Efficiency of the continuous editing process grinding circles

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Abstract. Conducted experimental studies have shown the high efficiency of using continuous dressing and its varieties - cleaning during grinding. The conditions that ensure the minimum wear of the ruling and working circles for various processing conditions are determined. It is established that the minimum wear of the circles takes place at a relative speed of the working and ruling circles, close to zero. At the same time, the productivity of the dressing process and the processing efficiency are practically not reduced. It is shown that the greatest efficiency of continuous dressing takes place when grinding materials that are prone to adhesive setting with the components of the abrasive wheel. Recommendations are given on choosing the ligament and firmness of the ruling circles. The mechanisms of wear of the circles at various slip coefficients are established. Ensuring the angle of intersection between the circles, as a rule, increases the efficiency of the process, in addition, reduces vibration in the editing system. An increase in the angle of crossing over 10° increases the wear of the circles. The use of continuous cleaning reduces wear on the working circle and does not distort its macro profile. It was found that the ruling circles with an abrasive, which was created using the technology of self-propagating high-temperature synthesis (SHS), have greater wear resistance than circles of a similar characteristic from elbor, but inferior to diamond.

1. Introduction

Creating high-precision and reliable machines and mechanisms is impossible without the implementation of finishing processing operations. The achievements in the field of abrasive processing observed in recent years, related to the improvement of existing processing schemes, the use of new materials, coolant, etc., do not allow us to talk about the full realization of the possibilities of this type of processing [1-8].

At the same time, the requirements for the quality and efficiency of grinding, as one of the processes of finishing abrasive processing, are constantly increasing.

Abrasive grinding wheels is actually cyclical in nature, when the cutting ability, reaching maximum values, gradually decreases, and to restore it requires editing, restoring the cutting characteristics of the wheel. Processing with periodic dressing of the abrasive grinding wheel makes it most simple to ensure the accuracy and quality of the surface being machined, but does not make it possible to achieve maximum process efficiency, primarily high productivity. One way to increase
productivity while ensuring quality indicators is to increase the frequency of edits, and ideally, the transition to continuous editing of the circle [1-4]. The prerequisites for this are considered in [4-7].

Thus, the editing circle, carried out to restore the properties of the working tool, is an integral part of the process. The quality of processing and the efficiency of the grinding process as a whole depend on the proper organization of the dressing process. Work with dull circles leads to an increase in the force impact on the material being processed, to a decrease in the quality of the formed surface according to the defectiveness parameter, to an increased unproductive consumption of the circles [1, 8-15].

A significant number of works [1-15] are devoted to questions of editing grinding diamond wheels. However, existing editing methods are not without drawbacks and do not meet the requirements of modern production. Modern machining centers are equipped with continuous dressing systems for diamond wheels on a metal bond, designed for machining solid carbide tools. Continuous dressing systems for modern deep grinding machines have also been developed. They are absent from machines operating with various abrasives in serial and large-scale production, as well as on specialized CNC machines. This work is devoted to improving the editing of abrasives for such machines.

2. Experimental evaluation of the effectiveness of continuous editing

The experiments with continuous dressing of the circles were carried out on a modernized 3G71 machine with flat grinding of samples from steels 5 and 12X18H10T and BT3-1 titanium alloy. As the ruling roller, a PP20x20x10 diamond wheel was used, in which a diamond layer with a grain of 500/400 was applied by a galvanic method, and abrasive wheels of the same size on a ceramic bond with grain sizes F40 and F54 (GOST R 52381-2005) made of green silicon carbide, boron carbide and electrocorundum. The ruling elements were mounted on special mandrels [16, 17].

To identify conditions that ensure minimal wear of the circles - rollers, studies were carried out on grinding 12X18H10T steel with a productivity \( Q = 800...1200 \text{ mm}^3 / \text{ min} \) under various conditions of passing and counter dressing. The longitudinal movement of the roller - circle during editing was 1 m / min, the transverse feed per stroke - from 0.001 to 0.005 mm. It is accepted to express the slippage rate using the coefficient \( k \) with the corresponding sign [18]. A minus sign means that with a passing edit, the linear speed of the roller - circle is greater than the linear speed of the working circle. With a plus sign, the opposite is true. With counter editing \( k > +1 \) [18].

In Figure 1 shows the results of the wear of the \( \xi \) roller at different break-in angles for the diamond roller (Fig. 1, a) and the circle 63CF54R7V (Fig. 1, b).

![Figure 1](image-url)

Figure 1. Depreciation of the governing elements: a - diamond roller; b-circle 63CF54R7V.
As follows from table 1, the roughness of the treated surface varies slightly. This is due to the fact that the cutting surface of the grinding wheel is constantly being updated and risks from sticking on the wheel (metallization), which actively accompany the grinding process of 12X18H10T steel, are eliminated.

**Table 1.** The roughness of the treated surface $R_a$, microns, with a change in the coefficient of $k$

| Material          | Characteristic of the working circle | Roughness $R_a$, microns, when editing: |
|-------------------|-------------------------------------|----------------------------------------|
|                   |                                     | Periodic  | Continuous |
| A circle          |                                     | -0.8      | -0.2       | 0          | +0.2      | +0.5      | +0.8      | +1.2      | +1.8      |
| Diamond           |                                     | 0.32...0.39 | 0.34...0.38 | 0.33...0.37 | 0.32...0.37 | 0.32...0.38 | 0.31...0.41 | 0.30...0.42 | 0.29...0.45 |
| 63CF54R7V         |                                     | 0.31...0.38 | 0.33...0.38 | 0.33...0.38 | 0.32...0.38 | 0.32...0.38 | 0.32...0.38 | 0.31...0.41 | 0.30...0.42 |

Two jumps were established in increasing the wear of the roller: the first when exiting the condition when $k \approx 0$, and the second when the roller changes the direction of rotation relative to the circle, providing counter edition. Minimum wear of the roller during passing editing, when $k \approx 0$ confirms the specificity of the proposed method of continuous editing.

A coarse-grained diamond roller is tens of times more wear-resistant than a circle made of green silicon carbide.

**3. Determination of optimal conditions for continuous editing**

Observation of the wear of the grains of the circle and the roller show that at $k \approx 0$, conditions are created for their mutual self-sharpening, since they are chipped under conditions close to static. Apparently, the decisive role in this is played by vibrations in the technological system. To maintain their sharpness, a smaller amount of mutual interference is required, which reduces wear. In this case, it is advisable to talk not about editing, but about its variety - continuous cleaning of the circle. The dressing process is accompanied by an increase in the normal cutting forces of $P_y$ and a decrease in the tangential forces of $P_z$. The increase in vibrations leads to periodic recovery of the microprofile of the roller.

Under the established conditions of editing, when $k \approx 0$, the wear of the roller is less by 20...50% than for the case when $k = \pm 0.2$, and the wear of the circle is 10...30%.

The advantage of continuous dressing and cleaning is that when grinding with low productivity, the choice of the characteristics of the wheel loses crucial. For example, table 2 shows the results of grinding with a productivity $Q = 850$ mm³/min of various materials (dressing with a circle-roller). The roughness is reduced by 1.5...3.0 times.

**Table 2.** Grinding results with productivity $Q = 850$ mm³/min (dressing with a circle-roller)

| Material          | Characteristic of the working circle | Roughness $R_a$, microns, when editing: |
|-------------------|-------------------------------------|----------------------------------------|
|                   |                                     | Periodic  | Continuous |
| Steel 5           | 91AF100K5V                          | 0.32...0.36 | 0.32...0.36 |
|                   | 92AF54K6V                           | 0.83...0.85 | 0.83...0.85 |
|                   | 63CF60M5V                           | 0.22...0.25 | 0.22...0.25 |
| Steel 12X18H10T   | 91AF100K5V                          | 0.72...0.75 | 0.32...0.36 |
|                   | 92AF54K6V                           | 0.37...0.40 | 0.34...0.37 |
|                   | 63CF60M5V                           | 0.42...0.46 | 0.24...0.28 |
| Alloy BT3-1       | 91AF100K5V                          | 0.63...0.65 | 0.48...0.50 |
|                   | 92AF54K6V                           | 1.65...1.70 | 0.83...0.86 |
|                   | 63CF60M5V                           | 1.65...1.70 | 0.99...1.02 |
The metallization of the wheel during grinding leads to the appearance of gripping bridges with the material being processed, the growth of adherents on the working circle, and the appearance of deep scratches on the surface being treated. Continuous dressing removes sticks and eliminates the formation of deep scratches and contributes to a significant reduction in roughness. Based on the foregoing, continuous dressing is most effective when grinding materials that are prone to adhesion to the components of the abrasive wheel.

Studies have shown that diamond-free continuous dressing can in some cases be more effective than diamond dressing. Very high wear resistance of large diamonds leads to the appearance of wear pads on them and the loss of their ruling ability, which also contributes to the occurrence of vibration during dressing.

The research results led to the conclusion that, in the presence of a control system, the ceramic bond is preferred for the ruling circles. The main disadvantage when using wheels from conventional abrasives is a significant reduction in wheel diameters in a short time, which complicates the process control. It is advisable to choose working circles on a ceramic bond, which is more suitable than others for working in conditions of abundant supply of cutting fluid. The hardness of the ruling circles should be 2...4 steps harder than the workers. Its choice depends on the structure of the circle: with large numbers of the structure of the circle, it is recommended to take hardness more (GOST R 52587-2008).

Good prospects have been revealed for the use of the ruling circles manufactured at the Samara State Technical University, for which the abrasive is created using the technology of self-propagating high-temperature synthesis. Experimental wheels made using this technology in most cases showed greater wear resistance than other diamond-free wheels of a similar characteristic. The wear resistance of the experimental circles turned out to be three or more times higher than the circles of green silicon carbide. However, when processing BT3-1 titanium alloy, circles with boron carbide grains are more effective, because have a great ability to remove metallization. This fact confirms the advisability of expanding diamond-free dressing in production.

Dressing with a diamond wheel is necessary in processing conditions when it is necessary to obtain high precision of the workpiece or shaped surface. For example, the resistance of a diamond roller on a galvanic bond with grains of 500/400 when straightening a circle 92AF54K7V is higher than circles of green silicon carbide by 30 and more times, and circles with grains of SHS - 10...15 times.

We managed to obtain the maximum performance during diamond-free grinding, for example, of VK6M carbide with passing continuous dressing of the 64CF54M7V circle with the 63CF54R7V circle, when the angle of intersection was \( \phi = 7...10^\circ \), and the relative speeds of rolling in the circles were close to zero. Therefore, continuous dressing with a diamond-free tool allows you to remove large allowances from high strength materials. It is applicable for diamond and elbor grinding [19].

With continuous dressing, the workability of hardened and non-hardened steels 30ХГСН2А, P6M5, 4X5B2ФС, 40Х13, X12М, XВГ, 45 and other materials was determined. Combinations of various workers and ruling circles were investigated. Under optimal conditions of editing, there is no significant difference in such indicators of the grinding process as surface roughness, process productivity, cutting forces. An increase in the hardness of working circles should be accompanied by an increase in the hardness of the ruling circles and a mutual reduction in their wear.

It was found that when grinding inviscid materials with low productivity, the recommended hardness of the working circles can be increased by 2...3 steps or by 1...2 numbers to reduce the structure number.

When grinding hard-to-work materials or with a high productivity of the process, the hardness can be increased by 1...2 steps, and the structure number increases by 3-5 numbers. If the hardness is left at the recommended level, then the structure number must be increased by 2...4 numbers.

The greatest efficiency of continuous dressing was obtained when working in the cleaning mode. Low slip speeds and forces between the circles provide an effective microprofile of the working circle while reducing its wear to 0.005...0.001 microns per revolution. The presence of a longitudinal feed and the presence of a crossing angle during dressing removes metallization and other grinding
products from the pores of the circle. The ruling circle practically does not distort the cylindricality of the worker. The insignificant diameter and mass of the ruling circle do not directly affect the waviness of the working circle. However, maintaining in working condition the microprofile of the working circle, contribute to its effective operation in the mode of high-frequency self-oscillations. Cleaning is not able to prevent the dynamic system from switching to the low-frequency self-oscillation mode, and a short-term transition from the cleaning mode to the editing mode allows this to be done. Thus, alternating between continuous cleaning and dressing, you can use the working circle to complete wear. At the same time, its wear occurs mainly when removing the material, and not due to dressing. This follows from the fact that when grinding steels, the working circle wears out 5...14 times more in volume than the ruling one.

Under optimal working conditions with continuous cleaning of the wheel, the specific wear of the abrasive is usually less than with periodic dressing. When processing difficult materials, it is reduced to 5 times or more.

Positive results were obtained when grinding parts from electrotechnical materials, the treated surfaces of which have special requirements. These include: increased fragility, limitation of temperatures and their fluctuations in finishing operations, the absence of significant residual stresses of any sign, deep scratches and disturbances in the magnetic texture, and more. Heating temperatures should not exceed Curie points $T_c$. For the magnetically soft alloy mu - metal $T_c = 400^\circ$C, Recovac alloy - 280°C, Permenorm 500H2 - 440°C. For such materials, fine-tuning with special cooling agents is used [1, 20].

In [19], during grinding of the Ю14ДК24 alloy with continuous dressing, it was not possible to obtain the required quality on the entire surface of the sample. In some areas, magnetic reorientation caused by thermal exposure was observed. Additional cleaning of the circle with a bar, which allows you to almost completely remove metallization from abrasive grains, gives the desired result.

The same result was obtained by the authors of this article with continuous passing editing, when $k = - (0.1...0.3)$, and $\varphi = 7...12^\circ$, circles made of green silicon carbide. The productivity of the process increases by 30%, the stability of the process and the quality of the treated surface are increased, manual operation - cleaning is excluded.

4. Conclusions
Experimental studies have shown areas of effective use of continuous editing. It increases the productivity of the process, contributes to a significant reduction in roughness when grinding materials that are prone to adhesion to the components of the abrasive wheel.

Ceramic ligament is preferred for ruling circles. The hardness of the ruling circles should be 2...4 steps harder than the workers.

Prospects for the use of ruling circles made using the technology of self-propagating high-temperature synthesis are revealed.

It has been established that at a relative slip speed close to zero, conditions are created for mutual self-grinding of the grains of the circle and the ruling roller, which can be explained by vibrations and torsional vibrations in the contact zone. At the same time, a kind of continuous editing is observed - continuous cleaning of the circle. Its use allows to reduce the wear of the working circle to 0.005...0.010 microns per revolution and does not distort the macro profile of the working circle, which operates in the natural running-in mode. The optimal angle of intersection of circles $\varphi$ depends on the vibration resistance of the entire technological system.

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