CONDITIONS FOR ENERGY CAPACITY REDUCING OF TREATMENT AT DIAMOND GRINDING

Prof. Dr. Eng. Feodor NOVIKOV[1], **Prof. PhD. Eng. Cătălin IANCU**[2], **General Director PhD. Eng. Vladimir POLYANSKY**[3], **Sen. Staff Scientist Yury GUTSALENKO**[4]
[1]Simon Kuznets Kharkov Nat. Univ. of Economics, fokusnic1@rambler.ru
[2]C-tin Brâncuşi Univ. of Tg-Jiu, ciancu@utgjiu.ro
[3]Empire of Metals Ltd., tools@imperija.com
[4]Nat. Tech. Univ. "Kharkov Polytech. Inst.", gutsalenko@kpi.kharkov.ua
[1,3,4]Kharkov, Ukraine, [2]Targu Jiu, Romania

Abstract: *The main parameters of diamond grinding were determined analytically, taking into account the formation of steady cutting relief on the working surface of a wheel. This made it possible to substantiate the conditions for reducing the energy intensity of processing (conditional cutting stress), which consist in the use of both multi-pass grinding and high-performance depth grinding at a relatively low workpiece speed. It is shown that grinding with diamond wheels on metal bonds leads to an increase in the intensity of processing. Therefore, it can be reduced by increasing the grain size of the wheel, as well as by applying continuous electroerosive dressing or diamond spark grinding, which allow for the bulk destruction of grains and their timely removal from the working surface of the wheel, which maximizes the use of significant technological capabilities of diamond wheels on metal bonds with a significant increase productivity and quality of processing..*

Keywords: diamond grinding, processing power consumption, conditional cutting stress, specific machining productivity, cutting relief of the wheel, metal bond.

1. INTRODUCTION

Diamond wheels on durable metal bonds have significant technological capabilities in terms of improving the performance of machining products made from materials with improved physical and mechanical properties. This allows to effectively use such wheels in the operations of pre-grinding without the use of conventional abrasive tools and with providing improved performance and processing quality. As practice shows, these wheels, as a rule, do not work in the self-sharpening mode and require the use of electroerosive dressing to restore the cutting ability [1, 2] or the use of diamond spark grinding, which ensures a high sharpness of the cutting relief of the diamond wheel [2, 4]. In order to effectively use diamond wheels in these conditions, it is important to correctly determine the optimum grinding organizing solutions according to the criteria of productivity, energy intensity, cost and quality of processing. In this regard, the work theoretically and experimentally substantiated the conditions for reducing the specific energy capacity of processing as the most important factor in improving the efficiency of grinding with diamond wheels on durable metal bonds.

2. ANALYTICAL RESEARCH

In [5] it was shown that for each grinding mode, each characteristic of the diamond wheel and the material being processed, there is its own very specific established cutting relief of the diamond wheel, different from the original (after dressing) and determined from the energy balance of the technological system. At the same time [6], the indicators of the thermomechanics of grinding and, consequently, its energy intensity are analytically related to the physico-geometric organization of microcutting. On this basis, analytical dependencies were obtained to determine the main parameters of diamond grinding (Fig. 1):

$$H = 0{,}74 \cdot \left(\frac{630 \cdot \pi \cdot \overline{X}^3 \cdot V_{det} \cdot \sqrt{t \cdot \rho}}{m \cdot V_c} \right)^{1/7} \cdot \left(\frac{P_0}{\sigma_s} \right)^{2/7}; \qquad (1)$$

$$H_{max} = 1{,}81 \cdot \left(\frac{630 \cdot \pi \cdot \overline{X}^3 \cdot V_{det} \cdot \sqrt{t \cdot \rho}}{m \cdot V_c} \right)^{5/7} \cdot \left(\frac{\sigma_s}{P_0} \right)^{4/7}; \qquad (2)$$

$$(1 - \eta) = 2{,}44 \cdot \left(\frac{630 \cdot \pi \cdot \overline{X}^3 \cdot V_{det} \cdot \sqrt{t \cdot \rho}}{m \cdot V_c} \right)^{4/7} \cdot \left(\frac{\sigma_s}{P_0} \right)^{6/7}; \qquad (3)$$

$$\sigma = 0{,}82 \cdot \left(\frac{m \cdot V_c}{630 \cdot \pi \cdot \overline{X}^3 \cdot V_{det} \cdot \sqrt{t \cdot \rho}} \right)^{4/7} \cdot P_0^{6/7} \cdot \sigma_s^{1/7}, \qquad (4)$$

where H – maximum depth of insertion of the cutting grain into the processed material, counting it from the top of an unworn, maximally protruding grain, m; H_{max} – maximum (probabilistic) slice thickness by a grain of a wheel, m; $\eta = x / H$ – dimensionless coefficient that determines the degree of grain blunting and changing within 0 ... 1 (for sharp grains $\eta = 0$, for blunt grains $\eta \to 1$); x – linear wear of the grain, m; σ - conditional cutting stress (processing power consumption), N/m^2; m – relative volume concentration of grains in the wheel; $\overline{X}$ – grain size of the wheel, m; V_c, V_{det} – respectively, speed of the wheel ("circle") and workpiece ("detail"), m/s; t – depth of grinding, m; $\rho = 1/R_c + 1/R_{det}$; R_c, R_{det} – respectively, radius of the wheel and workpiece, m; P_0 - total load acting on the grain maximum protruding from the bond, N; σ_s – ultimate compressive strength of the processed material, N/m^2.

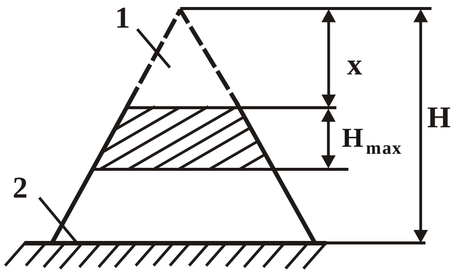

Fig. 1. *Design scheme of grinding process parameters:*
1 – worn part of the cutting grain; 2 – level of wheel bond

In work [7], it was shown that during machining the conditional cutting stress corresponds to the power consumption of processing.

As follows from the above dependencies, along with the traditional parameters of the cutting mode (V_c, V_{det}, t) and diamond wheel characteristics (m, $\overline{X}$), they contain total load P_0, acting on the grain maximum protruding from the bond, and the ultimate compressive strength of the processed material σ_s. Obviously, the parametric stabilization of the cutting relief of the diamond wheel will occur under the condition that the total load P_0 reaches values of force at which the grain will collapse. Therefore, in a steady grinding process, this value should be considered constant, as well as σ_s. Therefore, the nature of changes in the parameters of the grinding process H, H_{max}, η, σ quite uniquely determined by the value $\left(\frac{630 \cdot \pi \cdot \overline{X}^3 \cdot V_{det} \cdot \sqrt{t \cdot \rho}}{m \cdot V_c} \right)$, included with varying degrees in all the above dependencies. With its increase parameters H, H_{max}, $(1-\eta)$ also increase and conditional cutting stress (processing power consumption) σ, on the contrary, decreases. Based on this, increase in parameters V_{det}, t, $\overline{X}$ and decrease V_c and m should be considered as the main condition for reducing σ that is consistent with the practice of grinding. From a physical point of view, the effect of reducing σ due to the increase in the ratio of the slice thickness and the rounding radius of the top of the diamond grain [1].

Reduction of the parameter P_0 should be considered as the main condition for reducing σ from the including P_0 in relationship (4) with the greatest degree. This is achieved by using less durable diamond grains and bonds of a wheel (from the point of view of reducing the strength of grain retention in a bond). This explains the effectiveness of the use of organic and ceramic bonds of diamond wheels compared to metal bonds, for which the parameter P_0 and, accordingly, the conditional cutting stress (processing power consumption) σ more. Therefore, in order to reduce σ, when grinding with diamond wheels on strong metal bonds it is necessary to increase the parameters of the grinding mode V_{det} and t. However, taking into account that the specific processing performance $Q_{ud} = V_{det} \cdot t$, dependence (4) can be represented as:

$$\sigma = 0{,}82 \cdot \left(\frac{m \cdot V_c}{630 \cdot \pi \cdot \overline{X}^3 \cdot \sqrt{V_{det} \cdot Q_{ud} \cdot \rho}} \right)^{4/7} \cdot P_0^{6/7} \cdot \sigma_s^{1/7}, \qquad (5)$$

whence it follows that to reduce σ it is advisable to increase V_{det} and Q_{ud}, those. use multi-pass grinding with a relatively shallow grinding depth t and increased workpiece speed V_{det}.

Deep grinding with relatively low part speed V_{det} it is also effective, since with its reduction it is possible to actually proportionally increase the specific processing capacity Q_{ud} no increase σ. At the same time, the multi-pass grinding scheme still has great technological capabilities as compared with deep grinding from the point of view of reducing the conventional cutting stress (processing power consumption) σ, which predetermines its wider application in practice.

One of the important conditions for reducing σ is the reduction in the granularity of the wheel $\overline{X}$, which is included in the relationship (5) with a high degree 12/7. However, as it is known, the limiting force leading to the destruction of the diamond grain, i.e. strength P_0, with increasing grain girth $\overline{X}$ also increases. With this in mind the wheel granularity $\overline{X}$ will actually enter in the relationship (5) with the degree of 12/7 - 6/7 = 6/7, i.e. with the same degree as the total load P_0. Therefore, the wheel granularity $\overline{X}$ and the strength of the diamond grain (determined by the parameter P_0) equally but oppositely affect σ. Therefore, by increasing the granularity of the diamond wheel on the metal bond, it is possible to significantly reduce σ, as evidenced by the practice of grinding.

At the same time, it is rather difficult to implement these conditions in practice. This is due to the difficulty of ensuring the volume destruction of diamond grains, since they, as a rule, prematurely, without the volume destruction, fall out of the bond of the wheel. While total load P_0 less force which destroys the grain. On the one hand, this leads to a decrease in σ in accordance with dependence (5), on the other hand, it does not allow full use of the high cutting properties of expensive diamonds.

Thus, the results of experimental studies of the nature of wear of wheels from different grades of diamonds and cubic boron nitride are shown in [1] (Fig. 2). As it can be see, when using diamond grade AC2, characterized by the lowest strength, the number of grains with chips and wear areas is approximately the same, and there are no grains dropped from the bond. As the strength of diamond and cubic boron nitride grains increases, i.e. with the transition to diamond grade AC15 and cubic boron nitride KP, the number of grains with chips and wear areas is reduced, and the number of dropped grains from the bond increases significantly and becomes predominant in the wheel wear mechanism. Naturally, this does not allow to fully implement in practice the high cutting properties of diamond and cubic boron nitride wheels, since the total load P_0 is less than the force of destroying the grain.

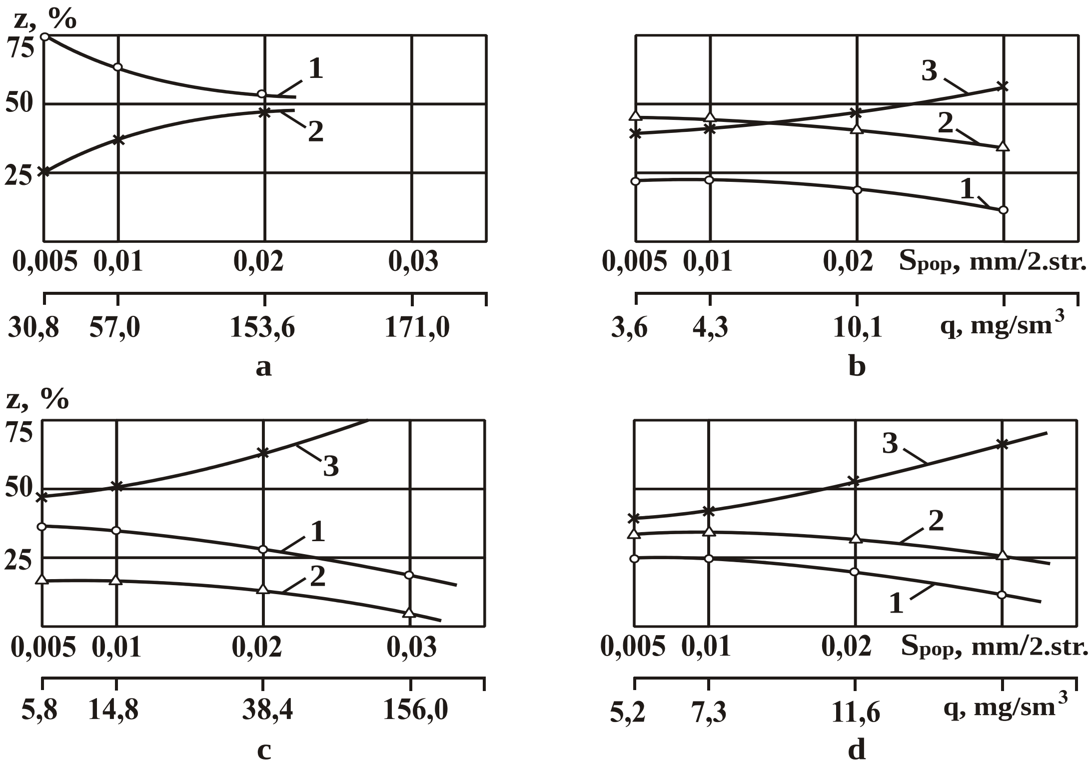

Fig. 2. *Wear of various grades of diamonds and cubic boron nitride* [1]. *Grains with chips (1), wear areas (2) and fallen grains (3): a, b, c – diamond AC2 (a), diamond AC15 (b) and CBN KP (c) on steel ШХ15 (100CrMn6); d – diamond AC15 on steel P12ФM5 (1.3318 DIN)*

Experimental data shown in Fig. 2 are obtained in relation to the circular outer multi-pass grinding. In this case, the conditional cutting stress (processing power consumption) σ with increasing workpiece speed V_{det} and depth of grinding t continuously decreases [8], and, quite intensively, since, according to (4), along with the decrease in σ with an increase in grinding parameters V_{det} and t there is a decrease in the total load P_0 due to premature precipitation of the diamond grains from a wheel bond without their bulk destruction.

The nature of the change σ is subject to more complex relations when a round external deep grinding with a relatively low speed of the workpiece and a longitudinal feed, close to the height of the diamond wheel (Fig. 3 [7]). As follows from Fig. 3, conditional cutting stress (processing power consumption) σ initially increases and then decreases with increasing grinding depth t. A fairly intense increase σ takes place with decreasing workpiece speed V_{det}. From a physical point of view, this kind of change σ is due to the fact that with increasing t there is an increase P_0, and this, according to (4), leads to an increase in σ. In this case, the diamond grains do not collapse and fail to fall out of the bond, but only wear out with the formation of wear areas on them. Value σ decreases in accordance with the dependence (4) when the limit P_0 is reached by increasing t, and, as a rule, grains in the bond of wheel lose stability. In this case, the nature of the change σ about the same as with multi-pass grinding [8].

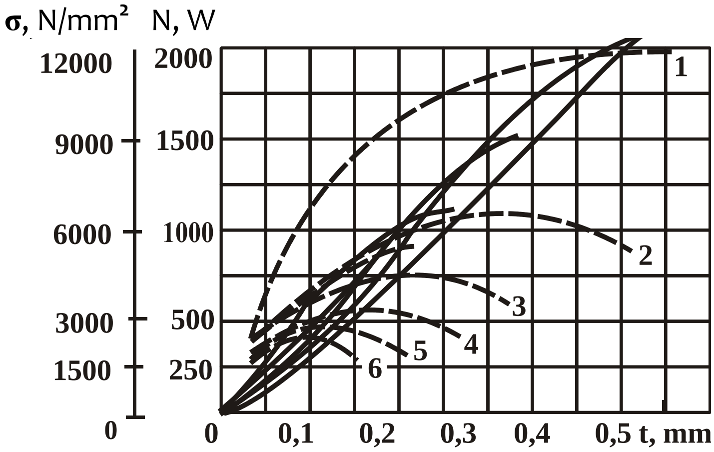

Fig. 3. Dependences of the conditional cutting stress σ (– –) and grinding power N (—) on grinding depth t: processed material – hard alloy WC85%-Co15%; diamond wheel – 1A1 300 25 5 AC6 250/200 M1-01 4; 35 m/s; 22.5 mm/rev.; coolant – 3% solution $NaNO_3$; V_{det}: 1 – 1 m/min;
2 – 2 m/min; 3 – 3 m/min; 4 – 4 m/min; 5 – 5 m/min; 6 – 6 m/min

Limit value P_0 is achieved at lower grinding depths t with increasing part speed V_{det}. Specific processing capacity Q_{ud} is about the same in points of maximum conditional cutting voltage (processing power consumption) σ, regardless of workpiece speed V_{det}. Based on the dependence (4), this suggests that the decrease in σ happens by increasing V_{det}. Since there is a multiple decrease in maximum values σ with increasing of workpiece speed V_{det}, this may be due to an additional decrease in the total load P_0 in connection with the more intense effect of the resulting microchips on the bond of the wheel and the decrease in the strength of the retention of diamond grains in it. Consequently, the strength of the retention of grains in a bond is mainly determining of the value σ, those processing power consumption. From a physical point of view, this means that σ depends on the mechanism of wear of the diamond wheel, to wit the faster the process of premature precipitation of diamond grains from the bondl of a wheel begins, the less σ.

It should be noted that the nature of the change σ depends on the intensity of friction of the bond of the diamond wheel with the processed material, the higher it is, the greater σ. At low speed details V_{det}, linear wear value for the maximum protruding grain above the level of the bond before it falls out $x = H - H_{max}$ is significant and, therefore, obviously, in this case, the intensity of friction of the bond of the wheel with the processed material is higher and, accordingly, the conventional cutting stress (processing power) σ is higher. Extremely effective way of reducing the energy intensity of processing in these conditions should be considered the use of electroerosive dressing of a diamond wheel on a metal bond [1, 2] or diamond spark grinding [3, 4], which allow for the volume destruction of grains and their timely removal from the working surface of the wheel, and this maximizes the use of significant technological possibilities of diamond wheels on metal bonds with a significant increase in productivity and quality of processing.

3. CONCLUSION

The obtained research results have been tested in the successful practice of industrial enterprises and are recommended for use in the development and implementation of high-performance grinding technologies with diamond wheels on metal bonds of various products, in particular made of metallic and non-metallic materials of high hardness.

REFERENCES

[1] **Bakool**, **V. N. et al.** *Synthetic diamonds in engineering*. Kiev, Naukova dumka, 1976, 350 p. – In Russian.

[2] *High Tech Processes in Engineering.* Ed. by **A. G. Grabchenko**. Kharkov, KhSTU, 1999, 436 p. – In Ukrainian.

[3] **Bezzubenko, N. K., and Gutsalenko Yu. G.** Intensive grinding and special design machines. *Eastern-European Journal of Enterprise Technologies*, 2010, No. 5/1(47), pp. 70-71. – In Russian.

[4] **Gutsalenko, Yu. G.** *Diamond-spark grinding of high functionality materials* [Online resource]. Kharkov, Cursor, NPU «KhPI», 2016, 272 p. [3,75 Мб], access code: http://web.kpi.kharkov.ua/cutting/dsghfm-monograph.pdf. – In Russian.

[5] Physico-mathematical theory of the processes of material's treatment and engineering technology. Ed. by **F. V. Novikov and A. V. Yakimov**. In 10 vols. Vol. 1: *Mechanics of material cutting*, Odessa, Odessa Nat. Polytech. Univ., 2002, 580 p. – In Russian.

[6] **Gutsalenko, Yu., C. Iancu, F. Novikov, and O. Klenov.** Physico-geometric interpretation of microcutting to development of the theoretical thermomechanics of grinding. *Fiability & Durability*. Târgu-Jiu, "C-tin Brâncuşi" Univ. of Tg-Jiu], 2017, No. 2(20), pp. 134-141.

[7] **Novikov, F. V.** *Fundamentals of mathematical modeling of technological processes of machining*. Dnepr, Lira, 2018, 400 p. – In Russian.

[8] **Ryzhov, E. V. et al.** *Surface quality during diamond abrasive processing*. Kiev, Naukova Dumka, 1979, 244 p. – In Russian.

[9] **Soshnikov, S. A.** *Improving the performance of diamond wheels when grinding carbide products with intermittent surfaces*. PhD Thesis of Techn. Sc. Tula, Tula Polytech. Inst., 1984, 23 p. – In Russian.