Technological features of a new design of a face grinding wheel

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Abstract. In article, addresses the issues connected with the decrease of the thermal impact on detail surface faced gringding wheel. The new design of a face grinding wheel with the faltering cutting and rising parts of a continuous working surface, with transition from the hollows to the ledges on an Archimedean spiral (Patent №0183) is developed. The characteristic of an Archimedean spiral is the sum of two uniform motions of the tool and the detail, and practically provides the constancy of an grains attack angle located on all length of a ledge. The method of the parameterization of a new design for grinding wheel is developed. Analytical expression about the quantity of the actually working abrasive grains and regularity of their distribution on an Archimedean spiral of the cutting ledge are received. It is established that the grinding wheel of a new design in comparison with a standard circle promotes considerable (up to 30%) reduction of roughness of a polished surface.

1. Creating breakthrough surface with a new construction side shingle circle. The cutting edge of the working surface was interrupted, and the whitening part was made entirely from archway to arched spiral.

2. Conducting theoretical researches for the parameterization of the new construction side-bye circle.

3.Theoretical researches of conditions of formation of geometrical parameters of surfaces in curlization with new constricted lateral circle circle

4. An experimental study of the effectiveness of a flat-blasting operation with a new constructed side-circle circle. Comparative determination of contact temperature, shear force and bracedness dependency laws.

5. New konstruksiyaləı burnish circle design, develop and prepare proposals for the determination of economic efficiency. Conducting experimental testing of new construction side-by-side circle.

The comparative analysis of graphic dependences shows that at application of a new design of a face circle reduction of roughness of a polished surface is observed considerable (up to 30%).

Key words. the grinding wheel, faltering circle, Archimedean spiral, roughness, cutting force, granularity, waviness.

Introduction. The efficiency of the process for the face grinding is expressed in the high geometrical precision and productivity of this process which is tens times surpasses productivity of the flat grinding by the periphery of a circle. Therefore, a study of the issue on a research and improvement of the process of face grinding, especially to decrease in temperature impact on the processed surface, numerous researches have been devoted [31]. Generalizing results of the analysis of the researches in the field of the face grinding, it is possible to concentrate generally on three directions of decrease in the thermal impact on the processed surface of the details:

- management of the grinding process modes,
- application of the lubricant cooling technological means (LCTM),
- application of grinding wheels with a faltering surface.

The most effective method of increasing the efficiency and improvement of the quality of abrasive processing is the application of circles with a faltering working surface. At the same time, one of the defining factors influencing course of the process of grinding is the sizes of the processed surfaces, more precisely, the contact zone sizes. At flat grinding by the circle end, the zone of contact has considerable size in comparison with other types of grinding. This feature leads to essential variety of the specific characteristics of the process of grinding in different points of contact zone. Numerous efficiency of the face grinding process is expressed in the high geometrical precision and productivity of this process which is tens of times surpasses productivity of flat grinding by the periphery of a circle. Therefore, a study of the issue and improvement of process of face grinding, especially to decrease in temperature impact on the processed surface, numerous researches have been devoted. Generalizing results of the analysis of the researches in the field of the face grinding it is possible to concentrate generally on three directions of decrease in thermal impact on the processed detail surface:

• management of the grinding process modes,

• application of the lubricant cooling technological means (LCTM),

• application of grinding wheels with a faltering surface.

The aim of the study. The most effective method of increase the efficiency and improvement of the quality of the abrasive processing is the application of circles with a faltering working surface. At the same time, one of the defining factors influencing the course of the process of grinding is the sizes of the processed surfaces, more precisely, the contact zone sizes. At flat grinding by a circle end, the zone of contact has the considerable size in comparison with other types of grinding. This feature leads to the essential variety of the specific characteristics of the grinding process in the different points of the contact zone. The numerous factors leading to uneven abrasive impact on the processed surface especially brightly are expressed at the big areas of contact.

It should be noted that process of face grinding by circles with a faltering working surface is followed by vibrations. The most significant sources of fluctuations when grinding are: imbalance of a faltering grinding wheel which is caused by errors of its form and sizes, the sizes of the cutting ledges and their number, uneven density of the structure of the tool and shock impact of a faltering part of a grinding wheel on the processed detail surface. Vibration in the MTDI system in turn leads to deterioration micro and macro-profiles of polished surfaces and limits scales of application of faltering grinding [31].

Generalizing results of the carried-out analysis we establish the fact that each of above-mentioned ways of decrease in thermal impact on the processed surface has the positive and negative moments. Among considered, an effective way is faltering grindings. Improving the grinding wheel design with a faltering working surface, defining it optimum parameters and operating conditions, including the modes of grinding and a way of cooling it is possible to increase efficiency of process of face grinding in addition.

Proceeding from the above it is possible to come to a conclusion that process of thermal emission in a contact zone at face grinding has difficult character. Except for traditional factors of thermophysics it is necessary to pay attention as well to the characteristics of abrasive grains works for working end face of a grinding wheel. Not in view of physical essence of these features and without having mathematical model of process of the cutting happening in a zone, it is difficult to define optimum conditions of decrease in thermal impact on the processed surface.

Subject of study. The idea of the decrease in thermal impact on the processed surface by means of constructive design of a grinding wheel has led to the emergence of circles with faltering (segment circles), eccentric, inclined, etc. surfaces (tab. 1). These ways through the decrease in thermal impact on the processed surface, however, as it is mentioned above works well, they steadily lead to increase in vibration of the technological system because of the shock influence at faltering grinding and imbalance, when grinding with excentric and inclined circles. The imbalance of grinding wheels in turn leads to increase of the tension in a circle, to deterioration quality of the polished surfaces and occuring on them burning, increasing he impingement attack of the circle, premature failure spindle and other knots of the machine. Among above-mentioned designs of face grinding wheels the greatest distribution has received segment circles which equip serially released flat grinding machines with a vertical spindle and a rectangular table.

Analyzing work of circles with a faltering working surface - segment circles it will easily be convinced that cutting work at the same time is performed generally by the grains located on an external working layer of a segment and on a forward edge of its end face with height of size of longitudinal feed of a detail on one segment of a circle. It is attested that the intensive sparkling of grains of this zone from a sheaf (Fig. 1b). In process of the impingement attack there happened self-design of the segment external profile. At the same time, on an external surface of a segment is formed the working surface having some angle of attack to the cutting plane. The similar phenomena was observed by professor A.I. Yakimov [31] at peripheral grinding by circles with a faltering working surface. Wherein the profile of a ledge receives a spiral outline. The section point between a frontal and back zone of grinding at the same modes has eventually the fixed situation. The self-sharpining circle proceeds evenly on all profile with maintaining constancy of an angle of attack.

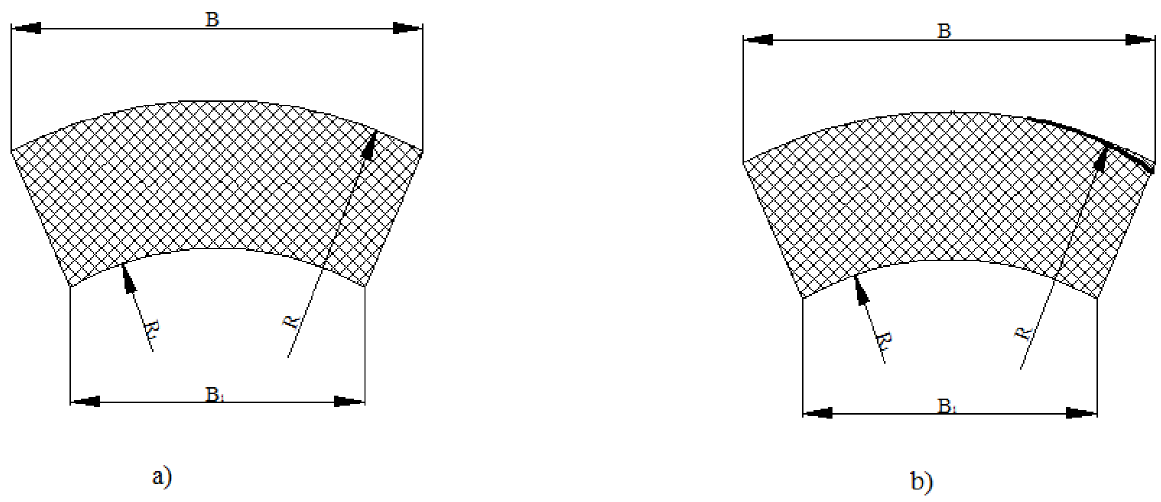

Fig. 1. Self-design of an external profile of a segment in the process of grindings:
a) before alignment, b) after alignment

The specified phenomenon is especially characteristic at deep and draft multipass grinding with big feeds to the depth. These judgments lead to a thought that the main center of thermal emission in a contact zone of a segment circle is frontal - the cutting strip of a contact zone. In the subsequent strips actually working grains getting to already cut through scratches of spark-out work. And the spark-out abilities of conditional strips increase in process of removal from a frontal zone on the decreasing geometrical progression. Thus, the working end face of a segment conditionally breaks into two parts – the front cutting frontal page, the second is the subsequent spark-out strips. The exponential form of oscillograms of distribution of temperature in a contact zone is a clear proof of the aforesaid [27].

The intermittency of a working end face of a circle in the spark-out part slightly influences process thermal emission in a contact zone at the same time because of intermittence of a surface, this part of a ledge is one of the main reasons for emergence of vibrations in technological system and by that leads to deterioration of processing reducing the spark-out ability of a working end face of a circle.

Therefore, decrease of intensity of thermal emission in the cutting frontal part of a working end face of a circle where it has the dominating value, by creation of intermittence in this zone and elimination of the centers of emergence of vibrations by performance the spark-out part by continuous, are the most optimal solutions of increase in efficiency of process of a face research. Thus, by the corresponding constructive design it will be possible to reduce at the same time thermal impacts on the processed surface and vibrations in technological system.

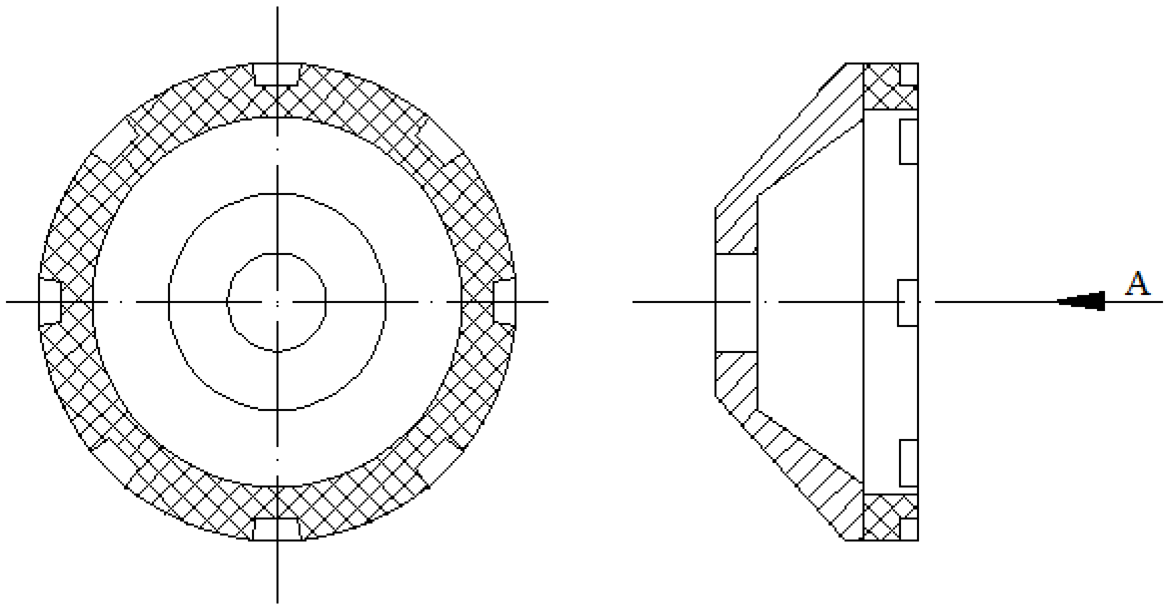

Fig. 2. Face grinding wheel with a faltering working surface

During creation of intermittence in a frontal strip of a working end face of a circle, at the expense of cuts the total of the actual grains decreases and therefore load of the cutting grains increases. The blow force perceived generally by grains of the site of a working ledge, adjacent to a forward edge, though is rather less, but will promote to emergence of vibrations in technological system. Height of the site of a forward edge perceiving interference corresponds to the size of longitudinal feed of the grinding wheel coming to one ledge of a faltering surface.

For elimination of the periodic interference in this zone and by that sources of vibrations, it is required profiling of the cutting ledges of a faltering part of a working end face of a grinding wheel so that promoted increase in quantity of the cutting grains of a working ledge and creation of conditions for rather equilibrium distribution of an allowance between them coming to one ledge of a faltering part of a frontal strip. The problem of increase in quantity of the actually working grains in a working layer of an abrasive circle and equilibrium distribution of an allowance between these grains is solved an outline of a profile of the cutting ledge on an Archimedean spiral, i.e. transition from the hollow to a ledge in the cutting frontal strip is carried out on an Archimedean spiral. Thus, the formula of an invention Face grinding wheel which has been protected in the State Committee on Standardization of Metrology and Patent Studies has been formulated and the patent of the same name at No. 0183 (Fig. 3) is taken out.

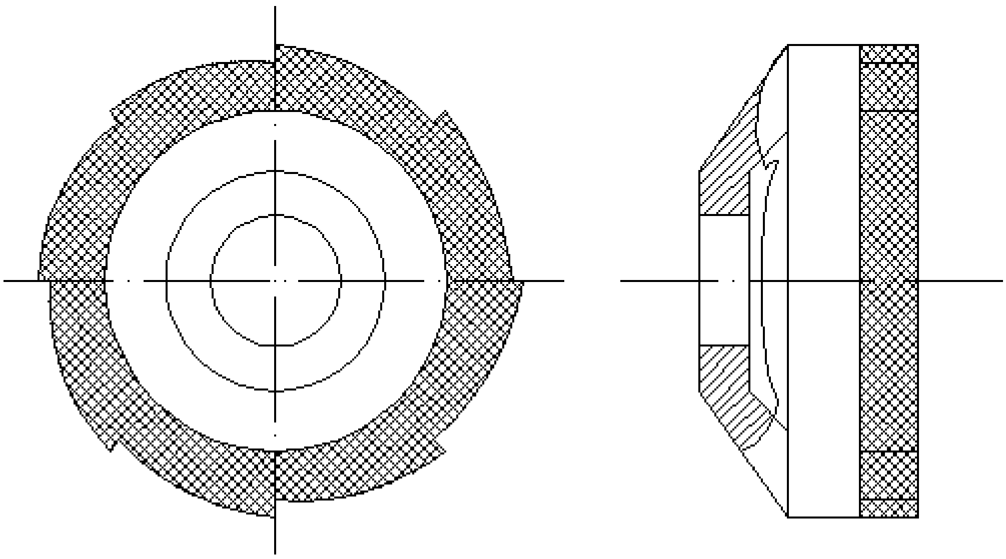

Fig. 3. Face grinding wheel with the ledges outlined on an Archimedean spiral

At a faltering circle the ledges outlined on an Archimedean spiral remind mills with form-relived teeth, at the same time in relation to a cutting zone the forward surface has the form of an Archimedean spiral, and a back surface a flat form. Characteristic of a form-relive is the frontal surface on an Archimedean spiral which keeps constancy of a profile and by that an angle of attack of the cutting grains located on it.

Theoretical researches. The Archimedean spiral turns out by means of summation of two even load distribution – forward as a result of longitudinal feed of a detail and a grinding wheel, rotary by means of rotary motion. The Archimedean spiral practically provides with the corresponding characteristic constancy of an attack angle of the grains located on all its length. Theoretically, constancy isn't present, but the deviation little and practically for the process of grinding they can be neglected. Form-relive of the new design of a face grinding wheel can make on the special form-relieve machine with form-relive cutters and grindings. Perhaps also implementation of a double form-relive. At the same time, the cutting part of a surface of a ledge form-reliving with falling of a nape at a size K and back with falling of a nape at a size K_1. When milling the value undertakes equal (1,2-1,5) K [17]. The double form-reliving leads to the final division of the frontal and back parts of the cutting ledge that limits technological capabilities of the frontal part at various modes of grinding. The provision of a point of intersection of the Archimedean spirals with the various falling of a nape should be defined proceeding from the value of a ratio V_d/n . At unstable value of this ratio the provision of a point of the section of a frontal and back zone will move.

THEORETICAL REQUISITES

In case of increasing size ratio to V_d/n part of the allowance will be removed a rear zone of the cutting ledge. Wherein, the point of intersection of a frontal and rear zone will promote to emergence of shock influence. In case of reduction of this ratio the allowance for a ledge entirely is removed a forward part of a frontal zone of a ledge that will undoubtedly lead to reduction of number of active abrasive grains and increase in load of them. Creation of a double relieving work from a position of technological construction, will lead to a complication of technological process of production of a grinding wheel and increasing its production cost.

$$S_{ob} = \frac{V_d}{n_k} = \frac{V_d \pi D_k}{1000 V_k} \quad (1)$$

At face grinding the feed per revolution of the disc is defined by a formula where V_{ud} - is speed of longitudinal moving of a detail to m/min, n_k - is the frequency of rotation of a circle in rpm, D_k - is the diameter of a grinding wheel in mm, V_k - is the speed of rotation of a grinding wheel in m/s.

Feed per revolution on the cutting ledge of a grinding wheel with a faltering working surface is determined by a formula

$$Sz = \frac{S_{ob}}{Z} = \frac{V_d \pi D_k}{1000 V_k Z} \quad (2)$$

where , Z -is the quantifer of ledges of the faltering cutting part of a circle.

For the definition of the characteristic of the Archimedean spiral according to which ledges of a faltering part of a grinding wheel the size of a step of an Archimedean spiral are outlined we equate to the size of longitudinal feed per revolution on one ledge of a faltering part. To this value of a step there can correspond two spirals differing from each other in the direction of rotation of a circle. At rotation of a circle the grinding wheel with the ledges outlined by the left spiral (fig.4 a) and vice versa (fig.4 b) is clockwise applied.

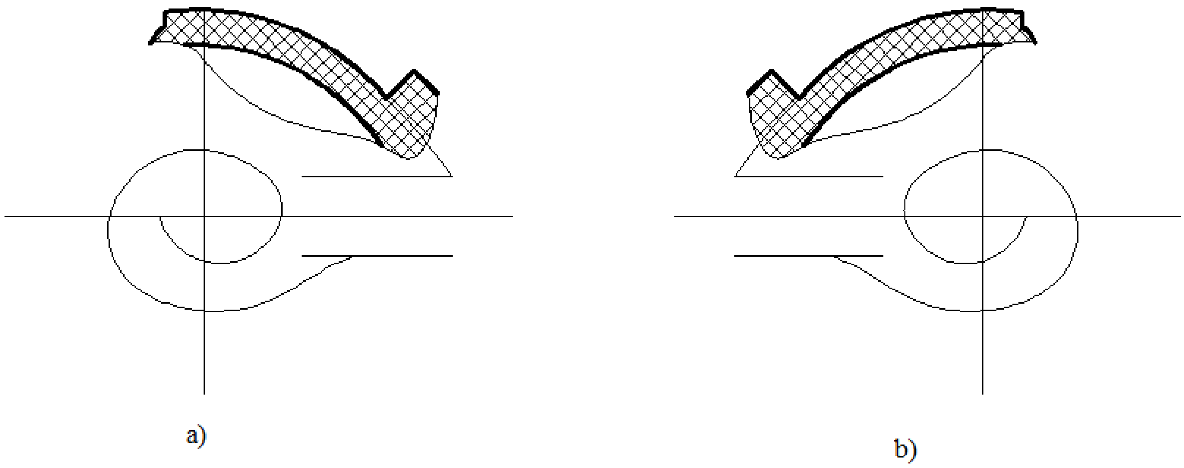

Fig.4. Definition of the characteristic of the Archimedean spiral.

a) left spiral, b) right spiral.

The polar equation of the Archimedean spiral is presented in the form

$$\frac{p}{a} = \frac{\varphi}{2\pi} \qquad (3)$$

where - p is the increment vector radius, and - a is the step of te Archimedean spiral at a whole revolution vector radius,and φ is the current value of a polar angle of rotation vector radius.

We will write down the equation (3) in a look

$$\rho = K\varphi \qquad (4)$$

where- K is the parameter of the Archimedean spiral. K is the - grain arrangement vector radius at its turn is defined by the size of an increment of the current value on a corner in one radian

$$K = \frac{\alpha}{2\pi} \qquad (5)$$

To turn of radius of a vector ρ from any its situation on a corner, it corresponds the same increment of the distance.

Writing down value K in a formula (4) we will receive

$$p = \frac{\alpha}{2\pi}\varphi \qquad (6)$$

Values of an angle of rotation depending on quantity of ledges are presented in tab. 1.

tab. 1

z	3	6	12	24
φ, в град	120	60	30	15

In a formula (6) equating a step of an Archimedean spiral to the size of longitudinal feed per revolution of a circle detail we will receive

$$\rho = \frac{V_d D_k \varphi}{2000 V_k} \qquad (7)$$

The increment vector radius on the cutting ledge outlined on an Archimedean spiral will be (tab. 1)

$$\rho = \frac{V_d D_k \varphi}{2000 V_k Z} \qquad (8)$$

tabl.2

Z	3	6	12	24
φ	120	60	30	15
ρ	Sob/3	Sob/6	Sob/12	Sob/24

Thus, creation of intermittence in cutting - the frontal zone with transition from a ledge to the hollow on an Archimedean spiral and performance continuous can lower the caring part of a working surface of a face grinding wheel considerably temperature impact on the processed surface and vibrations of the MTDI technological system that also the quality of a polished surface in total will lead to increase in efficiency of process.

- For identification of essence of process of grinding with application of a new design of a face circle, development of a technique of parametrization of its faltering part, definition of the characteristic of a working surface and development of practical recommendations about its application we will analyse the mechanism of work of the grains located in a working layer of the cutting ledge outlined on an Archimedean spiral. For the purpose of the analytical description of the mechanism of work of active abrasive grains of ledges of the offered design, as well as in standard cases of mathematical modeling and the analysis, we will make some schematization of the process of grinding for development of the practical recommendations. For this purpose according to work we accept below-mentioned submitted formulations:

• Grains in a circle and in its layers are focused randomly,

• In the process of grinding, in process of a sparkling of a grain circle are opened and appear on a working layer, thus their casual orientation remains,

• Not all grains of a working surface of a circle participate in work on removal of an allowance and create thermal impulses,

• The nominal surface of contact of a circle with a detail is a projection of the actual surface of contact to a conditional external surface of a circle.

• The circle which is carried out throug top of the most acting grains in a working layer of the tool will be called an external surface of a circle.

• The circle replacing the actual surface of a ligament in boundaries grain space of the tool will be called the surface of a ligament a circle.

• A working layer of a circle is the layer located between an external surface of a circle and the surface of a ligament.

While grinding, one of the main reasons for uneven abrasive impact on the processed surface is the changing of the speed of cutting of grains in a contact zone in size and in the direction. Change of cutting grain speed in size happens on the width of a working end face of a circle because of change of district speed of the grains located on different concentric circles $V_z = F(R)$. At the grains located on one circle change of speed of cutting occurs in the direction $V_z = F(\varphi)$. Depending on the direction of longitudinal feed per revolution of a detail in relation to an axis of symmetry of a circle, a part of grains of a contact zone work against feed per revolution of a detail, having made counter grinding, and other part on feed per revolution of a detail having made passing grinding [16]. It is obvious that, at a chaotic arrangement of grains in a working layer of a circle such variety of speeds and operating conditions of grains of a zone of contact will lead to uneven abrasive impact on the processed surface including on process of thermal emission in a contact zone.

Other essential factor leading to uneven abrasive influences in a zone of contact is that work of cutting is performed generally by the grains located on a peripheral, frontal strip of a working end face of a circle with a feed per revolution width on a circle. At the subsequent turns of a circle the cut-through site of a surface repeatedly meeting from a working surface of a circle, breaks it into conditional strips with different extent of abrasive impact on the processed surface. Depending on the number of repeated meetings a part of grains of each strip get on already cut through flutes. At the same time, the extent of abrasive influence and therefore, the process of thermal emission decreases on the decreasing geometrical progression. In work [16] analytical expression of the change of the amount of actually working abrasive grains on the width of a working end face of a circle is offered. On the basis of this formula, the analytical expression of the quantity of actually working abrasive grains within the area of contact when grinding with the application of a new design of a face circle is received.

$$i_k = \frac{0{,}167\,\beta\sqrt{k}}{\alpha^{3/4}\sqrt{tg\gamma}\,X_1^2\sqrt{1-\varepsilon}}\sqrt{\frac{\omega}{1000V_{k\ p}}}\,\frac{(1-q^{\frac{b}{s}})S}{1-q}\,R_i\sqrt{1+\frac{V^2}{(60V_k)^2}}\,K_1\sum_{j=1}^{b/s}[D-(2J-1)S], \qquad (9)$$

Where β – the amendment on a symmetric arrangement of a curve of distribution of depth of tops of the grains in the working layer of a circle, γ - a half average verisimilar value of a corner of the top cutting grain, ω - specific productivity, mm / with; K - concentration diamond or the cubic boron nitride grains, %; α - grain form coefficient; $\overline{X}$ - average value of the size of grinding sills grains ; V_d - speed of longitudinal movement of a detail, m/min; K_1 - the coefficient considering intermittence in a frontal zone of a working end face of a new design of a grinding wheel; V_k = speed of rotation of a grinding wheel, m/s; D - outer diameter of a working end face of a circle, mm.

At face grinding besides grains of a working end face, work of cutting is performed also by the grains located on an external surface of a circle. From this point of view determination of the probable quantity of the actually working grains and regularities of their distribution on the surface of the cutting ledge of a circle outlined on an Archimedean spiral is important and can accompany disclosure of the mechanism of work of a new design of a grinding wheel.

The ledges outlined on an Archimedean spiral conditionally are divided into two parts. A forward part of a ledge where the abrasive grains located in a layer directly not participate in the grinding process, it will be conditionally called rear zone, and an end-cutting part where we occur the process of the cutting will be called the cutting part. The position of the section point of the cutting and rear parts of a ledge isn't fixed and can change the position depending on cutting mode elements, in particular, from a ratio of longitudinal feed of a detail to a circle turn, i.e. from the characteristic of an Archimedean spiral. With increase in a ratio V_d/n_k the position of the section point moves from the cutting part to the rear part and vice versa. In other words, the ratio of the cutting part to the rear part is defined depending on inclination corner size - an angle of attack of a frontal zone of the cutting ledge. At the same time, the process of interaction of the cutting grains with the processed surface will also proceed differently. Depending on the size of an angle of attack the cutting grains settle down on different radiuses from the center of rotation of a circle and moving on certain trajectories, delete an allowance with separate thin layers. At the big characteristic of an Archimedean spiral and respectively great values of an angle of attack of grain work with big depths of introduction in metal and the main part of an allowance at the same time is removed the grains located on a forward part of the cutting ledge. Being on different radiuses from the center of rotation of a circle, grains rotate on concentric circles deleting an allowance with separate thin layers.

During such abrasion removal of the metal, heat generated in a zone of micro sites of single grains, extends through the longitudinal lying and underlying layers of the remained allowance. However this heat does not distribute on length and depth of metal is removed with facing [27] According to such scheme removal of an allowance physicomechanical properties and structural conditions of the detail layer it will be mainly formed from thermal influence of the grains located on the spark-our part of a circle working end face, and to a lesser extent from the grains located on the cutting ledge which is outlined by the Archimedean spiral.

The reduction of the specific number of thermal impulses and increase share of heat which is taken away with facing will lead to reduction of volume of the absorbed heat of the detail at faltering grinding. With increasing in depth of incision of abrasive grains the specific weight of work of friction decreases. At active micro cutting, the work spent for friction decreases up to 80%. If to consider losses on friction of a sheaf and also sticking of metal to a circle surface in the course of grinding, then the specific weight of work of friction will be even more [27].

For assessment of the cutting ability of circles with the ledges outlined on an Archimedean spiral in a zone of a frontal strip it is necessary to know probable amount of the cutting grains and the nature of their distribution. Distribution differently altitudes of grains from the surface of a ligament ranging from 0 to H_{max} with sufficient reliability can be described the law of normal distribution. Experience shows that the curve of distribution has the center of grouping at distance of N_{cp} - 0,5 H_{max} from an external surface of a circle. Mass distribution of the sizes of abrasive grains is described by the law of normal distribution, with an average square deviation [27]

$$Y_m(X_i) = \frac{1}{\sigma_m \sqrt{2\pi}} \exp[-\frac{(X_i - X_m)^2}{2\sigma_m^2}], \qquad (10)$$

$$\sigma_0 \approx \frac{1}{6}\Delta_{\max} \approx \frac{1}{6}(\bar{X} + 3\sigma)(1-\varepsilon) \ ,$$

Where X_i - is the current size; $\bar{X}_m$- is the average fibular size at distribution for mass; σ_m - is the average square deviation of the grain size at distribution for mass.

For environments of the fibular size

$$\bar{X}_m = 10{,}6 \text{ N},$$

where N is the granularity in accordance with GOST P 52381-2015.

For average square deviation

$$\sigma_m = 0{,}17\bar{X} \ .$$

At the engineering calculations transition from distribution curve parameters on the mass of grains $\bar{X}_m$ and σ_m to distribution curve parameters by their quantity is carried out by $\bar{X}$ and σ.

For powders of wide range of granularity

$$\bar{X}_m = 0{,}88\bar{X}_m \text{ и } \sigma = 0{,}94\sigma_m$$

For powders of narrow range of granularity

$$\bar{X}_m = 0{,}96\bar{X}_m \text{ и } \sigma \approx \sigma_m .$$

It is known that under the influence of a large number of independent or poorly dependent factors curves of dispersion of their sizes approach the theoretical curve of the normal dispersion. From this point of view, differently altitude of grains from the surface of a ligament can schematically be presented in the form of the dot chart (fig. 5).

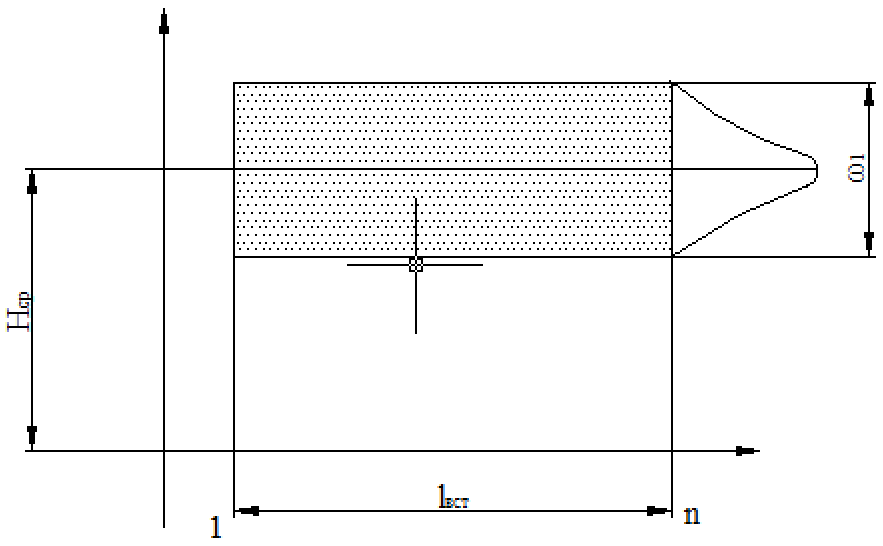

Fig. 5. The dot chart of distribution differently altitudes of grains from the surface of a ligament

At the same time, the average value of height of Ncp grains about which sizes of depth of separate grains grouped will have an appearance of an arch of a sheaf, concentric to a surface. For descriptive reasons representations of regularity of distribution of grains on the cutting ledge should be passed from the polar system of coordinates to rectangular. At the same time, with some schematization of the considered site with the extent of a ledge of the circle faltering part it is possible to present in the form of direct parallel abscissa axis.

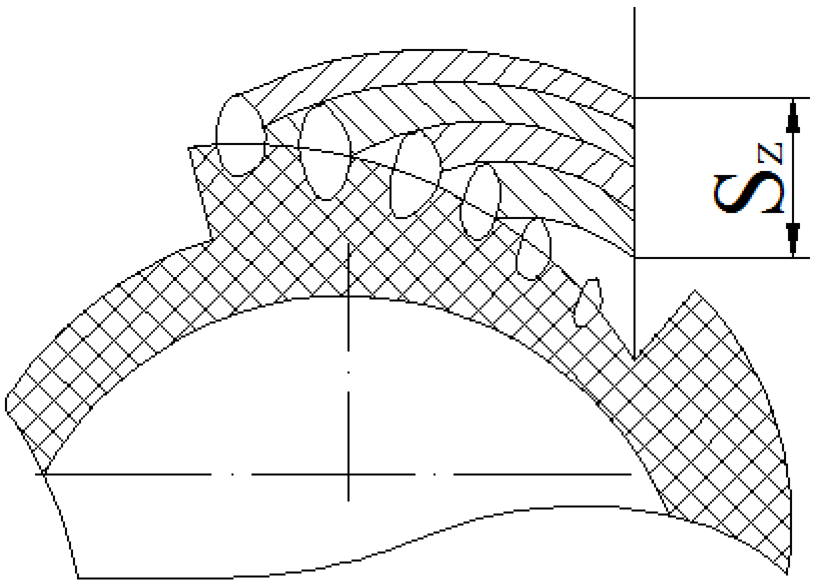

Fig. 6. Distribution of an allowance for a ledge between the grains located on the surface outlined on an Archimedean spiral

Let's say that weeded polar system as the center of rotation of a grinding wheel coincides with the beginning of rectangular system and a polar axis with the positive direction of abscissa axis OX. Abrasive grain *M* is any point of the plane. Its rectangular coordinates are *X* and *Y* and polar coordinates are ρ and φ. At the same time, transition from polar coordinates to rectangular is made on formulas.

$$X = \rho Cos\varphi, \quad Y = \rho Sin\varphi \qquad (11)$$

We will assume that during grinding of grain on a surface of a ledge are located not on an arch of a circle and on an Archimedean spiral where dispersion from the center of rotation of a circle it is decreased in direct ratio to ledge length. At the same time, radius a vector of a surface of a ligament at the rotation of the circle clockwise decreases in direct ratio to a circle angle of rotation that is schematically shown in the form of the dot chart presented in fig. 8. If for average height Ncp of the grains located on a working layer of the ledge surface outlined on an Archimedean spiral for construction of the dispersion curve from the center of rotation of a circle, it is possible for each of intervals into where the field of dispersion is broken with some probability there will be an equal quantity of grains. In other words, the size of radius of a vector of an arrangement of grains on a circle surface evenly would dissipate on all field of dispersion i.e. under the law of equal probability.

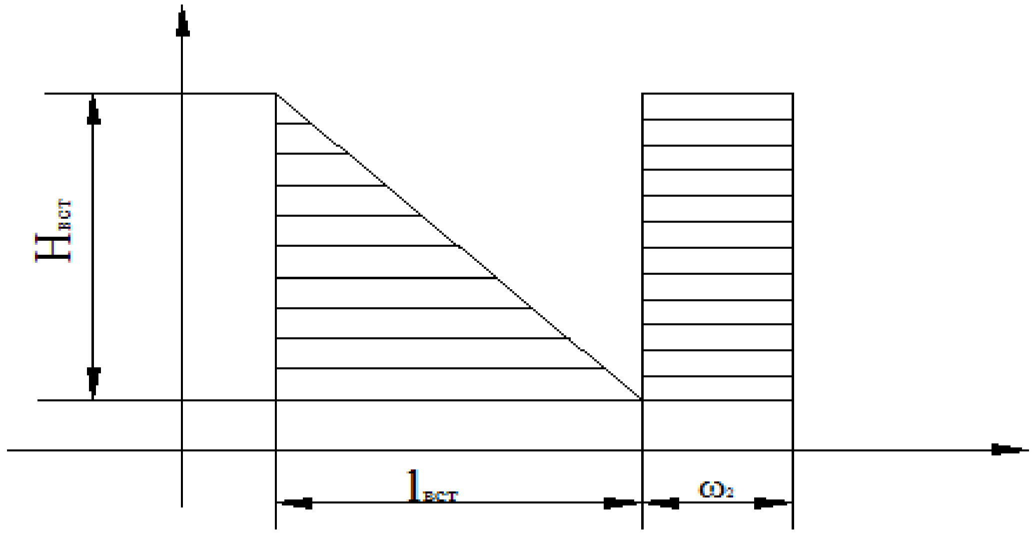

Fig. 7. Dispersion of average value the radius of vectors of grains on a ledge surface outlined on an Archimedean spiral.

We will return now to the most probable arrangement of grains at which along with the dominating influence of a profile of the linking of a ledge outlined on an Archimedean spiral on the relation of the center of a circle, a large number independent factors of one order of sizes in the form of differently altitude of grains in parallel works. The dot chart for such case will have the view shown in fig. 8

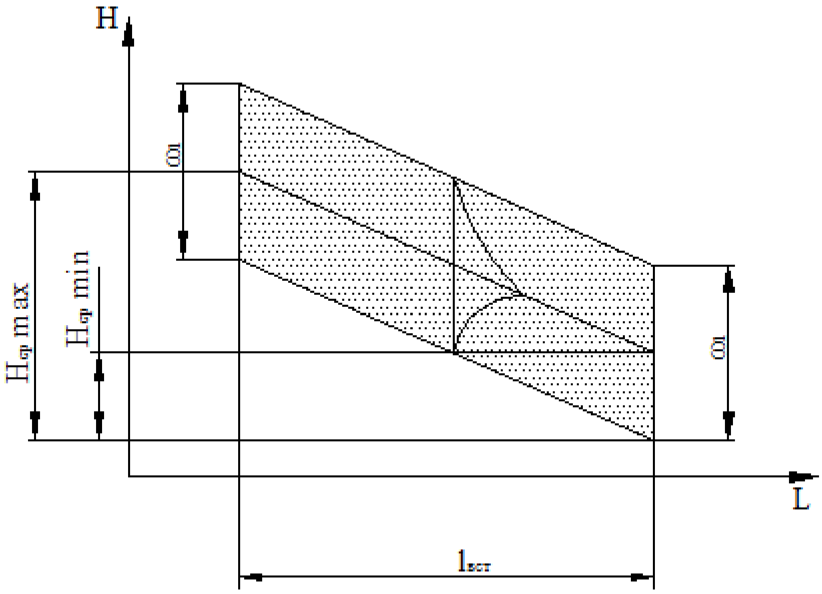

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Fig. 8. Dot chart differently altitudes of the grains of the working surface of a ledge outlined on an Archimedean spiral.

Apparently, from this chart the average value of the radius of the vector of grains on the surface of a ledge outlined on an Archimedean spiral is decreased evenly, despite differently altitudes of the grains in general. The analysis of the constructed curve dispersion shows that field of dispersion of the sizes, the radius of vectors of the grains located on the surface of the cutting ledge outlined on an Archimedean spiral is of the sum of sizes of the field of the dispersion generated by cumulative action of a large number of independent factors of one order of sizes in the form of differently altitude of grains on the relation of a surface of a ligament and size of shift of the middle of this field of dispersion under the influence of the dominating factor in the form of change the radius of a vector of a surface of a ligament is proportional to an angle of the rotation on the relation of the direction of longitudinal feed of a detail on an Archimedean spiral, that is (fig. 9)

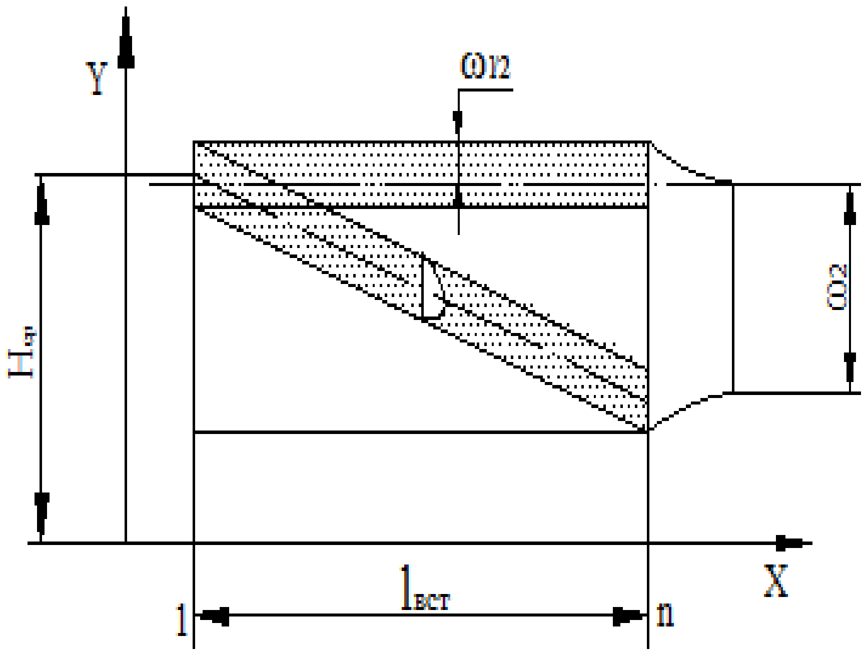

Fig. 9. A distribution curve differently altitudes of the grains located on a working ledge outlined on an Archimedean spiral.

From it is visible that the size of the field of dispersion the radius of vectors of the grains located on the surface of a ligament the cutting ledge represents the sum of sizes of the fields of dispersion generated by cumulative action of a large number of independent factors of one order of sizes in the form of differently altitude of grains on the relation of a surface of a ligament and size of shift of the middle of this field of the dispersion happening under the influence of action of the dominating factor in the form of change of radius of a vector of a surface of a ligament of a ledge it is proportional to an angle of rotation on the relation of the direction of longitudinal giving i.e. on an Archimedean spiral

$$\omega_3 = \omega_1 + \omega_2 \qquad (12)$$

where , ω_1 - is the the size of the field of normal dispersion differently altitudes of the grains from the surface of a ligament a grinding wheel which are cumulative action of a large number of independent factors of one order of sizes

ω_2 - is the size of shift of the middle of the field of dispersion differently altitudes of grains under the law of equal probability, change of the current value the ligament surface vector radius from the center of circle rotation because of an outline of the cutting ledge on an Archimedean spiral that in this case plays a role of the dominating factor

$$\omega_2 = \beta\varphi,$$

where β - is the constant coefficient;

φ – is the current polar corner in degrees.

Writing down values ω_1 and ω_2 in a formula (12) we will obtain

$$\omega_3 = (\bar{X} + 3\sigma)(1 - \varepsilon) + \beta\varphi \qquad (13)$$

The curve of dispersion represents composition of curves dispersion of normal distribution and the equal probability shown in the drawing.

Size of ω_1 can be defined from the expression

$$\omega_1 = 6\sigma_0 \qquad (14)$$

Where , σ_0 - is the average square deviation differently altitudes of grains

$$\sigma_0 = \frac{1}{6}\Delta_{\max} \approx \frac{1}{6}(\bar{X} + 3\sigma)(1 - \varepsilon) \qquad (15)$$

Where , $\Delta_{\max}$ is the layer size in the plane, perpendicular to a circumference of the circle, $\bar{X}$ is the arithmetic average value, σ -is the average square deviation differently altitudes of grains by quantity, ε is the average square deviation differently altitudes of grains by quantity.

The size of shift of the middle of the field of dispersion differently of altitude of grains under the law of equal probability is determined by a formula

$$\omega_2 = \frac{V_и D_k \varphi}{2000 V_k Z} \qquad (16)$$

Writing down values ω_1 and ω_2 from formulas (14 and 16) in a formula (13) we will receive sizes of the field of dispersion differently of the altitude of the grains located on the surface of a ledge outlined on an Archimedean spiral.

$$\omega_3 = (\overline{X} + 3\sigma)(1 - \varepsilon) + \frac{V_u D_k \varphi}{2000 V_k Z} \qquad (17)$$

The analysis of size and character of the field of dispersion differently of altitude of grains on a surface of a ledge of a faltering frontal strip of a face grinding wheel shows that at an outline of ledges on an Archimedean spiral differently altitude of the grains located on a ledge surface considerably increases, and the nature of the curve dispersion corresponds composition of curve dispersion of the normal distribution and equal probability. With increase differently in altitude of the cutting ledges, the number of actively working grains increases, there is more uniform distribution of the allowance for processing coming to a share of one ledge between active grains of a surface of a ledge, the cutting ability of a grinding wheel increases and by that the efficiency of process of grinding increases.

Method. As the abrasive tool standard grinding wheels 5C 415x85x330 with the characteristic of Э16МСМ1КВ, ЛПП 300x20x127 with the characteristic of the ЛО 12100 Б1, ЧК100x25x20 with the characteristic 14А40СМ1К and a new design of a face grinding wheel ЧК 100x25x20 with the characteristic 14А40СМ1К and ЛПП 300x20x127 with the characteristic of the ЛО 12100 Б1 with the faltering cutting part of a working surface, transition from hollows are applied to ledges on an Archimedean spiral. In quality Through-Spindle Coolant applied 3% solution of soda in water. At the same time, providing identity of all experimental conditions, only the grinding wheel changed.

The purpose of pilot studies was definition of influence of parameters of the mode of grinding on mechanisms of formation of geometrical parameters of a surface and physicomechanical properties of a layer when grinding by standard face circles and circles of a new design with the faltering cutting part of a working surface. By comparison of the received results qualitatively advantages of a new design of a grinding wheel have also quantitatively been defined.

Object of pilot studies I was operation of face grinding of flat surfaces of details on machines with back and forth motion of a detail. Prototypes of preparations have been accepted from the tempered steel 40X with a hardness of 35-40 HRC with sizes of cross section 30x20mm.

Arrangement of the task. It has been investigated: contact temperature, normal component of cutting force, roughness, and errors of a geometrical form of polished surfaces standard circles and circles of a new design.

Levels of factors and intervals of variation tabl.3

Levels of factors	Notation	$V_{k,,}$ (n в об/мин) м/сек	S_{np} , м/мин	t,в мм
Basic level	0	15,7(3000)	3	0,03
Variation interval	∇X_i	1,05	1,5	0,015
Upper	+1	16,75(3200)	4,5	0,045
Lower	-1	14,65(2800)	1,5	0,015
Star Top	+1,215	16,97575(3536)	4,8225	0,048225
Lower	-1,215	14,42425(2464)	1,1775	0,011775

Standard circle

tabl..4

v	X1	X2	X3	X1	X2	X3	Tc
1	-	-	-	12,89	1,5	0,015	720
2	+	-	-	16,75	1,5	0,015	700
3	-	+	-	14,65	4,5	0,0155	750
4	+	+	-	16.75	4,5	0.015	760
5	-	-	+	14.65	1,5	0.045	730
6	+	-	+	16.75	1,5	0.045	740

7	-	+	+	14.65	4,5	0.0455	740
8	+	+	+	16,75	4,5	0,045	820
9	-1,215	0	0	14,424	3	0,03	680
10	+1,215	0	0	16,976	3	0,03	720
11	0	-1,215	0	15,7	1,8925	0,035	699
12	0	+1.215	0	15,7	3,1	0,035	740
13	0	0	-1,215	15,7	3	0,012	730
14	0	0	+1.215	15.7	3	0,048	735
15	0	0	0	15,7	3	0,03	690

$$\hat{Y} = 3710{,}8 - 341V_k - 159V_d - 13999t + 7{,}9V_kV_d + 793{,}6V_kt + 9{,}7V_k^2 + 8{,}3V_d^2 + 36444t^2 \quad (18)$$

tabl.5

Points of the plan v	X_1	X_2	X_3	$\bar{Y}_v$	S_v^2	$\hat{Y}_v^2$	$((\bar{Y}_v - \hat{Y}_v)^2$
1	710	700	750	720	700	722	4
2	680	730	690	700	700	695	25
3	790	725	735	750	1677	738	144
4	730	750	800	760	1300	760	0
5	720	760	710	730	700	717	169
6	710	720	790	740	975	739	1
7	715	780	725	740	1900	733	49
8	865	795	800	820	1525	805	225
9	720	670	650	680	1300	703	529
10	695	760	705	720	1225	731	121
11	679	683	735	699	976	671	784
12	710	780	730	740	1300	754	196
13	760	710	720	730	700	702	784
14	715	720	770	735	925	726	81
15	680	720	670	690	700	702	144
				10954	$\sum S_v^2$ =16603	10898	$\sum = 3256$

New design tabl.6

v_i	X_1	X_2	X_3	X_1	X_2	X_3	t_n
1	-	-	-	12,89	1,5	0,015	515
2	+	-	-	16,75	1,5	0,015	510
3	-	+	-	14,65	4,5	0,0155	545
4	+	+	-	16.75	4,5	0.015	565

5	-	-	+	14.65	1,5	0.045	520
6	+	-	+	16.75	1,5	0.045	545
7	-	+	+	14.65	4,5	0.0455	535
8	+	+	+	16,75	4,5	0,045	625
9	-1,215	0	0	14,424	3	0,03	470
10	+1,215	0	0	16,976	3	0,03	525
11	0	-1,215	0	15,7	1,8925	0,035	495
12	0	+1.215	0	15,7	3,1	0,035	545
13	0	0	-1,215	15,7	3	0,012	540
14	0	0	+1.215	15.7	3	0,048	530
15	0	0	0	15,7	3	0,03	495

$\hat{Y}$ =4608-489,1V_k-150,2V_d-3686,2t+7,1V_kV_d+793,6V_kt+14,69V_k^2+8,6V_d^2+25555 t^2

(19)

tabl.7

Points of the plan v	Y_1	Y_2	Y_3	$\overline{Y}_v$	S_v^2	$\hat{Y}_v$	$(\overline{Y}_v-\hat{Y}_v)^2$
1	505	540	500	515	450	522	49
2	560	490	480	510	1900	510	0
3	525	530	580	545	924	540	25
4	550	600	545	565	924	573	64
5	565	490	505	520	1575	506	196
6	515	525	595	545	1900	546	1
7	515	520	570	535	925	530	25
8	655	600	620	625	775	615	100
9	450	510	450	470	1200	503	1089
10	505	500	570	525	1525	547	484
11	525	480	480	495	675	504	81
12	535	580	520	545	975	558	169
13	520	510	590	540	1700	502	1444
14	570	515	505	530	1225	518	144
15	475	540	470	495	1525	502	441
				7960	18148	7976	4312

On the basis of the conducted pilot researches on orthogonal planning of the second order graphic dependences of a contact temperature on grinding mode elements, in particular from the speed of cutting (fig. 4.a), feed per revolution of a circle (fig. 4.b) and depth of cutting on one pass have been constructed. The analysis of the received graphic dependences confirms adequacy of theoretical models about efficiency of a face grinding wheel of a new design.

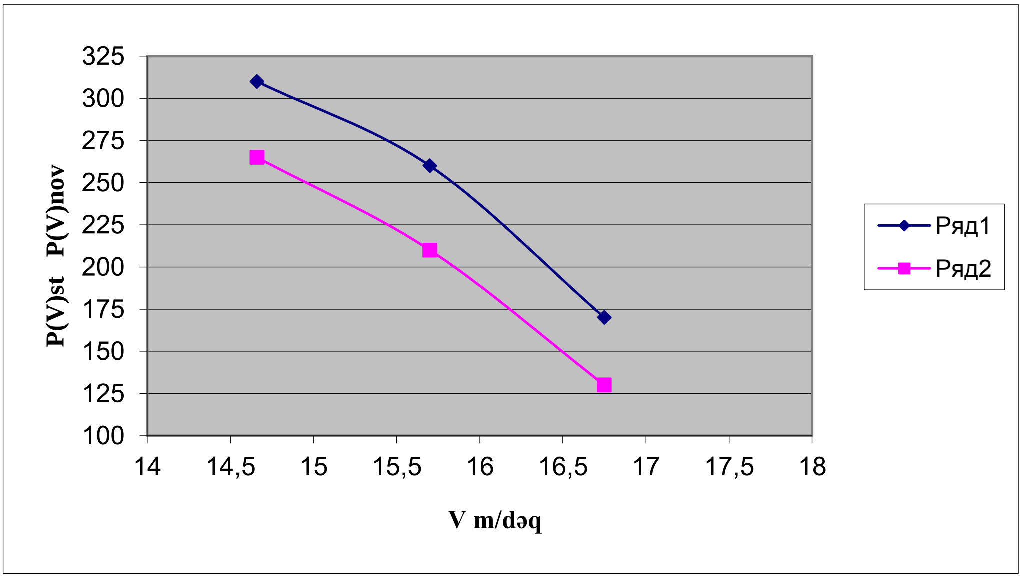

Fig. 10. Dependence of a normal component of force of cutting on cutting speed, at the processing: 1-standard circle, the 2nd circle of a new design

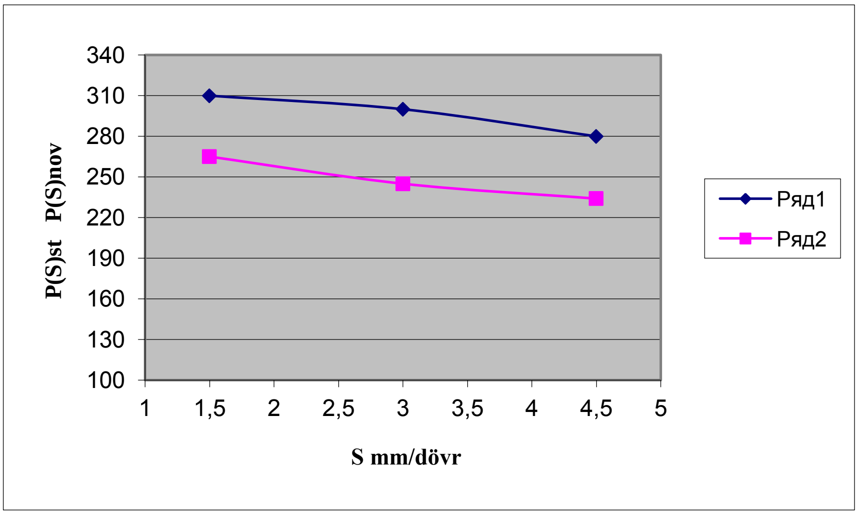

Fig. 11. Dependence of a normal component of force of cutting on giving on a turn at the processing: 1- by the standard circle, the 2 - by the circle of a new design

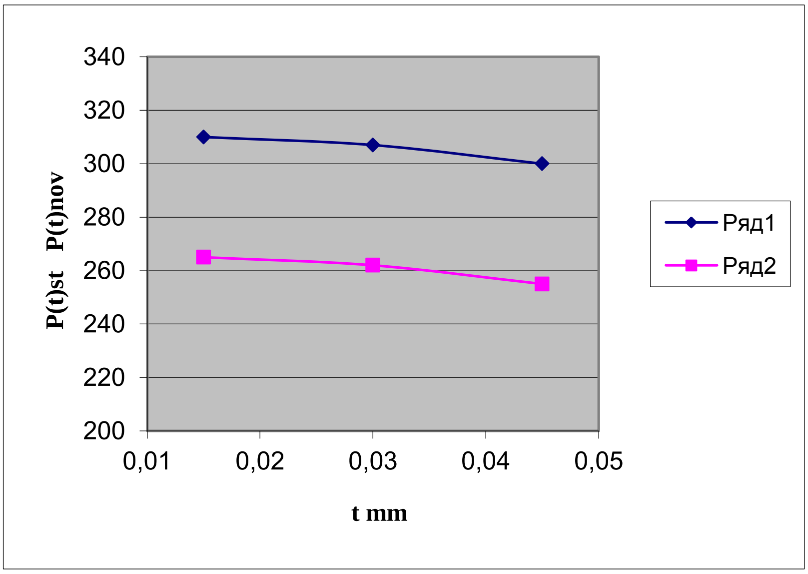

Fig. 12. Dependence of a normal component of force of cutting on cutting depth on pass, at the processing: 1- by the standard circle, the 2- by the circle of a new design

The analysis of the received models and graphical dependencies shows that initial technological prerequisites of the mode parameters influence of the grinding and intermittence of the working surface of the grinding wheel on the contact temperatures of the grinding process have found the experimental confirmation. Follows from these dependences that at the corresponding selection of a rational combination of the elements of the grinding mode decrease in temperature impact on the processed surface can achieve. When grinding with application of the new designed grinding wheel, in comparison with a standard circle, the contact temperature considerably (up to 30%) decreases. The high efficiency of a new designed grinding wheel is explained by the fact that the removed material layer evenly is distributed between working grains of a surface of a ledge, outlined on an Archimedean spiral. The received empirical models of process of grinding allow to establish the high efficiency of the new designed grinding wheel and to define a rational combination of the grinding mode elements for the identification of the basic conditions of their introduction.

Conclusion.

1. Generalizing results of the conducted researches it is established that at the mechanisms of face grinding process concealing the sufficient potential opportunities disclosing their physical essence and regularities of formation that it is possible to find the necessary design-technology solutions promoting increase in efficiency of the grinding process.

2. The new design of a face grinding wheel with the faltering cutting and spark-out parts of a continuous working surface, with transition from hollows to ledges on an Archimedean spiral is developed. The characteristic of an Archimedean spiral is the sum of two uniform motions - forward as a result of longitudinal feed of a detail and a grinding wheel, rotary by means of rotary motion, and practically provides constancy of an angle of attack of the grains located on all its length. The offered design of a face grinding wheel has been protected in the State Committee on Standardization of Metrology and the Patent of maintaining and the patent of the same name at No. 0183 is taken out.

3. It is established that creation of intermittence in cutting - the frontal zone with transition from a ledge to the hollow on an Archimedean spiral and performance continuous can raise the spark-out part of a working surface of a face grinding wheel considerably efficiency of process of grinding, way:

- decrease in temperature impact on the processed surface;
- decrease in roughness of a polished surface;
- rather uniform distribution of an allowance for a ledge between the cutting abrasive grains.
- decrease shock impact on the processed surface and by that reduction of vibrations of the MTDI technological system.

4. The technique of parametrization of a new design of a grinding wheel is developed. Analytical expression amount of actually working abrasive grains and

regularity of their distribution on an Archimedean spiral of the cutting ledge is received when grinding with a face circle of a new design;

5. By implementation of the orthogonal plan of the second order for three factors mathematical models of dependence of roughness of a polished surface on grinding mode parameters have been received: speeds of grinding, speed of a detail and depth of cutting, when grinding both standard, and a new design of a circle. The comparative analysis of graphic dependences shows that at application of a new design of a face circle reduction of roughness of a polished surface is observed considerable (up to 30%).

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Abstract. Abstract Introduction Theoretical requisites Arrangement of the task

Conclusion References

Mesoscale experiment of indentation fragmentation Mesoscale experiment principle

Macroscale experiment of indentation fragmentation Macroscale experiment principle

Macroscale experimental results and discussion

Contrastive analysis and discussion of shale indentation fragmentation Contrast analysis and discussion of LMX shale indentation hardness

Contrast analysis and discussion of LMX shale elastic modulus

Conclusion

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