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FALTERING GRINDING WITH APPLICATION OF ECOLOGICALLY SAFE FIRM LUBRICANTS

С.М. Уминський, О.О. Якімов, Л.В. Бовнегра, Н.М. Кліменко, В.О. Балан. **Переривчасте шліфування із застосуванням екологічно безпечних твердих мастильних матеріалів.** Для запобігання появи прижогов при шліфуванні застосовують мастильно-охолоджуючі технологічні засоби (МОТЗ) і переривчасті круги. Велика кількість МОТЗ являє реальну загрозу для здоров'я людини й навколишнього середовища, а застосування переривчастих кругів стримується через велику кількість небажаних побічних ефектів, що виникають при їхній роботі. Ціль дослідження – зниження небажаних ефектів, що супроводжують процес переривчастого шліфування, і зменшення шкідливого впливу на здоров'я людини при досягненні необхідної якості оброблюваної поверхні. Теоретично обгрунтована й експериментально перевірена можливість забезпечення необхідної якості на операції шліфування за рахунок застосування переривчастих кругів і екологічно безпечних твердих змащень. Для підвищення стійкості шліфувальних кругів і поліпшення якості поверхневого шару оброблюваних деталей розроблений склад твердого імпрегнатора, що володіє добрими мастильно-охолоджуючими і антіфкційними якостями, що дозволяють мастилу залишатися в зоні різані. Експериментально встановлено, що при шліфуванні імпрегнованим кругом потужність, що витрачається на різання на 30...40 % менше, ніж при шліфуванні звичайним кругом. Встановлено, що виділення в процесі шліфування імпрегнованим кругом водню і азоту і їх адсорбація на ювенільній поверхні інтесіфіцірує процес знеміцнення поверхневих шарів оброблюваного матеріалу і, як наслідок знижує енергоємність процесу стружкоутворення. Результати досліджень можуть бути впроваджені на операціях плоского шліфування і заточування металорізального інструменту. Електронно-мікроскопічні дослідження оброблених поверхонь показали, що шліфування імпрегнованими колами значно зменшує адгезійні схоплювання оброблюваного матеріалу з абразивними зернами і, як наслідок, зростає ріжуча здатність шліфувального круга.

Ключові слова: тверде змащення, ріжуча здатність, импрегнірований круг

S. Uminsky, O. Yakimov, L. Bovnegra, N. Klimenko,V. Balan. **Faltering grinding with application of ecologically safe firm lubricants.** To prevent the appearance of burns when grinding, lubricating and cooling technology means and intermittent circles are used. The vast majority of lubricating and cooling technology means represents a real threat to human health and the environment, and the use of intermittent circles is hampered by non-human side-effects arising from their work. The purpose of the study is to reduce the non-human effects associated with the process of discontinuous grinding, and to reduce the harmful effects on human health when the desired quality of the surface to be treated is achieved. The theoretically proved and experimentally tested the possibility of providing the required quality for grinding operations by using intermittent circles and environmentally sound solid lubricants. In order to increase the stability of the grinding wheels and improve the quality of the surface layer of the workpieces, a solid impregnator with a good lubricating and cooling and anti-friction properties has been developed to allow lubrication to remain in the cutting zone. It has been experimentally established that when grinding on a impregnated circle, the power consumed for cutting is 30...40 % less than when grinding with a normal circle. It has been established that the extraction during the grinding process with the impregnated circle of hydrogen and nitrogen and their adsorption to the juvenile surfaces intensifies the process of hardening of the surface layers of the material to be processed and, as a consequence, reduces the energy intensity of the process of chip formation. The results of research can be implmented on the operations of flat grinding and sharpening of metal-cutting tools. Electron-microscopic studies of the treated surfaces showed that when grinding with impregnated circles, the adhesion setting of the material to be processed with abrasive grains significantly decreases and, as a result, the cutting ability of the grinding wheel increases.

Keywords: impulse, the firm greasing cutting ability, lubricants, a circle

Introduction. To prevent the occurrence of burns when grinding the lubricant-cooling technical means and intermittent circles are used. The overwhelming majority of the means is a real threat to human health and the environment, and the use of intermittent circles is hampered due to undesirable side effects arising from their work.

Formulation of the problem. Grinding is often the final operation of the process, which must ensure the quality of the surface layer of the part being manufactured. The required physicomechanical state of the surface layer of the workpiece is often not ensured due to the high thermal stress of the grinding process. Reducing the temperature in the cutting zone can be achieved by using grinding wheels

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with a discontinuous working surface and lubricant-cooling technological means (LCM). In the works [1, 2], an analysis of modern production processes was carried out, on the basis of which it was concluded that one of the main environmental pollutants are the lubricant-cooling technological means.

Evaporation, splashing, LCM spill, as well as their concentration in chips, rags, possible discharge into the sewer system causes irreparable damage to the environment [3]. Means used for grinding are extremely harmful to human health. In particular, trichlorethylene, orthophosphates can cause depression of the nervous system; nitrides and their combinations with diethanolamines are the strongest carcinogens; sulfur compounds are extremely toxic. As a result of grinding with the use of coolants, the ambient air is polluted with chemicals such as aldehydes, hydrogen chloride, formaldehydes, sodium nitrates, etc., which pose a high threat to human health [1, 2, 3].

The works [1 – 6] are devoted to finding ways to reduce the harmful effects of LCM on the environment, and the works [7 – 9] solve the problem of minimizing their effect on human health.

The aim of the work is to ensure the required quality of the surface layer of parts on the grinding operations with the use of coolants, the negative impact of which on the environment and human health will be minimized.

The presentation of the main material. To develop effective measures for controlling the thermal stress of the grinding process, it is necessary to know the contribution of the energy expended on cutting and friction. The tangential component of the cutting force P_z can be represented as

$$P_z = P_{z.t} + P_{z.r}\,; \tag{1}$$

$$P_{z.t} = f \cdot P_y\,; \tag{2}$$

$$P_{z.r} = \delta \cdot S\,, \tag{3}$$

where f – coefficient of friction of grains of a circle with the material being processed;

δ – conditional cutting stress, N/m^2;

S – sectional area of cut, m^2.

It is known from [10] that

$$P_{z.r} = \frac{2 \cdot [\delta]_s}{K_{s.r}} \cdot S\,, \tag{4}$$

where $[\delta]_s$ – compressive strength of the material being processed, N/m^2,

$$K_{s.r} = \frac{P_{z.r}}{P_y} = \frac{P_z - P_{z.t}}{P_y} = K_s - f\,. \tag{5}$$

In view of (2) and (4), expression (1) takes the form

$$P_z = f \cdot P_y + \frac{2 \cdot [\delta]_s}{K_{s.r}} \cdot S\,. \tag{6}$$

Dividing the dependence (6) on P_y with $K_s = P_z / P_y$, we get

$$K_s = f + \frac{2 \cdot [\delta]_s}{K_{s.r} \cdot P_y} \cdot S\,. \tag{7}$$

We transform the dependence (7) to the form

$$P_y = \frac{2 \cdot [\delta]_s \cdot S}{(K_s - f) \cdot K_{s.r}}\,. \tag{8}$$

Taking into account (5) we get

$$P_y = \frac{2 \cdot [\delta]_s \cdot S}{(K_s - f)^2}\,. \tag{9}$$

Taking the total cutoff area of all working grains S in the form of the ratio of processing performance Q to the speed of the circle V_{kp}, the expression (9) can be represented as

$$Q = \frac{P_y \cdot V_{kp} \cdot (K_s - f)^2}{2 \cdot [\delta]_{com}}. \qquad (10)$$

From the expression (10) it follows that the grinding performance Q significantly depends on the parameter $K_s = P_z / P_y$, which is included in the form of the square of the difference $(K_s - f)^2$. This parameter varies in a very wide range: from zero (the case of transition from the cutting process to the process of friction), to values of 0.6...0.8 (the case of high-performance grinding, when $K_s \geq f$). As the cutting grains wear out and the grinding wheel becomes blunt $K_s \to f$, the machining performance decreases. Difference $(K_s - f)$ is a parameter that is very sensitive to change K_s, especially when K_s it is little different from the coefficient of friction f.

Consequently, grinding performance can be controlled on the basis of parameter optimization $K_{s.r}$. This parameter can be stabilized in time due to modes that provide self-sharpening of a circle or by using impregnating compositions and circles with a discontinuous working surface. To increase the grinding performance Q, it is necessary to increase K_s or decrease the friction coefficient.

To increase the durability of grinding wheels and prevent the appearance of grinding defects (burns and cracks) on the surfaces being treated, a solid lubricant was developed [11], which contains environmentally friendly and inexpensive substances. The components of the composition of solid lubricants are taken in the following ratios, wt.%: Stearic acid 60…65; Oleic acid 20…25; Acetamide – else.

The above composition has good lubricating and cooling and anti-friction properties, as well as good adhesive properties, allowing the lubricant to remain in the cutting zone. The advantage of acetamide is that when it is introduced into the lubricant does not deteriorate the environment of the workplace.

Manufacturing technology of solid lubricant is as follows. Stearic acid is poured into a container and heated to dissolve (90…110°), oleic acid and acetamide are added, all components are mixed until completely dissolved in stearin and poured into molds. Acetamide increases the adhesion of the composition, increases the temperature stability of the entire mixture of substances and their solution in stearic acid.

Molecules of oleic and stearic acids are absorbed on the contact surfaces of the grinding wheel and the metal being processed, effectively acting on the friction process. At high temperatures, physical absorption is accompanied by chemical exposure between the absorbed male molecules of stearic and aleic acids with the metal being treated, with the formation of metallic soaps. The latter have good antifriction properties and protect the abrasive grains from wear [12]. At elevated temperatures (200…400°), in the zone of contact of the grinding wheel with the metal being processed, combustion and decomposition of surface-active substances occur with the formation of highly active hydrogen gas. Hydrogen and nitrogen released during the cutting process facilitate the cutting process. The presence of hydrogen and nitrogen in the grinding zone and their abscession onto juvenile surfaces intensifies the process of weakening of the surface layers of the material being processed.

The results of measurements of the power Q expended on cutting, when grinding with ordinary and impregnated circles, ПП 250×20×76 24А 25 СМ2 6 К5 are shown in Fig. 1.

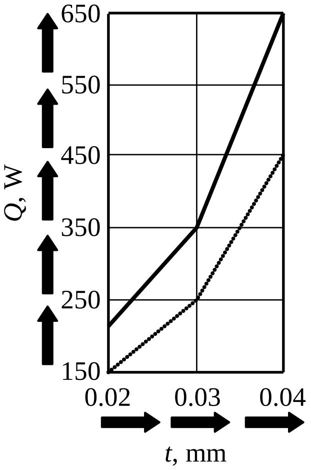

Fig. 1. Dependence of power, spent on cutting, on the depth of grinding: continuous lines – grinding with a continuous circle, dotted lines – grinding with an impregnated circle

Samples of C105W2 steel were processed on a 3Г71М surface grinding machine in the mode: circumferential speed of a circle $V_{kr} = 35$ m/s; longitudinal feed $V_{det} = 10$ m/min; depth of cut $t = 0.02$ mm, $t = 0.03$ mm, $t = 0.04$ mm.

From the graphs it can be seen that when grinding with an impregnated wheel, the power expended on cutting is 30...40 % less than when grinding with an ordinary wheel. This is due to less energy to overcome external friction.

Fig. 2, Fig. 3 shows the experimental data on the comparative assessment of the cutting capacity of a continuous, intermittent (number of cavities $n = 12$, the ratio of the width of the depression to the length of the cutting protrusion $N = l_2/l_1 = 0.6$) and the intermittent imprinted circles of the ПП 250×20×76 24А 25 СМ2 6 К5 in time when processing samples of steel C105W2 on a surface grinding machine model 3Г71М according to the elastic scheme ($F_y = 1.2$ N/mm) without lateral feed.

Fig. 2 shows the dependences, $A_{ud} = f(\tau)$, $K_s = f(\tau)$ and Fig. 3 is a graph $K = f(\tau)$, where K is the specific metal removal per unit of time, mm^3/(s·N).

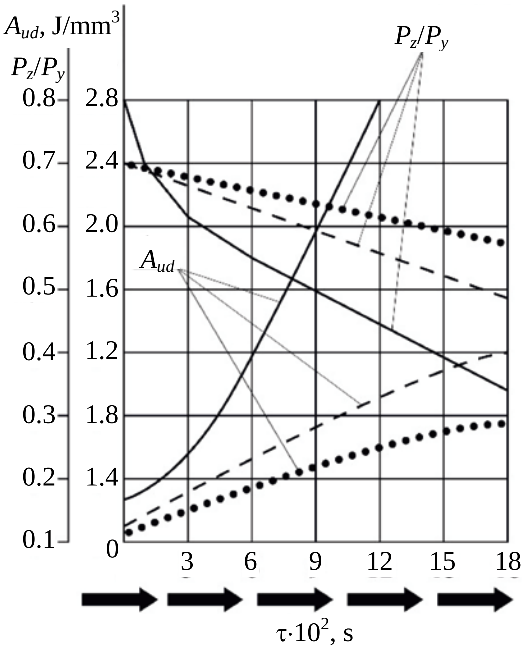

Fig. 2. The dependence of the specific work of grinding A_{ud} and the ratio of the components of the cutting P_z / P_y force from the time of grinding τ: continuous lines – grinding in a continuous circle; dashed lines – grinding in intermittent wheels; dotted lines – grinding with intermittent impregnated wheel

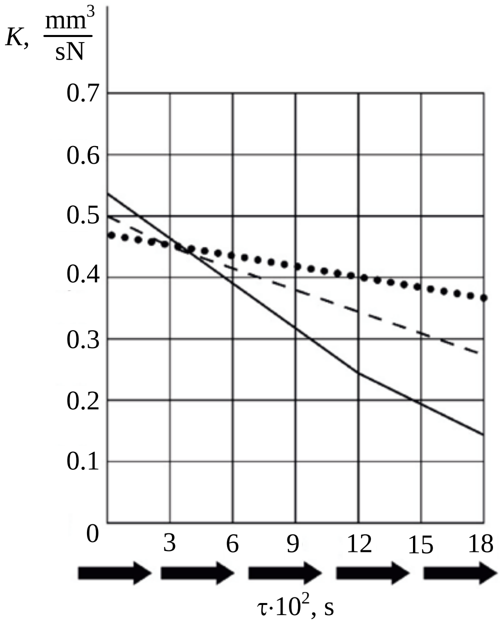

Fig. 3. Comparative evaluation of the cutting ability of a continuous (continuous line), intermittent (dashed line) and intermittent impregnated (dotted line) circles in time

From the graphs presented in Fig. 2 and Fig. 3, it is clear that the parameters K_s and K, in varying degrees, characterize the cutting ability of an abrasive tool, after an 18-minute grinding period with an impregnated intermittent wheel, are approximately twice as large as when grinding normal (solid) circle.

The improvement in the cutting capacity of intermittent impregnated wheel grains compared to a conventional circle is due to the appearance of forced high-frequency vibrations in the elastic system of the machine due to interrupted cutting process, weakening of the surface layers of the material being processed, reduction of the friction coefficient and reduction of adhesion of the cutting grains with the material being processed.

From Fig. 2 it is clear that the specific work of grinding A_{ud} after a 12-minute period of grinding with a full circle increased from 0.35 to 2.8 J/mm^3 (i.e. 8 times), and when grinding with a discontinuous impregnated wheel only 6 times (from 0.1 to 0.6 J/mm^3).

Impregnating the wheels leads to a significant reduction in wear of the abrasive grains. This stabilizes the surface roughness during the grinding process. The roughness stabilization can be explained by the presence of lubricating films on the surface of the grains of the impregnated circle.

Figure 4 shows the results of electron microscopic examination of surfaces that are polished continuous (Fig. 4, *a*), intermittent (Fig. 4, *b*) and intermittent and impregnated (Fig. 4, *c*) circles of steel E3310.

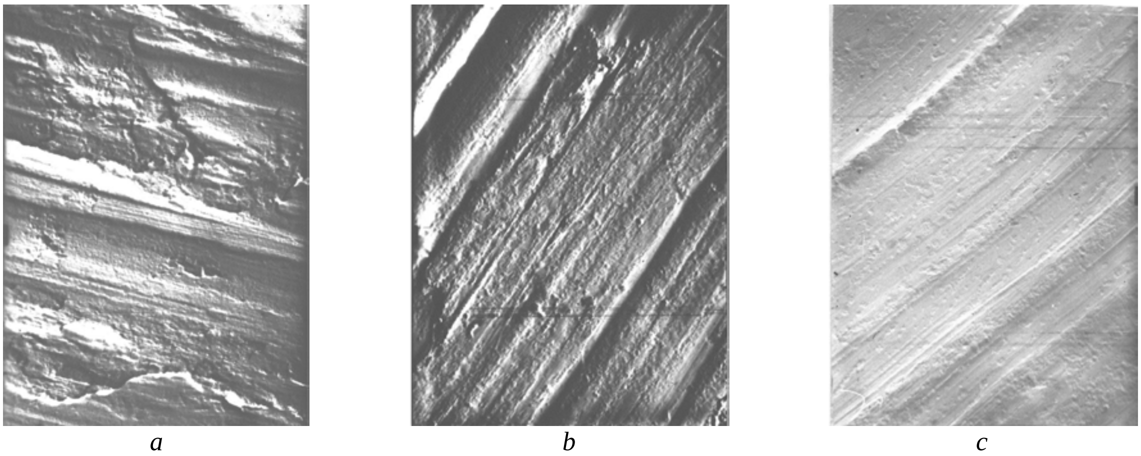

Fig. 4. Microprofile surface polished with continuous (a), intermittent (b) and intermittent impregnated (c) circles of $V_{kr} = 25$ m/s; $V_{det} = 0.033$ m/s; $S_r = 0$; t=0.05mm mm increase of 10000

This indicates a high temperature that occurs in the cutting zone. When grinding in a discontinuous circle, the risks formed by the sub-micro profile of abrasive grains are clearly visible. The degree of adhesive setting is much less than when sanding in a continuous circle. When grinding with an intermittent and impregnated wheel, traces formed by the sub-micro profile of abrasive grains are visible on the surface. Adhesive setting media are absent.

Fig. 5 shows the appearance of the working surface of the solid circle *a*) not impregnated with an impregnator; *b*) impregnated after 10 minutes of operation.

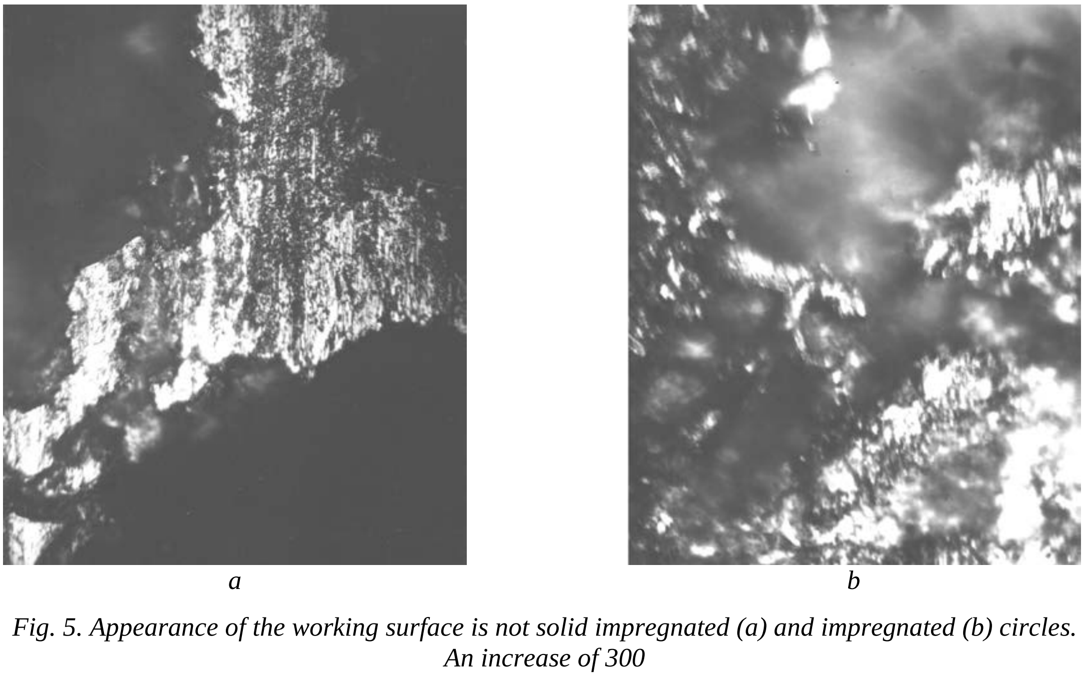

Fig. 5. Appearance of the working surface is not solid impregnated (a) and impregnated (b) circles. An increase of 300

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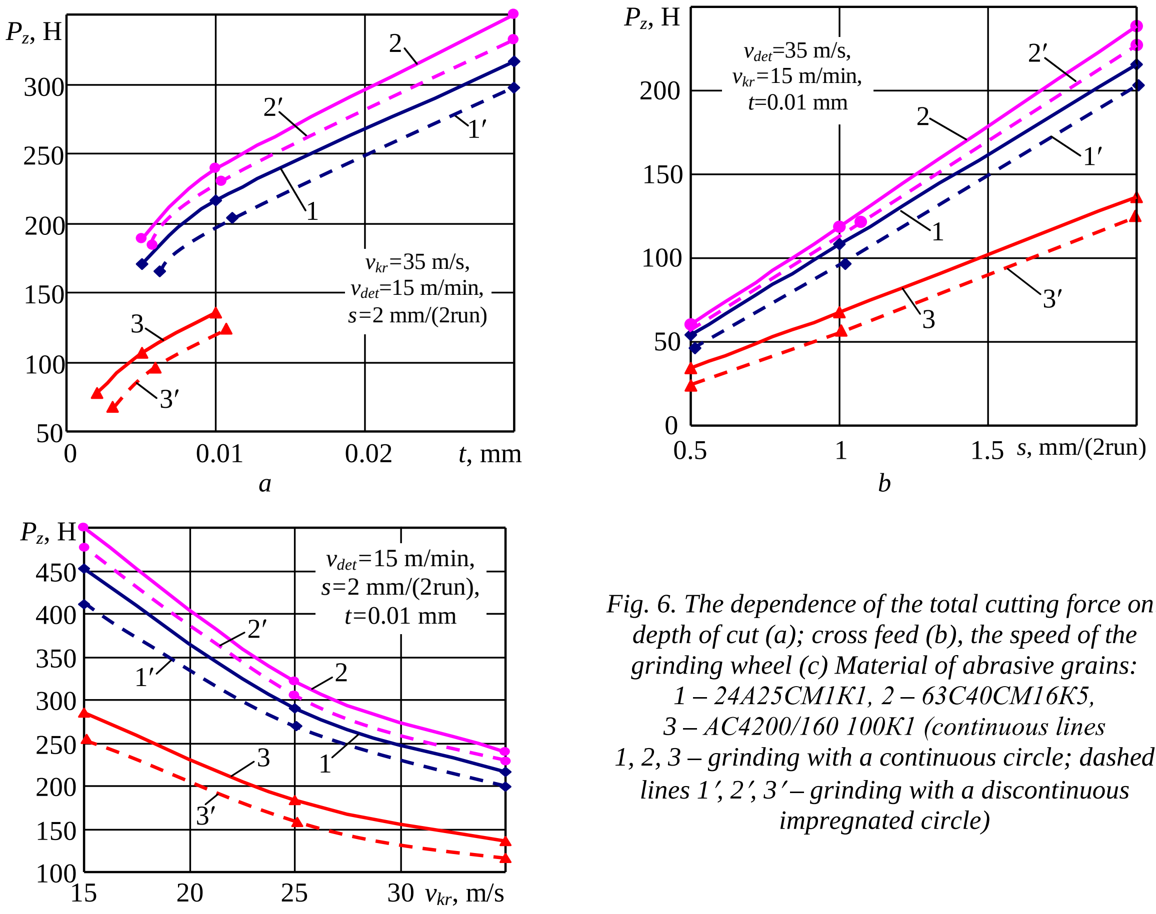
The characteristics of the 24A25CM16K5 impregnated circles are given in Table. The experiments were carried out on samples of steel E3310 under the m/s, m/s, mm modes.

Results of comparative tests of ordinary (non-impregnated) circles and subjects impregnated

Technological indicators	Ordinary circles			Circle intermittent impregnated		
	t=0.02	t=0.03	t=0.04	t=0.02	t=0.03	t=0.04
Temperature in the cutting zone °C	350	495	600	210	310	400
Cutting power, N	55	60	80	32	38	40
Specific grinding work J/mm ^{3}	16	21	30	8	15	20

Drawing impregnator on the working surface of the circle, gives an additional increase in the cutting ability of the circles. The conventional cutting stress decreases from σ=222000 MPa to σ=140000 MPa, that is, by 40 %. The parameter characterizing the share of energy consumed for friction f/k_s decreased from 76.1 to 70.0 %.

With an increase in the depth of cut from 0.005 to 0.03 mm, an increase in the total cutting forces is observed twice. This is due to the fact that with increasing depth of cut, the area of the contact patch of the circle with the part increases, as a result of which a larger number of cutting grains take part (curve 1, Fig. 6, *a*).



a

b

c

Fig. 6. The dependence of the total cutting force on: depth of cut (a); cross feed (b), the speed of the grinding wheel (c) Material of abrasive grains: 1 – 24A25CM1K1, 2 – 63C40CM16K5, 3 – AC4200/160 100K1 (continuous lines 1, 2, 3 – grinding with a continuous circle; dashed lines 1′, 2′, 3′ – grinding with a discontinuous impregnated circle)

With an increase in transverse feed, the total cutting forces increase for the same reason (curve 1, Fig. 6, *b*), that is, the area of the contact patch of the circle with the part increases and the number of simultaneously working cutting grains increases.

An increase in the speed of the grinding wheel leads to a decrease in the total cutting forces, due to the fact that the chip section is reduced, which is removed by the working abrasive grain (curve 1, Fig. 6, *c*).

By formulas (11) and (12), surface temperatures were calculated without cooling and taking into account the use of solid lubricants, respectively.

$$\begin{aligned} T_1 = {} & \frac{0.44\cdot P_{Z\Sigma}\cdot V_{kr}}{\pi\cdot\lambda\cdot\sqrt{Dt}\cdot S^{1,2}}\cdot\left[\frac{S}{2}\cdot\ln\left(\frac{\frac{\sqrt{Dt}}{2}+\sqrt{\left(\frac{\sqrt{Dt}}{2}\right)^2+\left(\frac{S}{2}\right)^2}}{\frac{S}{2}}\right)+\right. \\ & \left.+\frac{\sqrt{Dt}}{2}\cdot\ln\left(\frac{\frac{S}{2}+\sqrt{\left(\frac{\sqrt{Dt}}{2}\right)^2+\left(\frac{S}{2}\right)^2}}{\frac{\sqrt{Dt}}{2}}\right)\right]\cdot\frac{1}{27.7}, \end{aligned} \tag{11}$$

$$\begin{aligned} T_{1.C} = {} & \frac{0.44\cdot P_{Z\Sigma}\cdot V_{kr}-\sqrt{Dt}\cdot S\cdot\alpha\cdot\left(T_1-20\right)}{\pi\cdot\lambda\cdot\sqrt{Dt}\cdot S^{1,2}}\times \\ & \times\left[\frac{S}{2}\cdot\ln\left(\frac{\frac{\sqrt{Dt}}{2}+\sqrt{\left(\frac{\sqrt{Dt}}{2}\right)^2+\left(\frac{S}{2}\right)^2}}{\frac{S}{2}}\right)+\right. \\ & \left.+\frac{\sqrt{Dt}}{2}\cdot\ln\left(\frac{\frac{S}{2}+\sqrt{\left(\frac{\sqrt{Dt}}{2}\right)^2+\left(\frac{S}{2}\right)^2}}{\frac{\sqrt{Dt}}{2}}\right)\right]\cdot\frac{1}{27.7}, \end{aligned} \tag{12}$$

where α is the heat transfer coefficient. characterizing the intensity of heat exchange between the body and its environment, J/m^2 s°C.

The average value of the force of the contact patch:

$$P_{z\Sigma} = \frac{0.07\cdot B\cdot S\cdot n_{ud}\cdot(D\cdot t)^{0.347}}{V_{kr}{}^{0.44}}. \tag{13}$$

The actual number of working grains, taking into account [13]:

$$n_{ud} = 111\cdot 10^6\cdot N_z{}^{-1.3}\cdot N_{str}{}^{-0.17}, \tag{14}$$

where N_z – circle grain;

N_{str} – circle structure number;

or by designating $B = 5.46\left(\frac{K_v\sigma_d\cdot A\cdot r\cdot v_{\det}\cdot l_f}{R_{kr}}\right)^{0.3}\cdot\left(\frac{\varepsilon\cdot a}{V_{kr}}\right)^{0.7}$; (15)

σ_d – “Dynamic” tensile strength, taking into account the effect of both temperature and speed factor;

f – the area of contact of the grain with the metal;

$$A=\frac{\cos\gamma'-\mu\sin\gamma'}{\sin\theta'(1-\mu\cdot\mu')\cos(\gamma'+\theta')+(\mu+\mu')\sin(\gamma'+\theta')}; \qquad (16)$$

θ' – spallation angle;

γ' – front corner;

μ – coefficient of friction of grain on metal;

μ' – coefficient of internal friction during plastic deformation.

The angles γ' and θ' determined by the method of [12], as a result of which we obtain their dependence on the radius of curvature:

$$\gamma'=\frac{1}{2}\cdot\left(\pi-\arcsin\frac{3\cdot10^{-6}}{\sqrt{r}}\right),\ \ \theta'=45^{\circ}-\frac{\gamma'+\mu+\mu'}{2}, \qquad (17)$$

where r is the radius of curvature, μm;

S_z – is the feed to the grain;

φ – the angle of rotation of the radius connecting the grain to the center of the circle;

formally value $l_f=\dfrac{1}{\sqrt{n_{ud}}}$. (18)

Calculated temperatures arising from grinding with the plunge method of samples made of titanium alloy BT3-1 with a circle of 63C25CM16K5 in the $V_{kp}=30$ m/s mode; $V_{det}=0.10$ m/s; $t=0.01$ mm, 0.02 mm, 0.03 mm, 0.04 mm, 0.05 mm. Physico-mechanical properties of titanium alloy BT3-1:

$\lambda_{20^{\circ}}$=0.019 cal/sm·s·°C=7.955 W/m·°C; $\gamma_{20^{\circ}}$=4.5 g/sm^3=4500 kg/m^3; T_{pt}=1660 °C;
$C_{20^{\circ}}$=0.14 cal/g·°C=586.152 J/kg·°C; a=0.03 sm^2/s=0.03·10^{-4} m^2/s.

The results of temperature calculations are presented in Fig. 7.

From Fig. 7 shows that the use of solid lubricant of the new composition when grinding samples of titanium alloy BT3-1 reduces the temperature in the cutting zone by 1.5 times compared with the “dry” grinding in the same conditions.

Fig. 8 shows the region of parametric instability elastic system surface grinding machine constructed in a plane coordinate system with the axes n (the number of cutting projections on the discontinuous grinding wheel) and N (the ratio of width to length the depression of the cutting projection).

The areas were calculated using the formulas given in [13]. Calculations were performed for two parameter values.

$$K_0=C_0\cdot\left(\frac{t_l}{t_f}-1\right),$$

where C_0 – reduced stiffness of the elastic system of surface grinding machine, H/m;

t_l – cutting depth, set on the limb of the machine;

t_f – actual (true) cutting depth.

The ratio t_l/t_f was determined experimentally when grinding with discontinuous and intermittent impregnated circles ПП 250×20×76 24A 25 CM2 6 K5 $(n=12,\ N=0.6)$ samples of C105W2 steel by plunging method (without transverse feeding).

It is seen from Fig. 7 that with decreasing the K_0 parameter, the regions of the parametric instability of the elastic system of the machine narrow, which indicates a high damping properties of the impregnating composition.

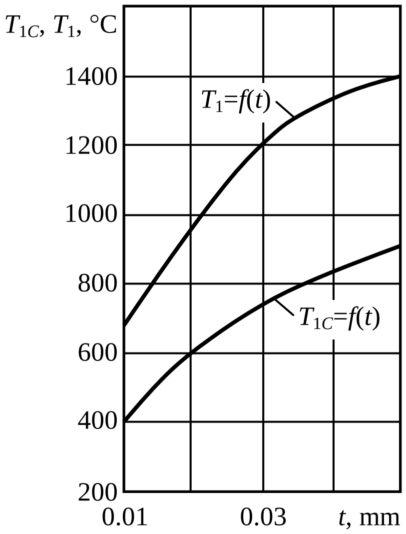


Fig.7. Temperatures in the cutting zone:
$T_1=f(t)$ – grinding without cooling;
$T_{1.c}=f(t)$ – grinding with a solid lubricant

Higher carboxylic acids (oleic $C_{17}H_{33}COOH$ and steoric $C_{17}H_{35}UN$) are capable of reacting with iron. As a result of these reactions, hydrogen H_2 is released.

$$2C_{17}H_{35}COOH + Fe \rightarrow$$
$$\rightarrow (C_{17}H_{35}COO)_2Fe + H_2,$$
$$2C_{17}H_{33}COOH + Fe \rightarrow$$
$$\rightarrow (C_{17}H_{33}COO)_2Fe + H_2 \uparrow .$$

N_2 nitrogen is formed from ammonia NH_3, which in turn, can be produced by the decomposition of acetamide, or from methylamine CH_3NH_2 by oxidation.

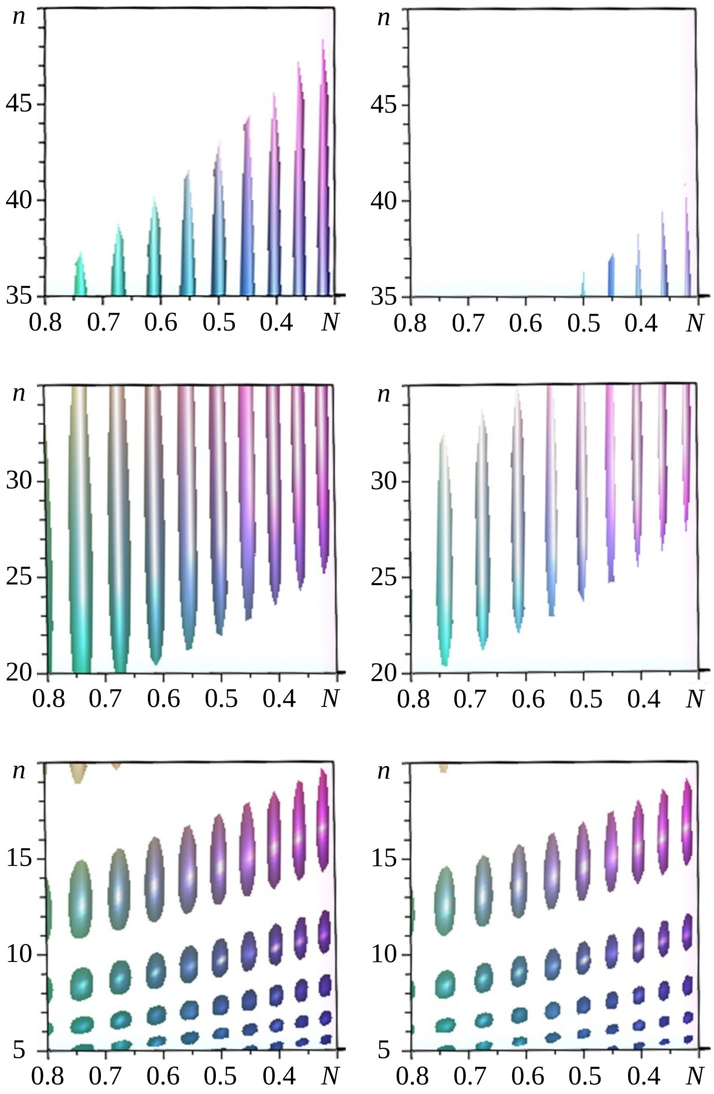


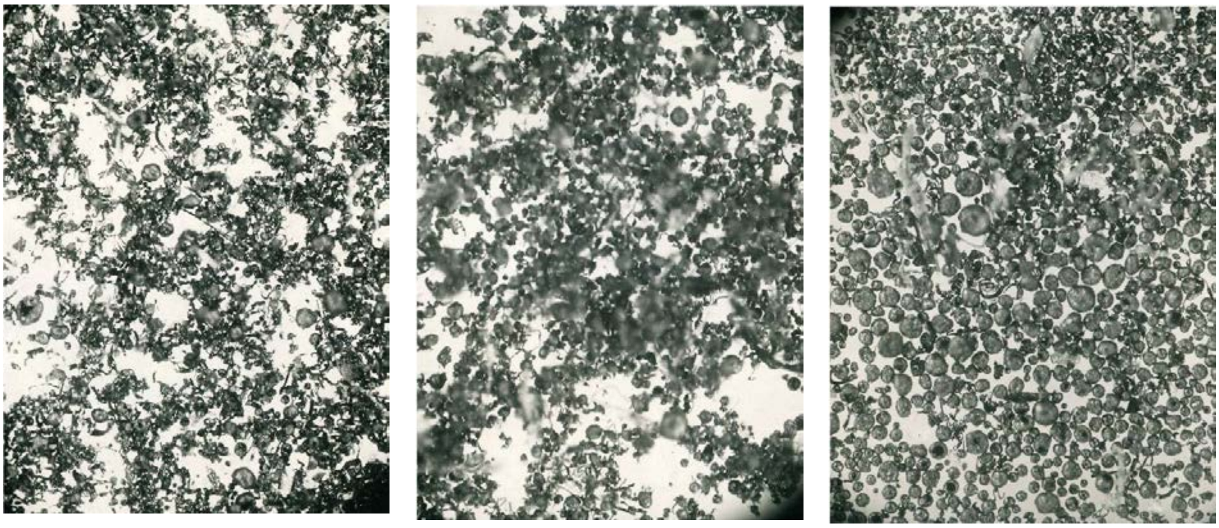
Fig.8. Areas of parametric instability of an elastic system of a surface grinding machine for (ordinary wheel) ($K_0 = 9 \cdot 10^6$ N/m) (left) and (impregnated wheel) ($K_0 = 4 \cdot 10^6$ N/m) (right)

Methylamine is one of the possible decomposition products of acetamide. The resulting hydrogen H_2 can react chemically with O_2, resulting in the formation of H_2O (vapor) or H_2O_2. Moreover, each of these substances contributes to the oxidation of iron. Acetamide is used as an inhibitor of this process.

The presence of hydrogen in the cutting zone intensifies the process of oxidation of iron shavings. Iron oxidation is accompanied by the release of a significant amount of heat, which leads to intensive melting of chips. This is confirmed by the presence of spherical chips after grinding with an impregnated wheel. The formation of a fragile oxide film on the chip facilitates its removal from the surface of the wheel and improves the course of the grinding process (Fig. 9, *c*).

The process of chip oxidation is facilitated not only by the impregnation of the wheel, but also by the use of abrasive tools with a discontinuous working surface. Intermittent lap works like a fan. A powerful air jet blows the chips from the cutting zone, intensifying the process of oxidation and combustion of the chips. During continuous grinding, oxidized chips also acquire a spherical shape, do not stick to the surface of the grains and do not penetrate into the pores of the circle (Fig. 9, *b*).

When grinding steel C105W2 with a solid, non-impregnated circle, chips are formed that have a tape or pin-shaped form (Fig. 9, *a*).



a *b* *c*

Fig. 9. The appearance of chips during grinding with continuous (a), intermittent (b) and intermittent impregnated (c) circles

Such chips are clogged in the pores of the abrasive tool and the grinding wheel often has to be edited.

Conclusions.

1. Theoretically revealed the possibility of stabilization in time of the cutting ability of abrasive wheels and, as a consequence, the quality of the surface of the workpiece.
2. A composition of an environmentally friendly solid lubricant has been proposed and experimentally tested, contributing to the increase in durability and cutting ability of impregnated wheels due to the formation of a solid lubricating film consisting of iron oxide on their working surfaces during grinding.
3. Electronic microscopic studies of the treated surfaces have shown that when grinding with impregnated circles, the adhesion of the processed material to abrasive grains significantly decreases and, as a result, the cutting ability of the grinding wheel increases.
4. By calculation and experimentally it has been established that an increase in the cutting ability of grinding wheels due to the use of solid lubricants is accompanied by a narrowing of the zones of parametric instability of the elastic system of the machine.
5. It has been established experimentally that after grinding with an impregnated wheel, the percentage of residual austenite in the surface layer of the workpiece is reduced and the surface roughness improves.

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