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Performance of abrasive reinforced wheels

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Abstract. The article considers the issue of increasing the performance of abrasive reinforced wheels used in the processes of cutting and grinding metals and building materials. The analysis of the design features of wheels with smooth and rough side surfaces is carried out and their influence on cutting efficiency, thermal processes and safety of work is investigated. Physical models have been proposed to explain the reasons for tool jamming during cutting rolled metal, taking into account the elastic deformations of the material and the action of mortise forces. It is shown that the use of wheels with rough side surfaces provides micro-cutting with protruding abrasive grains, reduces friction, improves heat dissipation and improves the quality of the treated surface. It has been established that such wheels are characterized by greater wear resistance (by 20–30%), reduced likelihood of jamming and increased safety of operation compared to traditional wheels with smooth surfaces. The practical significance of the results obtained lies in the possibility of using them to improve the design of abrasive tools and increase the productivity and reliability of cutting processes in metallurgy, construction and mechanical engineering.

Keywords: abrasive reinforced wheels, tool performance, rough side surfaces, cutting thermal processes, tool jamming, micro-cutting, wear resistance, operational safety.

INTRODUCTION

The use of abrasive reinforced wheels is an important component in the processing of metals, stone and other hard materials. These wheels are mainly used for grinding, cutting and stripping.

Abrasive wheels can be made of a variety of materials, such as:

- Corundum: The most common material used for metal processing.
- Aluminum silicate: Used for processing soft metals and alloys.
- Silicon carbide: Ideal for processing glass, ceramics, and other hard materials.

Abrasive wheels are used in many areas:

- Metallurgy: For grinding, cutting and polishing metal products.
- Construction: For processing concrete, stone and other building materials.
- Automotive industry: For car repair and maintenance.

The main advantages of their use include high efficiency: abrasive wheels provide fast and high-quality cutting, which increases productivity. They can be used on various types of equipment, such as grinders, cutting machines, and other tools, which adds to their versatility. Reinforced wheels are usually highly resistant to wear, which reduces the frequency of replacement and material costs. They provide a smooth surface, which reduces the need for further processing of materials. Modern production technologies provide increased safety for the use of abrasive wheels, reducing the risk of their destruction during operation.

Thus, abrasive reinforced wheels remain an important tool in many industries, and their use continues to grow due to the constant development of technology and materials.

PRESENTING MAIN MATERIAL

Abrasive reinforced wheels are wheels made of an abrasive material (e.g. aluminum oxide, silicon carbide) with additional reinforcement (fiberglass reinforcing mesh), which provides them with strength and safety when operating at high speeds.

A cutting abrasive wheel is made by pressing the abrasive mass in metal molds, consisting of a ring, an upper and a lower working plate (Fig. 1). In this case, the side surfaces of the wheel are smooth, since the abrasive grains are pressed into the bundle of the wheel.

With such designs of the side surfaces of the wheel, according to research [6], depending on the depth of the wheel insertion
into the processing material, up to 70% of the cutting power consumption is spent on overcoming the frictional force between the side surfaces of the wheel and the processed material. During the cutting process. Such wheels can jam, lose stability after a long stay in the cut, and burning is possible on the cutting surface.

In order to eliminate these shortcomings, circles with rough side surfaces were studied, the pressing of which took place due to the placement of elastic polyurethane gaskets between the working plates. In this case, abrasive grains are pressed into the elastic gaskets to a height equal to 1/3 ... 1/4 of their size (Fig. 2).

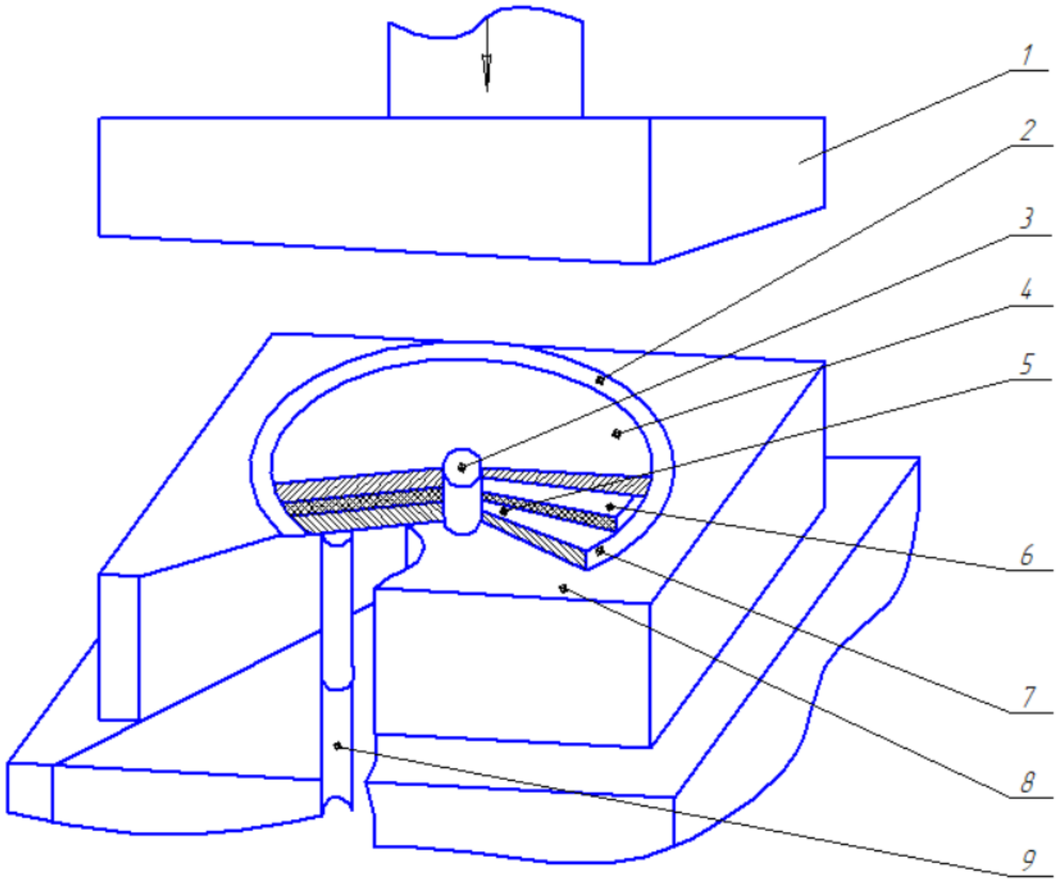

Fig.1. Circle formation scheme: *1* – press punch; *2* – mold ring; *3* – core; *4* – upper working plate; *5* – elastic gasket; *6* – abrasive wheel; *7* – lower working plate; *8* – press desktop; *9* – pneumatic pusher

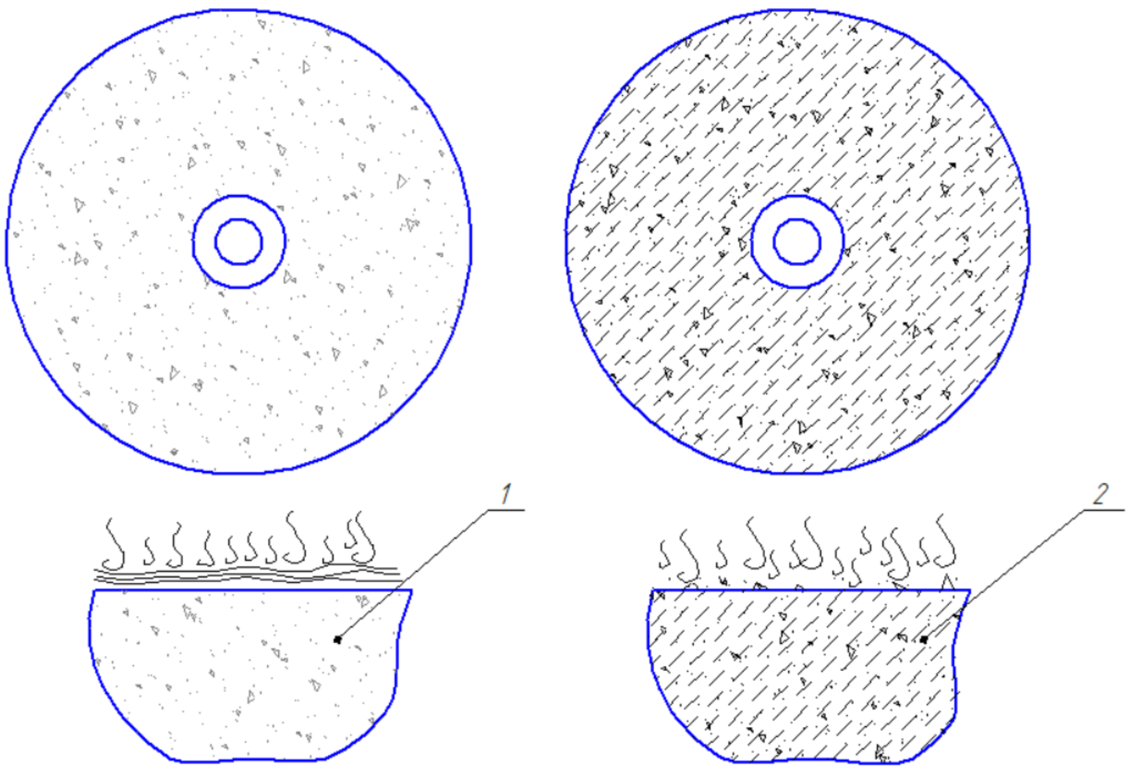

Fig. 2. Abrasive reinforced wheels: *1* – smooth side surface; *2* – rough side surface

Consider the effect of the side surfaces of the wheel on its performance. Let's dwell in more detail on the physical causes of jamming.

For technical reasons, at the installation sites, when cutting rolled metal with hand grinders, the profile is fixed at two points that are quite far from the cut point. Only thin metal products can be cut with abrasive wheels (their thickness cannot exceed a value equal to the radius of the wheel, from which 10 mm must be subtracted and the radius of the clamping flange) Of all types of rolled metal, we will choose a long bar of rectangular section $a \times b$, since the mathematical formula in this case has the simplest form, and the result can be transferred to rolled metal of any profile [1].

Since this thin bar is fixed at two points, then, as can be seen from Fig. 3, under the action of its mass, it will sag, while its initial length will change by a magnitude and will be equal to , where it is directly determined by Hooke's law [2]$L_0 \Delta L_0 L_1 \Delta L_0$

$$L_1 = L_0 + \Delta L_0 = L_0 \left(\frac{P}{Eab} + 1\right), \quad (1)$$

where is the mass of this rod applied to the center of gravity, kg;P

E – modulus of elasticity of the bar material, kg/m2;

L_0 – length of the bar, m;

a · b – cross-sectional area of the bar, m2.

If this bar is cut in the middle, then additional tapping forces will act on the bar . At the depth of cut, the load is perceived by the remaining part of the bar. The cross-sectional area that accepts the load is equal to. The elongation of the bar to a depth will be equal to:$P_b hb \cdot (a - h) \Delta L_1 h$

$$\Delta L_1 = L_1 \frac{P + P_b}{Eb(a-h)} = \\ = L_0 \left(1 + \frac{P}{Eab}\right) \cdot \frac{P+P_b}{Eb(a-h)}, \quad (2)$$

For the same reason, it can be considered that as a result of the desire of the material to retain its shape, there will be an elongation of the already cut part to the same extent as in the

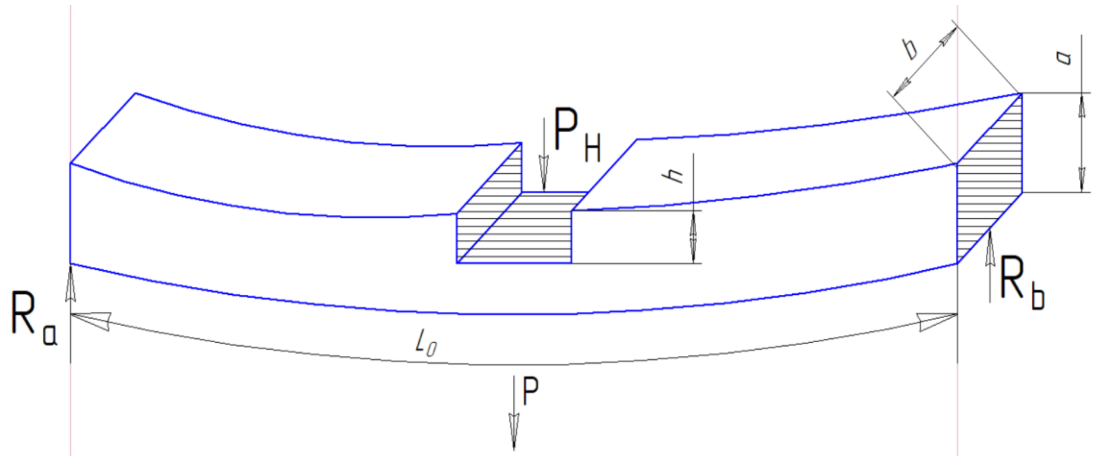

Fig. 3. Diagram of the forces acting on the thin profile during cutting

uncut. ΔL_1 The formula for can be transformed. Considering that ΔL_1

$$P = L_0 \cdot a \cdot b \cdot \rho \cdot c, \tag{3}$$

where ρ is the density of the material from which the bar is made, kg/m3.

Substituting expression (3) into expression (2), we get:

$$\Delta L_1 = L_0(1 + \frac{\rho L_0}{E}) \cdot \frac{P+P_b}{Eb(a-h)}, \tag{4}$$

Let's analyze the resulting formula. The magnitude of the narrowing of the cut ΔL_1 does not depend on the width of the cut itself and is directly proportional to the length of the sagging part. Usually, under installation conditions, steel is cut, for which g/cm$L_0\rho = 7{,}87^3$, kg/cm$E = 1{,}5 \cdot 10^{62}$, then

$$L_0 \frac{\rho}{E} = \frac{7{,}85}{1{,}5} \cdot 10^{-9} L_0 = 5{,}2 \cdot 10^{-7} L_0, \tag{5}$$

Formula (5) shows. When cutting metal products of considerable length fixed at the ends, the clamping of the cutting tool will begin immediately at the beginning of cutting. If, this term can be neglected. Consider the ratio $\frac{L_0}{E} \ll 1 \frac{P+P_b}{Eb(a-h)}$. If during cutting, then, given that,$P \gg P_b P = \rho \cdot L_0 \cdot b \cdot a$

$$\Delta L_1 = L_0\left(1 + \frac{\rho L_0}{E}\right) \cdot \frac{\rho L_0 ba}{Eb(a-h)} = (1 + + \frac{\rho L_0}{E}) \cdot \frac{\rho L_0^2 a}{E(a-h)}, \tag{6}$$

It is necessary to note the quadratic dependence ΔL on , since this parameter has a very strong effect on the cutting process. Therefore, in practice it is necessary to reduce it to a minimum. And finally, the effect in the denominator is reduced to the fact that the deflection and, as a result, the clamping with this method of fixing will increase as the mortuation is reached. When the limit is reached, when, the deformation will increase disproportionately to the load, since we go beyond the application of Hooke's law. the appearance of a residual burr [3-4].$L_0^2 L_0 (a-h)a \approx h\Delta L_1$

Another case is also possible when the cause of the tool jamming will be the action of the tie-in force, and in this case the clamping will be greater. Based on this, in practice, during the cutting of thin and thin-walled hardware with a small mass, as a result of going beyond the limits of Hooke's law (stress is too high), burs are observed.$P_b \gg P$

These results can be transferred to hardware of any profile, the main conclusions are the same everywhere, so the data are not given.

There may be other reasons for clamping the wheel in the cut, which are not related to the method of fixing the hardware, but due to the mechanism of the wheel [5].

The part of the circle located in the cut is similar to a beam, at the end of which two opposite directional forces act, which are fed and the tie-in reaction. In this case, the circle bends. The maximum deflection of the circle is in the middle. This causes the wheel to jam. In this case, the likelihood of jamming increases as the insertion depth increases and the point at which the deflection amplitude is greatest (in the middle, between the cutting edge and the clamping flange) approaches the cut.

The cutting grains are randomly placed. Due to the non-symmetrical placement of the cutting grains relative to the central axis of the wheel, the resulting force is equal to the difference in forces acting on the wheel from one side and the other, and is not equal to zero. This is another reason that causes fluctuations in the cuts. In addition, there is an imbalance of the wheel, the inaccuracy of its fixing on the axis of the drive machine. And when working with a hand grinder, transverse vibrations of the machine in the hands of the worker are inevitable.

The circle, as a result of the feed, moves translationally, and the combination of oscillations and translational movements leads to sinusoidal motion. The cutting surface is not flat, but sinusoidal in shape, which creates additional prerequisites for the contact of the side surfaces of the wheel with the cutting surfaces, that is, before the appearance of clamping forces.

Let us now proceed to consider the difference in the nature of the processes occurring as a result of contact of the side surfaces of abrasive reinforced wheels with smooth and rough side surfaces. In the first case, there is friction and deformation of the ends of abrasive metal grains on the surface of the cut. As it is known [7-8], during cutting metals, less than 5% of the energy is spent on chip removal, the rest of the energy is spent on its deformation. As a result, heat is released, the density of which is at a given point (on the distribution surface "side surface of the circle - cutting surface"). The equation of the balance of heat flows is as follows (heat can penetrate into a metal or into a circle)$qx = 0$

$$q = -\lambda \left.\frac{\partial T}{\partial X}\right|_{x=0} + \lambda' \left.\frac{\partial T'}{\partial X}\right|_{x=0}, \qquad (7)$$

where and are the $\lambda\lambda'$ coefficients of thermal conductivity of the matal and the material of the circle, respectively, W/mgrad.·

T and is the distribution of temperatures in the metal and the circle, K.T'

When the rough side surface of the abrasive reinforced wheel comes into contact with the kerf surface, the picture is qualitatively different. Since abrasive grains protrude from the bundle of the wheel to a height of about 1/3... 1/4 of the linear size, they are able to remove chips [3].

As indicated, the bulk of the energy is spent on its subsequent deformation, so the heat flux density is now distributed between the metal, the circle and the chips:q

$$q = -\lambda \left.\frac{\partial T}{\partial X}\right|_{x=0} = -\lambda' \left.\frac{\partial T'}{\partial X}\right|_{x=0} + \\ + mcT(x = 0), \qquad (8)$$

where mc is the mass and heat capacity of the chips removed at a given point, kg, J/kgdeg;·

$T(x = 0)$ – temperature on the surface of the cut, ºK·

A simple comparison of the formula (7) and (8) will show that, since their left parts are equal, the value of heat fluxes into the metal and the circle in the case of a smooth side surface is by an amount higher than $mcT(x = 0)$ the heat fluxes into an abrasive reinforced wheel with rough side surfaces, respectively.

In addition, since wheels with rough side surfaces microcut with protruding abrasive grains, the cut value is wider by 2/3 of the abrasive grain than that of wheels with smooth side surfaces, which leaves more room for the acting forces that press the side surfaces of the wheel in the cut. As the wheel moves into the depth of the metal, the protruding side grains prevent the wheel from jamming, due to the removal of metal from the kerf surface. Therefore, in practice, abrasive reinforced wheels with rough side surfaces do not jam during cutting [9].

Obviously, microcutting is carried out either as a result of clamping, or in those places of the cut where the vibrations of the wheel create sufficient forces for cutting. In other places or the surface of the wheel and the cut do not coincide and there is sufficient space between them, or the force pressing this grain against the metal is not enough to deform the latter and friction occurs. In this case, the abrasive grain is in direct contact with the heated metal, and not the bond, which creates a favorable thermal regime. After this section of the wheel leaves the cut, the grains are cooled by the surrounding air, as a result, less heat enters the wheel bundle.

Bakelite bond is heat-resistant. As an abrasive reinforced wheel with a smooth surface sinks into the cut, due to the transfer of heat along the side surfaces, a gradual destruction of the bond occurs, it loses strength, the wheel becomes flexible and unusable. For wheels with rough side surfaces, this process of heat transfer through the side surfaces also takes place, but the amount of heat transferred is less for the above reasons and in practice the cutting time is insufficient for the abrasive reinforced wheel to begin to lose strength. Therefore, wheels with rough side surfaces have a decisive advantage in cases where it is necessary to cut a solid profile with a width close to the maximum allowable for a given wheel.

An additional effect that improves the thermal regime during cutting is a significant intensification of heat transfer from the side surfaces of rough circles from the surrounding air. According to the data of the work [10], an increase in the heat transfer coefficient is possible twice, depending on a combination of factors. This is explained by the fact [11-12] that protruding abrasive grains destroy the laminar layer adjacent to the surface and provide the main resistance to heat transfer to the surrounding air, since heat transfer goes through it using thermal conduction. Turbulent vortices arise around the grains and convection becomes the mechanism by which heat transfer is carried out, which as a result sharply increases the speed and magnitude of heat transfer from the surface of the abrasive reinforced wheel. It is the more favorable thermal regime during cutting that can explain the fact that, depending on the depth of the tie-in, abrasive reinforced wheels with rough side surfaces, in addition to the listed advantages compared to wheels with smooth side surfaces, show 20-30% higher wear resistance.

Consider also the operation of cutting flexible discs consisting of fiberglass mesh with abrasive powder applied to the surface. Obviously, the amplitude of oscillations of such discs significantly exceeds the amplitude of the oscillations of the circles, therefore, as they tie in, the forces pressing the disc against the surface of the cut and leading it to the side will increase extremely quickly. This leads to increased friction on the side surfaces of the disc and rapid wear. Therefore, such discs can only be used for trimming work when the tie-in depth is insignificant.

Studies have shown that wheels with rough side surfaces are more advanced, safer and more economical than wheels with smooth side surfaces.

CONCLUSIONS

Abrasive reinforced wheels with shore side surfaces are a special type of tool used to process a variety of materials, including metals, wood, and composites. Shore side surfaces are characterized by a special shape that improves processing efficiency. They can have different profiles, which ensures optimal adhesion to the material to be processed. Among the advantages of such wheels are improved adhesion to the material, which reduces the effort required for processing, reduces heat - due to their special shape, such wheels can reduce heat during operation, which prevents overheating of the material and higher productivity - shore side surfaces allow you to achieve better results in a shorter time, which increases overall productivity.

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Працездатність абразивних армованих кругів

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Анотація. У статті розглянуто питання підвищення працездатності абразивних армованих кругів, що застосовуються у процесах різання та шліфування металів і будівельних матеріалів. Виконано аналіз конструктивних особливостей кругів із гладкими та шорсткими бічними поверхнями та досліджено їх вплив на ефективність різання, теплові процеси й безпечність роботи. Запропоновано фізичні моделі, що пояснюють причини заклинювання інструменту під час різання металопрокату, з урахуванням пружних деформацій матеріалу та дії сил врізування. Показано, що використання кругів із шорсткими бічними поверхнями забезпечує мікрорізання виступаючими абразивними зернами, зменшує тертя, покращує тепловідведення й підвищує якість обробленої поверхні. Встановлено, що такі круги характеризуються більшою зносостійкістю (на 20–30%), зниженою вірогідністю заклинювання та підвищеною безпекою експлуатації порівняно з традиційними кругами з гладкими поверхнями. Практичне значення отриманих результатів полягає у можливості їх використання для вдосконалення конструкції абразивного інструменту та підвищення продуктивності й надійності процесів різання в металургії, будівництві та машинобудуванні.

Ключові слова: абразивні армовані круги, різання, високоабразивні матеріали, температура, зв’язка, бічні поверхні, продуктивність інструменту, шорсткі бічні поверхні, термічні процеси різання, заклинювання інструменту, мікрорізання, зносостійкість, безпека експлуатації.