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F. Novikov, Kharkiv, Ukraine

OPTIMISATION OF INTERRUPTED GRINDING PARAMETERS ACCORDING TO THE TEMPERATURE CRITERION

Abstract. *In the paper analytical optimization of discontinuous grinding parameters according to temperature criterion is carried out and on its basis conditions for significant reduction of cutting temperature, which consist mainly in increasing the number of contacts of working ledges of discontinuous wheel with fixed cross-section of machined workpiece, are determined. It is established by calculations that providing 20 contacts the cutting temperature may be reduced up to 3 times in comparison with the conventional grinding by a continuous wheel. This is achieved in the conditions of deep interrupted grinding with relatively low workpiece speed, as in the conditions of traditionally used multipass interrupted grinding not more than 6 contacts of working ledges of an interrupted wheel with the fixed cross-section of the workpiece are realized and the cutting temperature is reduced only in the range of 50 %. It is established by calculations that the minimum of cutting temperature at discontinuous grinding is achieved under conditions of equality of lengths of the working shoulder and the notch on the discontinuous grinding wheel and their reduction. It is also established that excess of the length of the working ledge over the length of the notch of the discontinuous wheel leads to insignificant increase of the cutting temperature. This reduces the wear of the discontinuous wheel and increases the machining capacity without actually increasing the cutting temperature. The paper shows that the obtained theoretical solutions are a necessary condition for ensuring a significant reduction of cutting temperature in discontinuous grinding. A sufficient condition should be considered as complete or partial cooling of grinding zone between contacts of machined workpiece with working jaws of discontinuous grinding wheel by intensive supply of effective technological media into the grinding zone.*
Keywords: *cutting force; machining quality; working ledge of wheel; adiabatic bar; process medium; cutting ability of wheel.*

Introduction. Interrupted grinding is one of the most efficient methods of finishing abrasives which ensures high quality machined surfaces and prevents the formation of burn marks and other temperature defects. The main effect of interrupted grinding is a reduction in cutting temperature without sacrificing productivity. This is due to shock-cyclic interaction of the working ledges of discontinuous wheel with the workpiece, which allows, firstly, to maintain high cutting ability of discontinuous wheel in the process of grinding and, secondly, provides partial cooling of the machined surface in the period of passing over the cutting zone of discontinuous wheel notch. As Professor Yakimov A. V. in work [1], such double machining effect is inherent only in the method of discontinuous grinding, as it is impossible to achieve in conditions of conventional grinding with a continuous wheel.

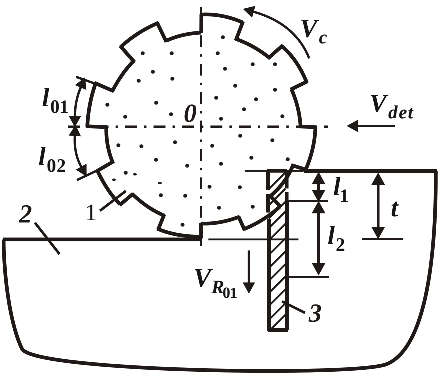
The method of interrupted grinding is widely used for machining products made of various hard metal and non-metal materials, especially when machining critical parts of aircraft technology [2] in finish grinding operations that require high quality machining. Thanks to its application, it is possible to reduce the cutting temperature by up to 50 % compared to conventional grinding with a continuous wheel. However, more significant reductions in cutting temperatures are required for more productive grinding operations. A positive example should be considered the work [3] which experimentally substantiated the conditions of grinding temperature reduction below the critical value during productive machining of titanium alloy Ti-6Al-4V with a special segmented wheel. In works [4, 5] technological possibilities of reduction of force and temperature of cutting, increase of productivity of processing of products from ceramic SiC at intermittent grinding by a segment wheel of special design T-Tool are also proved. Thus, it is established that the use of special designs of discontinuous wheels can reduce the cutting temperature. However, it is difficult to solve the problem of theoretically determining the conditions for significant reduction of cutting temperature during discontinuous grinding.

The most rigorous mathematical models for determining the cutting temperature in intermittent grinding have been developed by Yakimov A. V. [2] and Sizyy Yu. A. [6] on the basis of solving the differential equation of heat conduction of materials for various initial and boundary conditions taking into account the main regularities of the grinding process. It is theoretically established that due to periodical interruption of grinding process, contact time of working shoulder of discontinuous wheel with workpiece is much less than contact time of continuous wheel with workpiece. This, in fact, makes it possible to reduce the cutting temperature in discontinuous grinding. But the condition of additional removal by working ledge of discontinuous circle of layer of machined material, not removed for the period of grinding area passage by cutout of discontinuous circle, as a result of which actual material removal and cutting force at the moment of contact of working ledge of discontinuous circle with workpiece are increased and result in increase of cutting temperature. Similar theoretical solutions are given in [7, 8]. It follows from this that the process of discontinuous grinding is subject to more complex physical laws, which limit the possibility of more significant reduction of cutting temperature and increase productivity and quality of machining.

Further development of mathematical models of thermal processes in discontinuous grinding are the works [9, 10]. They give theoretical solutions for justification of cutting temperature reduction conditions for various grinding conditions, including the use of effective technological media and highly porous wheels, impregnation technology of discontinuous wheels. Calculation of lengths of working protrusions and troughs of discontinuous grinding wheels has been made [11]. However, it is rather difficult to use these solutions for optimisation calculations of discontinuous grinding parameters according to the temperature criterion because they are derived from the solution of differential equation of thermal conductivity of materials and are represented by complex mathematical dependences requiring numerical calculations. At the same time, in [12] it has been theoretically and experimentally quite unambiguously established that a significant reduction of cutting temperature in flat interrupted grinding can be achieved by increasing the number of thermal pulses in the grinding zone. This opens up new technological possibilities for determining the conditions for significant reduction of cutting temperature in discontinuous grinding. Therefore, in works [13, 14], the scientific prerequisites of this provision are substantiated.

For their further development it is necessary to carry out optimization of interrupted grinding parameters according to the temperature criterion on the basis of application of new mathematical approaches to calculation of cutting temperature. The aim of the work is theoretical determination of optimum conditions of interrupted grinding taking into account possibility of significant reduction of cutting temperature and development of practical recommendations on creation of highly efficient interrupted grinding processes

Research methodology. The theoretical approach proposed in [1, 15] was used to achieve this objective. Its essence is to determine the cutting temperature when grinding based on the conditions of interrupted circle cutting adiabatic rods, which conventionally represent the removed allowance of the workpiece (Fig. 1)



Figur 1 – Cutting temperature design for surface grinding, taking into account the cutting around adiabatic rods, the set of which represents a removable allowance: 1 - grinding wheel; 2 - processed material; 3 - adiabatic rod (l_1 is the length of the cut part of the adiabatic rod; l_2 is the depth of heat penetration into the surface layer of the workpiece; l_{01} is the length of the working protrusion of the intermittent circle; l_{02} is the length of the notch on the interrupted circle; V_c is the speed of the circle; V_{det} is the speed of the part; *t* – grinding depth)

Based on Fig. 1, the condition of continuity of the cut of an adiabatic rod of length h of time $(\tau_{01}+\tau_{02})$ determined by the dependency:

$$h = V_R \cdot (\tau_{01}+\tau_{02}) = V_{R_{01}} \cdot \tau_{01}, \tag{1}$$

where $V_R = V_{det} \cdot \sqrt{0{,}5 \cdot t / R_c}$ is the cutting speed of the adiabatic rod in a continuous circle, m/s; t – grinding depth, m; R_c – circle radius, m; $V_{R_{01}}$ is the speed of cutting the adiabatic rod by the working ledge of the discontinuous circle, m/s; $\tau_{01} = l_{01} / V_c$ is the time for the working protrusion (length l_{01}) to pass through the intermittent circle of the grinding zone, s; $\tau_{02} = l_{02} / V_c$ is the time of passing through the cutout (length l_{02}) of the discontinuous circle of the grinding zone, s.

From dependence (1) obtained:

$$V_{R_{01}} = V_R \cdot \left(1 + \frac{\tau_{02}}{\tau_{01}}\right). \tag{2}$$

As you can see, the speed $V_{R_{01}}$ is always greater than the speed V_R . Under the condition τ_{02} = 0, i.e. when grinding with a solid circle, these speeds are equal. As the time τ_{02} increases, the $V_{R_{01}}$ speed increases and can significantly exceed the V_R speed. Therefore, increasing the length of the notch on a discontinuous circle can lead to a significant increase in speed $V_{R_{01}}$. This is due to a decrease in the number of cutting grains on the working surface of the intermittent circle. Accordingly, the productivity of processing Q_k at the moment of contact of the working ledge of the intermittent wheel with the processed adiabatic rod will also increase due to the increase in the ratio τ_{02} / τ_{01} and will exceed the productivity of $Q = \Delta S \cdot V_R$ when grinding with a solid wheel:

$$Q_k = \Delta S \cdot V_{R_{01}} = Q \cdot \left(1 + \frac{\tau_{02}}{\tau_{01}}\right), \tag{3}$$

where ΔS is the cross-sectional area of the adiabatic rod, m^2.

In this case, the average processing performance during intermittent grinding will remain the same as when grinding with a solid circle, i.e. equal to $Q = \Delta S \cdot V_R$.

Let us establish the patterns of change in the cutting force and temperature during grinding, with continuous and intermittent circles. The tangential P_z and radial P_y components of the cutting force when grinding with a solid circle, as shown in the work [15], are described by analytical dependencies:

$$P_z = \sigma \cdot \frac{Q}{V_c}; \tag{4}$$

$$P_y = \frac{\sigma}{K} \cdot \frac{Q}{V_c}, \tag{5}$$

where σ is the conditional cutting stress, N/m^2; V_c – wheel speed, m/s; $K = P_z / P_y$ – grinding coefficient.

In intermittent grinding, dependences (4) and (5), taking into account dependence (3), take the form:

$$P_z = \sigma \cdot \frac{Q_k}{V_c} = \sigma \cdot \frac{\Delta S \cdot V_R}{V_c} \cdot \left(1 + \frac{\tau_{02}}{\tau_{01}}\right); \tag{6}$$

$$P_y = \frac{\sigma}{K} \cdot \frac{Q_k}{V_c} = \frac{\sigma}{K} \cdot \frac{\Delta S \cdot V_R}{V_c} \cdot \left(1 + \frac{\tau_{02}}{\tau_{01}}\right). \tag{7}$$

As can be seen, the tangential P_z and radial P_y components of the cutting force during intermittent grinding for the given values σ, K, ΔS, V_R and V_c are greater than when grinding with a solid wheel. This is because the $(1 + \tau_{02} / \tau_{01}) > 1$multiplier, i.e. the longer the time τ_{02}, the greater the cutting force components P_z and P_y.

However, as established experimentally in the works of A. V. Yakimov [1, 2], the conditional cutting stress σ is less, and the grinding coefficient $K = P_z / P_y$ is greater for interrupted grinding. This is due to the fact that the intermittent circle, as a result of shock-cyclic interaction with the workpiece during the grinding process, actually operates in the continuous intensive dressing mode and constantly maintains high cutting ability, while the solid circle loses the cutting ability over time. Thus, it has been experimentally established that under conditions of intermittent grinding, abrasive wheels of increased hardness are operable, which, during normal grinding, quickly become dull and lose their cutting ability. In this case, the intensity of friction of the discontinuous circle with the material being processed is significantly reduced, i.e. in the process of intermittent grinding, the energy expended on the cutting process and the removal of the material being processed predominate.

The cutting temperature during grinding with a solid wheel in the first approximation is determined by the analytical dependence [15]:

$$\theta = \frac{q \cdot l_2}{\lambda}, \tag{8}$$

where $q = N / \Delta S$ is the heat flux density, W/m^2; $N = P_z \cdot V_c$ – grinding power, W; $l_2 = \sqrt{2a \cdot \tau}$ is the depth of heat penetration into the surface layer of the workpiece, m; a is the coefficient of thermal diffusivity of the processed material, m^2/s; τ is the contact time of the solid grinding wheel with the material being processed, s; λ is the thermal conductivity coefficient of the processed material, W/(m·deg.).

Taking into account dependence (4), dependence (8) takes the form:

$$\theta = \frac{\sigma \cdot Q \cdot \sqrt{2a \cdot \tau}}{\lambda \cdot \Delta S} = \frac{\sigma \cdot V_R \cdot \sqrt{2a \cdot \tau}}{\lambda}. \tag{9}$$

As follows from dependence (9), the main condition for reducing the cutting temperature θ is to reduce the conditional cutting stress σ by providing a high cutting ability of the grinding wheel. An important factor should also be considered to reduce the contact time τ of the grinding wheel with the material being processed. This is achieved, as a rule, by using a multi-pass grinding scheme, characterized by a small grinding depth and an increased speed of the part.

In intermittent grinding during one contact of the working ledge of the intermittent wheel with the material being machined, the cutting temperature is described by the dependence:

$$\theta = \frac{\sigma \cdot V_R}{\lambda} \cdot \left(1 + \frac{\tau_{02}}{\tau_{01}}\right) \cdot \sqrt{2 \cdot a \cdot \tau_{01}}. \tag{10}$$

For a generalized analysis of dependence (10), we represent it in the form:

$$\theta = \frac{\sigma \cdot V_R}{\lambda} \cdot \left(1 + \frac{\tau_{02}}{\tau_{01}}\right) \cdot \sqrt{2 \cdot a \cdot \frac{\tau_{01}}{\tau_{02}} \cdot \tau_{02}}. \tag{11}$$

The ratio τ_{01} / τ_{02} has an ambiguous effect on the cutting temperature θ. In table. 1 and in fig. 2 shows the nature of the change in the dimensionless variable $\alpha = (1 + \tau_{02} / \tau_{01}) \cdot \sqrt{\tau_{01} / \tau_{02}}$, included in dependence (11), with a change in the ratio τ_{01} / τ_{02}.

Table 1 – Calculated values of the dimensionless value α and the length of the working protrusion l_{01} of a broken circle for l_{02} = 10 mm

τ_{01}/τ_{02}	0	0,25	0,5	1,0	2	3	4	5	6
α	∞	2,5	2,12	2,0	2,12	2,31	2,5	2,68	2,86
l_{01}, mm	0	2,5	5	10	20	30	40	50	60

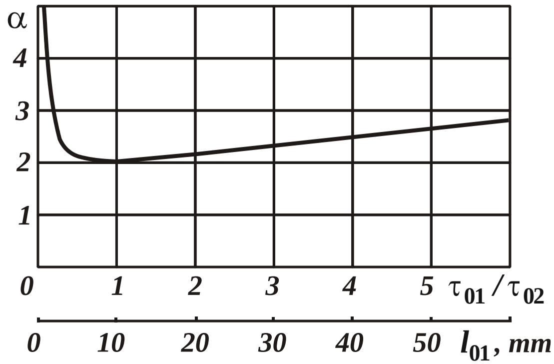


Figure 2 – Dependence of the dimensionless value α of the ratio τ_{01}/τ_{02} and the length of the working protrusion l_{01} of a broken circle: l_{02} = 10 mm

As you can see, the dimensionless value α passes the minimum point at the value of $\tau_{01}/\tau_{02} = 1$. Therefore, there is a minimum of the cutting temperature θ under the condition $\tau_{01}/\tau_{02} = 1$, i.e. provided $l_{01} = l_{02}$. In this case, an increase in the ratio τ_{01}/τ_{02} in the range $\tau_{01}/\tau_{02} > 1$ leads to an insignificant increase in the dimensionless value α and, accordingly, the cutting temperature θ. So, with an increase in the ratio τ_{01}/τ_{02} of 2 times, the value α increased by only 6%, and with an increase in the ratio τ_{01}/τ_{02} by 6 times, by 43% (Table 1). This indicates the possibility of using intermittent circles that have $l_{01} > l_{02}$, which is the case in practice. As shown in [2], at such values of the ratio $l_{01}/l_{02} > 1$, the wear intensity of the discontinuous wheel decreases and the grinding efficiency increases without increasing the cutting temperature.

In table. 1 and in fig. 2 shows the calculated values of the length of the working protrusion l_{01} of the intermittent circle, obtained based on the dependence $\tau_{01}/\tau_{02} = l_{01}/l_{02}$ for the given values of the ratio τ_{01}/τ_{02} and the length of the cutout on the intermittent circle l_{02} = 10 mm. Calculations have established that with an increase in the ratio τ_{01}/τ_{02}, the length of the working protrusion l_{01} of the intermittent circle increases.

To analytically determine the extreme value of the ratio τ_{01}/τ_{02}, the cutting temperature θ determined by dependence (10) should be subordinated to the necessary extremum condition: $\theta'_{\tau_{01}} = 0$. The result is:

$$\frac{\tau_{01}}{\tau_{02}} = 1 \cdot \tag{12}$$

Calculations have established that the second derivative $\theta''_{\tau_{01}}$ at the extremum point $\tau_{01} = \tau_{02}$ takes a positive value. Therefore, there is a minimum of the cutting temperature θ depending on the ratio τ_{01}/τ_{02}, which corresponds to the graph shown in Fig. 2. Then the minimum cutting temperature θ_{min}, taking into account dependences (10) and (12), will be determined by the dependence:

$$\theta_{min} = \frac{2 \cdot \sigma \cdot V_R \cdot \sqrt{2a \cdot \tau_{01}}}{\lambda}. \tag{13}$$

Let us compare the values of the cutting temperature during grinding, with continuous and intermittent wheels, determined by dependences (9) and (13) for the time $\tau = \tau_{01} + \tau_{02}$, i.e. for one contact of the working ledge of a discontinuous circle with an adiabatic rod (Fig. 1). To do this, we represent dependence (9), taking into account the condition $\tau_{01} = \tau_{02}$, in the form:

$$\theta = \frac{\sigma \cdot V_R \cdot \sqrt{2a \cdot 2\tau_{01}}}{\lambda}. \tag{14}$$

From the comparison of dependencies (13) and (14) it can be seen that the cutting temperature θ when grinding with a solid wheel is 1.41 times lower than the cutting temperature when grinding with an intermittent wheel. This is because dependence (13) is valid under the condition that the material being processed is removed from its one contact with the working ledge of the discontinuous circle.

With subsequent contacts, of course, the cutting temperature θ will increase due to the accumulation of the generated heat in the adiabatic rod. However, when providing intensive cooling of the adiabatic rod, as shown in [1, 2], it is possible to completely cool it down to subsequent contact with the working ledge of the discontinuous circle. In this case, the cutting temperature θ will periodically take on a maximum value equal to θ_{min} under the condition $\tau_{01} = \tau_{02}$. Therefore, the time τ_{01} can be significantly less than the time τ of contact between the solid grinding wheel and the adiabatic rod being machined. Therefore, the minimum cutting temperature θ_{min} will be less than the cutting temperature when grinding with a solid wheel, determined by dependence (9), which creates the main effect of interrupted grinding.

To compare the cutting temperatures during grinding, with intermittent and solid wheels, determined by dependencies (9) and (13), we consider their ratio, taking into account the conditions $\tau / (\tau_{01} + \tau_{02}) = n$ and $\tau_{01} = \tau_{02}$ for the given values σ, V_R, λ, a:

$$\frac{\theta_{min}}{\theta} = 2 \cdot \sqrt{\frac{\tau_{01}}{\tau}} = \sqrt{\frac{2}{n}}, \tag{15}$$

where n is the number of contacts of the working ledges of a discontinuous circle with an adiabatic rod (Fig. 1) until it is completely cut, i.e. for the time τ.

From dependence (15) it follows that the ratio θ_{min} / θ is quite unambiguously determined by the value n: the larger it is, the smaller the ratio θ_{min} / θ and the more efficient the use of intermittent grinding compared to conventional grinding with a solid wheel.

Research results. In table. 2 and in Fig. 3 shows the calculated values of the ratio θ_{min} / θ and the length of the working protrusion l_{01} of the intermittent circle for V_c =30 m/s and τ =10^{-2} s.

Table 2 – Calculated values of the ratio θ_{min} / θ and the length of the working ledge l_{01} of a broken circle for V_c = 30 m/s and τ = 10^{-2} s

n	2	4	6	8	10	20	40	80	160
θ_{min} / θ	1	0,7	0,58	0,5	0,447	0,316	0,22	0,158	0,11
l_{01}, mm	75	38	25	19	15	8	4	2	1

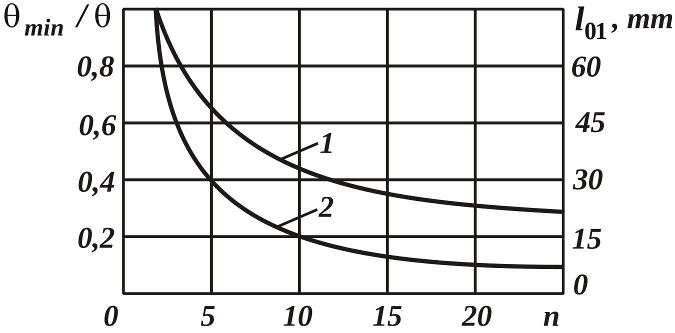


Figure 3 – Dependences of the ratio θ_{min} / θ (1) and the length of the working protrusion l_{01} (2) of the intermittent circle on the value of n : V_c =30 m/s; τ =10^{-2} s

Calculation of l_{01} values is made using dependencies: $l_{01} = \tau_{01} \cdot V_c$; $\tau / (\tau_{01} + \tau_{02}) = n$ and $\tau_{01} = \tau_{02}$. As a result, it was found $l_{01} = \tau \cdot V_c / 2n$.

The calculated value τ =10^{-2} s (Table 2) was obtained on the basis of the dependence [15]: $\tau = l / V_{det} = \sqrt{2t \cdot R_c} / V_{det}$ for initial data: t =0.02 mm; R_c =100 mm; V_{det} = 0.2 m/s; V_c=30 m/s, where $l = \sqrt{2 \cdot t \cdot R_c}$ is the length of the arc of contact of the solid circle with the workpiece, m.

As follows from Table 2, with an increase in n, the ratio θ_{min} / θ decreases over a wide range, reaching a value of 0.11 at n =160 and l_{01} =1 mm. Therefore, by reducing the length of the working ledge l_{01} of the intermittent wheel, it is possible to reduce the cutting temperature by up to 10 times when grinding with an intermittent wheel compared to grinding with a solid wheel.

In the works of Professor Yakimov A. V. [1, 2] it is shown that due to the use of intermittent grinding, it is possible to reduce the cutting temperature by up to 50%. Based on the table 2, this is due to the increase in n within n = 6 and the use of intermittent circles with an increased length of the working protrusion $l_{01} >$ 20 mm. Therefore, by increasing the value n within large limits (n >10) and, accordingly, reducing the length of the working protrusion l_{01} (to values l_{01} = 1 mm), it is possible to more significantly reduce the cutting temperature during interrupted grinding. The main limitation of reducing the length of the working ledge l_{01} is a decrease in its strength and increased wear of the discontinuous circle. This confirms the effectiveness of the use of intermittent circles in the operations of cutting materials, carried out with a cutting depth of up to 100 mm or more [16]. As a result, the thermal and power intensity of the machining process and, accordingly, the cutting temperature are sharply reduced, which makes it possible to ensure high quality and productivity of machining.

As follows from dependence (15), under the condition $\tau_{01} / \tau < 4$, the cutting temperature during grinding with an intermittent wheel will be less than the cutting temperature during grinding with a solid wheel. Therefore, let us consider more fully the main regularities of the decrease in cutting temperature during flat grinding with a discontinuous circle.

Taking into account the contact time of the working ledge of the discontinuous circle with the workpiece $\tau_{01} = l_{01} / V_c$, dependence (15) will take the form:

$$\frac{\theta_{min}}{\theta} = 2 \cdot \sqrt{\frac{l_{01}}{l} \cdot \frac{V_{det}}{V_c}} = 2 \cdot \sqrt{\frac{l_{01} \cdot Q_0}{\sqrt{2t \cdot R_c} \cdot t \cdot V_c}}, \tag{16}$$

where $Q_0 = t \cdot V_{det}$ is the specific processing capacity, m^2/s.

Based on dependence (16), it is possible to reduce the ratio of cutting temperatures during grinding with intermittent and solid wheels θ_{min} / θ for a given specific processing productivity Q_0 by reducing the length of the working ledge of the intermittent wheel l_{01}, increasing the grinding depth t and the wheel speed V_c. Obviously, the greatest effect from the use of discontinuous circles is achieved under conditions of deep-feed grinding with a relatively low speed of the part V_{det}, since the grinding depth t is included in dependence (16) with the highest exponent.

For example, the value n, taking into account the dependencies $\tau / (\tau_{01} + \tau_{02}) = n$ and $\tau_{01} = \tau_{02}$ for the given values t =0.1 mm; R_c =100 mm; V_{det} =0.05 m/s; V_c =30 m/s; l_{01}=10 mm is equal to n =134. Accordingly, the ratio θ_{min} / θ = 0.122, i.e., under conditions of deep interrupted grinding, it is possible to significantly (up to 10 times) reduce the cutting temperature compared to conventional grinding with a solid wheel. In this case, the specific productivity of processing Q_0 is equal to 300 mm^2/min, which is a rather high value, which is achieved in practice under conditions of high-performance grinding.

Under the conditions of multi-pass intermittent grinding (t =0.01 mm; R_c =100 mm; V_{det} =0.5 m/s; V_c =30 m/s; l_{01}=10 mm; Q_0 =300 mm^2/min), the value n =5, and the ratio θ_{min} / θ =0.632, which allows only slightly (within 50%) to reduce the cutting temperature compared to conventional grinding with a solid wheel. Therefore, it is most effective to use intermittent wheels in creep grinding conditions. This is consistent with the practice of using diamond intermittent wheels when removing significant allowances in the operations of grinding products from highly hard non-metallic materials, including the operations of cutting materials, grinding deep grooves [16, 17], etc.

Dependence (15) was obtained for the condition of the extremum (minimum) of the cutting temperature during interrupted grinding, i.e. conditions $\tau_{01} = \tau_{02}$.

In the general case, the ratio of cutting temperatures during grinding with intermittent and solid circles $\theta_{int} / \theta_{sol}$, determined by dependencies (10) and (9), is described by:

$$\frac{\theta_{int}}{\theta_{sol}} = \left(1 + \frac{\tau_{02}}{\tau_{01}}\right) \cdot \sqrt{\frac{\tau_{01}}{\tau}} . \qquad (17)$$

As can be seen, under the condition $\tau_{01} = \tau_{02}$, dependences (17) and (15) are identical.

For a given time τ of contact of a solid grinding wheel with the material being processed, the nature of the change in the ratio $\theta_{int} / \theta_{sol}$ with a change in the length of the working ledge of the discontinuous wheel l_{01} is identical to the nature of the change in the dimensionless quantity $\alpha = (1 + \tau_{02} / \tau_{01}) \cdot \sqrt{\tau_{01} / \tau_{02}}$ included in dependence (11). Under the condition $\tau_{01} > \tau_{02}$, the ratio $\theta_{int} / \theta_{sol}$ will increase with an increase in the ratio τ_{01} / τ_{02} and the length of the working protrusion of the discontinuous circle l_{01} (Table 1), but not so significantly. This makes it possible to effectively use interrupted wheels that have a shoulder length longer than the length of the cutout on the circle, reducing the wear of the broken circle and increasing productivity without actually increasing the cutting temperature and reducing the quality of processing.

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Федір Новіков, Харків, Україна

ОПТИМІЗАЦІЯ ПАРАМЕТРІВ ПЕРЕРИВЧАСТОГО ШЛІФУВАННЯ ЗА ТЕМПЕРАТУРНИМ КРИТЕРІЄМ

Анотація. *У роботі проведено аналітичну оптимізацію параметрів переривчастого шліфування за температурним критерієм та на її основі визначено умови суттєвого зменшення температури різання, які полягають, головним чином, у збільшенні кількості контактів робочих виступів переривчастого круга із фіксованим поперечним перерізом оброблюваної деталі. Розрахунками встановлено, що за умови забезпечення 20 контактів температура різання може бути зменшена до 3-х разів порівняно із звичайним шліфуванням суцільним кругом. Це досягається в умовах глибинного переривчастого шліфування із відносно невеликою швидкістю оброблюваної деталі, оскільки в умовах багатопрохідного переривчастого шліфування із більш значною швидкістю оброблюваної деталі, яке традиційно застосовується, реалізується не більше 6 контактів робочих виступів переривчастого круга із фіксованим поперечним перерізом оброблюваної деталі і температура різання зменшується лише у межах 50 %. Розрахунками встановлено, що за умови рівності довжин робочого виступу та вирізу на переривчастому крузі досягається мінімум температури різання, зменшити який можна зменшенням довжин робочого виступу та вирізу на переривчастому крузі. Встановлено також, що перевищення довжиною робочого виступу довжини вирізу переривчастого круга призводить до несуттєвого збільшення температури різання. Це дозволяє зменшити зношування переривчастого круга і підвищити продуктивність обробки фактично без збільшення температури різання і, відповідно, зниження якості обробки завдяки виключенню припікань та інших температурних дефектів, які виникають на оброблюваних поверхнях. У роботі показано, що отримані теоретичні рішення є необхідною, але недостатньою умовою забезпечення суттєвого зменшення температури різання під час переривчастого шліфуванні. Достатньою умовою слід розглядати необхідність повного або часткового охолодження зони шліфування між контактами оброблюваної деталі із робочими виступами переривчастого круга шляхом інтенсивного підведення у зону шліфування ефективних технологічних середовищ.*

Ключові слова: *сила різання; якість обробки; робочий виступ круга; адіабатичний стержень; технологічне середовище; ріжуча здатність круга.*