinding wheel – t_{dr} and cost of purchase of new grinding wheel – C_{gr} , respective costs components have been assessed as:

$$C_{m gr} = C_m t_m \tag{2}$$

$$C_{m dr} = C_m t_{dr} \tag{3}$$

$$C_{gr m} + C_{gr dr} = C_{gr} \frac{t_m}{T_e} \left(\frac{\Delta V_{gr} + \Delta V_{dr}}{\Delta V} \right) \tag{4}$$

where: ΔV_{gr} – wear volume of abrasive layer of grinding wheel during grinding process, ΔV_{dr} – wear volume of removed abrasive layer during ECD–AC dressing, which is calculated basing on dimension of abrasive layer.

Adding to formula (1) relationships (2-4) we obtain relationship (5):

$$C = C_m t_m + C_m \frac{t_m}{T_e} t_{dr} + C_{gr} \frac{t_m}{T_e} \left(\frac{\Delta V_{gr} + \Delta V_{dr}}{\Delta V} \right) \tag{5}$$

Dividing both side of equation (5) by t_m we obtain relationships of unit cost grinding operation by super hard grinding wheel:

$$C' = C_m + \frac{C_m t_{dr}}{T_e} + C_{gr} \frac{\Delta V_{gr} + \Delta V_{dr}}{T_e \Delta V} \tag{6}$$

Basing on elaborated relationships the total calculations of cost of grinding operation and dressing and percentage share of components of constituent costs have been done. Calculation results concern grinding operation of sintered carbides using super hard grinding wheel: S3012 170x6x3x50 D125/100 M100 and dressing operation using ECD–AC method.

In calculations the values obtained in following investigation conditions: grinding time $t_m = T_e = 160 \text{ min}$, dressing time $t_{dr} = 12 \text{ min}$, wear volume of abrasive layer during grinding process $\Delta V_m = 401 \text{ mm}^3$, wear volume of removed abrasive layer during dressing process $\Delta V_{dr} = 50 \text{ mm}^3$, total volume of surface layer of the new grinding wheel $V = 9269 \text{ mm}^3$ and cost of the

new grinding wheel $C_{gr} = 422 \text{ Euro}$ and machine-hour cost of grinder $C_m = 20 \text{ Euro/h}$ have been considered.

Calculation results have been presented in Fig. 5-6. Analysis of obtained results points at significant share of unitary costs of dressing (about 5%) and costs of grinding wheel (25%) in total cost of grinding process using super hard grinding wheels

In grinding processes using grinding wheels with conventional abrasives, components of these costs do not exceed 3-5%, and are usually negligible. This fact justifies purpose of economical analysis of dressing of super hard grinding wheels and purpose of its optimization.

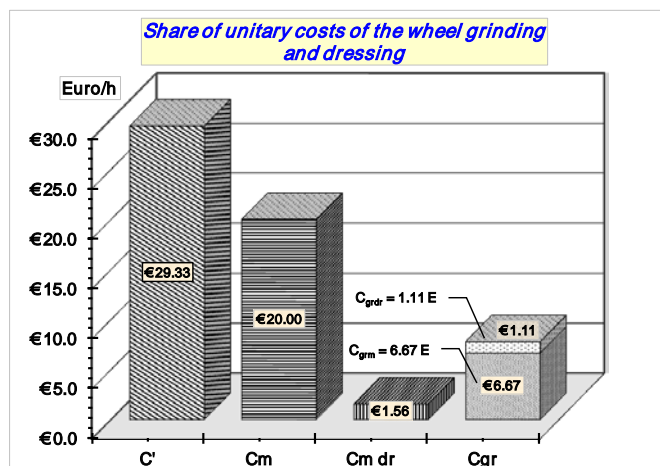


Fig. 5. Share of unitary costs of the grinding and dressing operation.

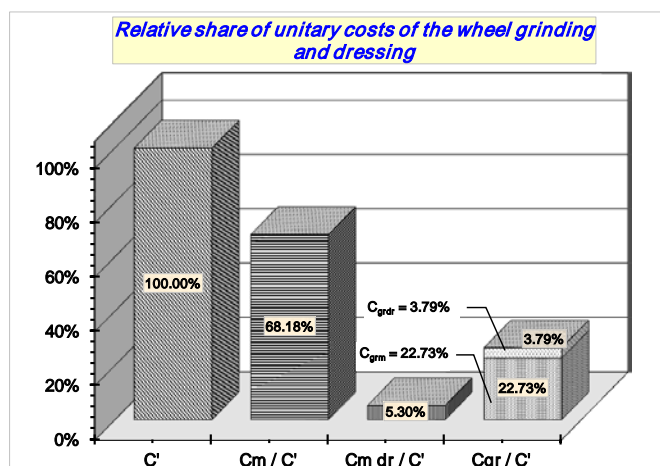


Fig. 6. Percentage share of unitary costs of grinding and dressing operation.

4. Conclusion

The effective method ECD-AC of dressing of super hard grinding wheels has been presented. This method consists of the anodic dissolution of the grinding wheel components (the metal bond and products loading on the CSGW), using alternating current in presence of low concentration of electrolytes.

The investigations carried out confirmed the usefulness of the ECD-AC method for forming the functional qualities of super hard grinding wheels. The investigations have confirmed that ECD-AC dressing method can be recommended for dressing of super hard grinding wheel. The implementation of ECD-AC method requires equipping the grinding machine with a cheap and a simple electrochemical unit.

Rational usage of operational properties of super hard grinding wheels with metal bond justifies purpose of performing economical analysis of costs of grinding and dressing.

Confirmation of this fact are obtained investigation results, which point at significant share of unitary ECD-AC dressing costs (about 5%) and cost of grinding wheel resulted from remove of

surface layer in this process (about 3%) in total unitary costs of grinding operation

It should be emphasized that in grinding processes using ceramic grinding wheels total cost of dressing and wear of grinding wheel do not exceed 3% and is usually negligible.

5. References

- [1] Abe T.: Future technology for silicon wafer processing for Ultraprecision Engineering, 13(1991) 4, pp. 251-255.
- [2] Cooley B.A., Juchem H.O.: Truing and dressing – a way through maze. De Beers Proceedings, 1990, pp. 7-38.
- [3] Friemuth Th., Lierse T.: Electro – contact discharge dressing (ECDD) of diamond wheels. IDR 32(1998)2, pp. 57-61.
- [4] Gołabczak A.: Electrochemical dressing of grinding wheels using alternating current. Abrasives Magazine, USA, 3(2000)6, pp. 16-20.
- [5] Gołabczak A.: Some problems of electrochemical and electrodischarge dressing of grinding wheels. Advances in Manufacturing Science and Technology, 26(2002)2, pp. 19-38.
- [6] Isasaki I., Tönshoff K., Howes T.D.: Abrasive machining in the future. Ann. CIRP, 42(1993) 2, pp. 723-731.
- [7] Liu I.H., Pei Z.J., Graham R., Fisher J.: Grinding wheels for manufacturing of silicon wafers: A literature review, International Journal of Machine Tools and Manufacture, 47(2007)1, pp. 1-113.
- [8] König W., Yegenoglu F., Stuckehold B.: Lower grinding cost and better workpiece quality by high performance grinding with CBN grinding. Journal of Gear Manufacturing, 1986, 1, pp. 8-21.
- [9] Shopf M., Beltrami I., Boccardo M., Kramer D.: ECDM (Electrochemical Machining), a new method for truing, a new method for truing and dressing of metal bonded grinding tools. Annals of the CIRP, 51(2000)1, pp.125-128.
- [10] Wegener K., Hoffmeister HW., Karpuschewski B.: Conditioning and monitoring of grinding wheels. Annals of the CIRP, 60(2011)2, pp. 757-777.