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# ХАБАРЛАРЫ

# ИЗВЕСТИЯ

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**V.N. Talamanov, E.V. Khekert, R.G. Dubrovin, G.L. Kozenkova*, V.A. Kozenkov, 2024.**
Admiral Ushakov Maritime State University, Krasnodar region, Novorossiysk, Russia.
E-mail: galleon56@mail.ru

# VIBRO-ROLLING OF PARTIALLY REGULAR MICRORELIEFS FOR MINING EQUIPMENT SURFACES

**Valery Nikolaevich Talamanov** – Associate Professor, Department of Lifting and Transport Machines and Complexes, Admiral Ushakov Maritime State University, Novorossiysk, Russia, e-mail: ptmk@nsma.ru, ORCID: https://orcid.org/0000-0001-8290-8693;
**Evgeny Vladimirovich Khekert** – Vice-Rector, Admiral Ushakov Maritime State University, Novorossiysk, Russia, e-mail: zur_mga@nsma.ru, ORCID: https://orcid.org/0000-0003-0953-3949;
**Ruslan Grigorievich Dubrovin** – Cand. Tech. Sc., Associate Professor, Admiral F.F. Ushakov State Maritime University, Novorossiysk, Russia, e-mail: r.g.dubrovin@yandex.ru, ORCID: https://orcid.org/0000-0001-7316-8072;
**Galina Leonidovna Kozenkova –** Associate Professor, Admiral Ushakov Maritime University, Novorossiysk, Russia, E-mail: galleon56@mail.ru, ORCID: https://orcid.org/0000-0002-5949-459X;
**Vladimir Anatolyevich Kozenkov** – Senior Lecturer, Department of Navigation, Admiral Ushakov Maritime State University, Novorossiysk, Russia, e-mail: vl.kozenkov@mail.ru, ORCID: https://orcid.org/0000-0001-6429-1992.

**Abstract.** The irregular nature of the surface microrelief that occurs when using traditional processing methods creates serious difficulties in solving problems of microgeometry optimization. These difficulties concern reliable, scientifically based standardization, technological support, and accurate measurement and control. This is why there was a need for microrelief regularization - the process of creating a regular microrelief on the surface. Regular microrelief is especially important for parts of mining and industrial equipment operating under extreme conditions: high load, abrasive impact, vibration, high temperature. Accurate microrelief increases strength, reduces friction and improves lubrication, which extends the service life of parts. For example, regular microrelief of gear teeth ensures smooth and reliable engagement, reducing noise and vibration, and accurate microrelief of the surface of balls or rollers in bearings reduces friction and increases the service life of the bearing. Significant progress in the field of surface quality standardization was achieved after the introduction of the standard for regular microrelief. The nomenclature of parameters and characteristics of partially regular microreliefs includes the relative area occupied by regular irregularities. In this paper, we considered cases where this parameter may ambiguously describe microgeometry. To avoid ambiguity in the description of the microgeometry of a partially regular microrelief, it is necessary to observe the multiplicity of the ratio of the amplitude and axial step of regular irregularities. This ensures the necessary accuracy of the obtained dimensions during processing and guarantees the high quality of the manufactured parts.

**Keywords:** Plastic surface treatment, partially regular microrelief, vibration rolling, microrelief regularization.

**В.Н. Таламанов, Е.В. Хекерт, Р.Г. Дубровин, Г.Л. Козенкова*, В.А. Козенков , 2024.**

Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік Теңіз университеті, Новороссийск, Ресей.

E-mail: galleon56@mail.ru

## ТАУ-КЕН ТЕХНИКАСЫНЫҢ БЕТТЕРІ ҮШІН ІШІНАРА ТҰРАҚТЫ МИКРОРЕЛЬЕФТЕРДІ ДІРІЛМЕН ОРАУ

**Валерий Николаевич Таламанов** – доцент, Көтергіш-көлік машиналары және кешендер кафедрасы, Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік Теңіз университеті, Новороссийск, Ресей, e-mail: ptmk@nsma.ru, ORCID: https://orcid.org/0000-0001-8290-8693;

**Евгений Владимирович Хекерт** – проректор, Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік Теңіз университеті, Новороссийск, Ресей, e-mail: zur_mga@nsma.ru, ORCID: https://orcid.org/0000-0003-0953-3949;

**Руслан Григорьевич Дубровин –** т.ғ.к., доцент, Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік Теңіз университеті, Новороссийск, Ресей, e-mail: r.g.dubrovin@yandex.ru, ORCID: https://orcid.org/0000-0001-7316-8072;

**Галина Леонидовна Козенкова** – доцент, Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік теңіз университеті, Новороссийск, Ресей, E-mail: galleon56@mail.ru, ORCID: https://orcid.org/0000-0002-5949-459X;

**Владимир Анатольевич Козенков** – аға оқытушы, кеме жүргізу кафедрасы, Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік Теңіз университеті, Новороссийск, Ресей, e-mail: vl.kozenkov@mail.ru, ORCID: https://orcid.org/0000-0001-6429-1992.

**Аннотация.** Дәстүрлі өңдеу әдістерін қолдану кезінде пайда болатын беттік микрорельефтің біркелкі еместігі микрогеометрияны оңтайландыру мәселелерін шешуде елеулі қиындықтар туғызады. Бұл қиындықтар сенімді, ғылыми негізделген стандарттауға, технологиялық қолдауға, дәл өлшеу мен бақылауға қатысты. Тұрақты микрорельеф әсіресе төтенше жағдайларда жұмыс істейтін тау-кен және өнеркәсіптік жабдықтардың бөліктері үшін өте маңызды: жоғары жүктеме, абразивті соққы, діріл, жоғары температура. Дәл микрорельеф беріктікті арттырады, үйкелісті азайтады және майлауды жақсартады, бөлшектердің қызмет ету мерзімін ұзартады. Мысалы, беріліс тістерінің тұрақты микрорельефі тегіс және сенімді қосылуды қамтамасыз етеді, шу мен дірілді азайтады, ал мойынтіректердегі шарлардың немесе роликтердің бетінің дәл микрорельефі үйкелісті азайтады және мойынтіректің қызмет ету мерзімін ұзартады. Беттік сапаны стандарттау саласында айтарлықтай прогреске тұрақты микрорельеф стандарты енгізілгеннен кейін қол жеткізілді. Ішінара тұрақты микрорельефтердің параметрлері мен сипаттамаларының номенклатурасына тұрақты бұзушылықтар алып жатқан салыстырмалы аймақ кіреді. Бұл жұмыста біз параметр микрогеометрияны екіұшты сипаттауы мүмкін жағдайларды қарастырдық. Жартылай тұрақты микрорельефтің микрогеометриясын сипаттауда түсініксіздікті болдырмау үшін тұрақты бұзушылықтардың амплитудасы мен осьтік қадамының арақатынасының еселігін сақтау қажет. Бұл өңдеу кезінде алынған өлшемдердің қажетті дәлдігін қамтамасыз етеді және өндірілген бөлшектердің жоғары сапасына кепілдік береді.

**Түйін сөздер:** беттерді пластикалық өңдеу, ішінара тұрақты микрорельеф, дірілді айналдыру, микрорельефті реттеу.

**В.Н. Таламанов, Е.В. Хекерт, Р.Г. Дубровин, Г.Л. Козенкова*, В.А. Козенков, 2024.**

Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия.

E-mail: galleon56@mail.ru

## ВИБРОНАКАТЫВАНИЕ ЧАСТИЧНО РЕГУЛЯРНЫХ МИКРОРЕЛЬЕФОВ ДЛЯ ПОВЕРХНОСТЕЙ ГОРНО-ПРОМЫШЛЕННОЙ ТЕХНИКИ

**Валерий Николаевич Таламанов** – доцент, кафедра подъемно-транспортных машин и комплексов, Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия, e-mail: ptmk@nsma.ru, ORCID: https://orcid.org/0000-0001-8290-8693;

**Евгений Владимирович Хекерт –** проректор, Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия, e-mail: zur_mga@nsma.ru, ORCID: https://orcid.org/0000-0003-0953-3949;

**Руслан Григорьевич Дубровин** – к.т.н., доцент, Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия, e-mail: r.g.dubrovin@yandex.ru, ORCID: https://orcid.org/0000-0001-7316-8072;

**Галина Леонидовна Козенкова** – доцент, кафедра подъемно-транспортных машин и комплексов, Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия, e-mail: galleon56@mail.ru, ORCID: https://orcid.org/0000-0002-5949-459X;

**Владимир Анатольевич Козенков** – старший преподаватель, кафедра судовождения, Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия, e-mail: vl.kozenkov@mail.ru, ORCID: https://orcid.org/0000-0001-6429-1992.

**Аннотация.** Иррегулярный характер микрорельефа поверхности, возникающий при использовании традиционных методов обработки, создает серьезные трудности при решении задач оптимизации микрогеометрии. Эти трудности касаются надежного, научно обоснованного нормирования, технологического обеспечения и точного измерения и контроля. Именно

поэтому возникла необходимость в регуляризации микрорельефа – процессе создания регулярного микрорельефа на поверхности. Регулярный микрорельеф особенно важен для деталей горнопромышленного оборудования, работающего в экстремальных условиях: высокая нагрузка, абразивное воздействие, вибрация, повышенная температура. Точный микрорельеф повышает прочность, снижает трение и улучшает смазку, что продлевает срок службы деталей. Например, регулярный микрорельеф зубьев зубчатых колес обеспечивает плавное и надежное зацепление, снижая шум и вибрацию, а точный микрорельеф поверхности шариков или роликов в подшипниках снижает трение и повышает долговечность подшипника. Существенный прогресс в области нормирования качества поверхности достигнут после введения в действие стандарта на регулярный микрорельеф. В номенклатуру параметров и характеристик частично регулярных микрорельефов включена относительная площадь, занимаемая регулярными неровностями. В данной работе мы рассмотрели случаи, когда этот параметр может неоднозначно описывать микрогеометрию. Чтобы избежать неоднозначности описания микрогеометрии частично регулярного микрорельефа, необходимо соблюдать кратность отношения амплитуды и осевого шага регулярных неровностей. Это обеспечивает необходимую точность получаемых размеров при обработке и гарантирует высокое качество изготавливаемых деталей.

**Ключевые слова:** пластическая обработка поверхностей, частично регулярный микрорельеф, вибронакатывание, регуляризация микрорельефа.

**Introduction.** The surfaces of parts machined by conventional methods have irregular microrelief resulting from inhomogeneous plastic deformation of the material. This makes it difficult to optimise the surface microgeometry, which creates problems when implementing roughness standards in industry (Balanovsky, et.al., 2018; Balanovsky, et.al., 2018).

That is why the need for microrelief regularisation - the process of creating regular microrelief on a surface - has arisen. Regular microrelief is especially important for parts of mining and industrial equipment operating under extreme conditions: high load, abrasion, vibration, elevated temperature. Precise microrelief increases strength, reduces friction, and improves lubrication, which extends the life of parts (Bosikov, 2023; Brigida, 2024).

For example, regular microrelief of gear teeth provides smooth and reliable meshing, reducing noise and vibration. Precise microrelief of the surface of balls or rollers in bearings reduces friction and increases bearing life. Regular micro-relief on excavator attachments such as buckets increases durability and reduces wear when working with soil and rock. Precise micro-relief on drill bits allows more efficient passage through hard rock and reduces bit wear.

Currently, there is no machining method that would fully provide regular microrelief, which would satisfy the requirements of reliable, scientifically based standardisation, technological support, accurate measurement and control. One of the most promising methods is vibration knurling. This method is based on thin plastic deformation of surface layers of metal using special tools and vibration. The complex relative movement of the machined surface and the deforming element allows creating a regular microrelief (Konyuhov, et. al., 2019; Konyuhov, et. al., 2019; Konyuhov, et. al., 2019).

Recently, scientists have conducted many studies, laboratory and performance tests of various machine and device parts with regular microrelief, which showed that parts with regular microrelief have higher performance properties compared to parts machined by traditional methods (Kravtsov, et. al., 2023; Gutarevich, et. al., 2023; Sokolov, et. al., 2023). In the future, further development of surface treatment technologies using vibration knurling and other innovative methods may lead to the creation of new materials and parts with improved properties capable of withstanding extreme loads and extending the service life of mining and industrial equipment.

**Partially regular microreliefs.** The standardisation of the surface microgeometry must ensure that it is fully described Only then can the optimisation of the microgeometry be guaranteed and a surface that meets the specified requirements be created Unfortunately, standard surface roughness parameters are not always sufficient for a complete description of the microgeometry For a more complete characterisation of surface roughness, the apparatus of harmonic analysis is used In this case, the surface profilogram is represented as a sum of harmonics This allows to take into account not only the average roughness, but also the shape and periodicity of irregularities Significant progress in the field of surface quality standardisation has been achieved after the introduction of the standard for regular microrelief - GOST24773 (Gladkov, et. al., 2023; Gladkov, et. al., 2024; Gladkov, et. al., 2023).

The methods of formation of regular microreliefs can be divided into two groups according to their intended purpose: methods that create a partially regular microrelief on the surface, and methods that allow creating a completely new regular microrelief (Ilyushin, et. al., 2019; Klyuev, et. al., 2022; Konstantinova, et. al., 2021).

The first group includes methods that modify the existing surface microrelief, such as vibratory knurling or laser treatment. These methods improve surface properties, but do not create a completely new microrelief.

The second group includes methods that create a completely new microrelief with specified parameters, such as 3D printing or electrochemical machining. These methods give more freedom in microrelief design, but often require specialised equipment and techniques. Fig. 1 shows views of partially regular microreliefs with continuously or discretely arranged recesses, between which the microrelief of the machined surface remains intact.

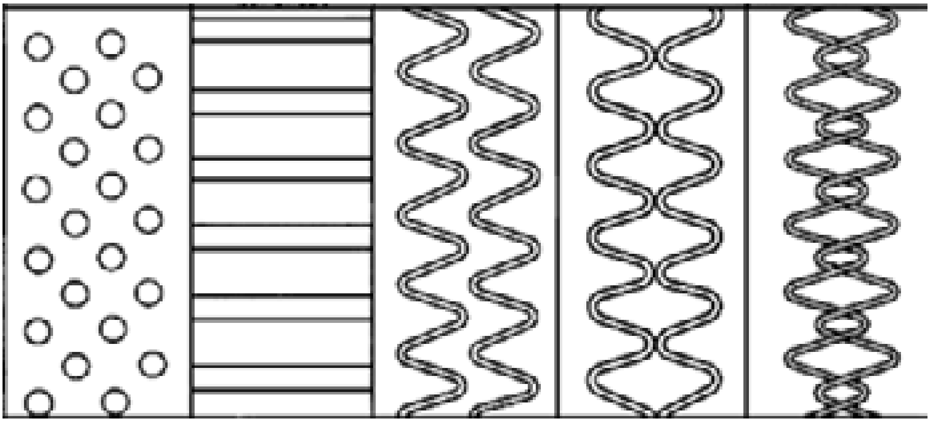


Fig 1. Types of partially regular microreliefs:
a - staggered arrangement of regular irregularities; b - circular arrangement of regular irregularities; c - no intersection of regular irregularities; d - incomplete intersection of regular irregularities; e - complete intersection of regular microreliefs.

Creation of various kinds of recesses on the working surfaces of machine parts to optimise their microgeometry, which act as 'lubrication pockets', has been practised for a long time. It allowed to increase considerably wear resistance of kinematic friction pairs. The high degree of homogeneity of microgeometry over the whole surface formed by vibro-rolling allows to characterise its microrelief by geometrical parameters keeping unambiguity over the whole working surface, instead of averaged statistical values of microrelief parameters, as it is done in GOST 2789.

However, despite the significant progress made in surface quality standardisation, due to the introduction of a standard for regular microreliefs - GOST 24773, not all parameters fully reflect the characteristics of microgeometry. For example, the parameter $F_H$ - relative area occupied by regular irregularities, ambiguously describes the microgeometry of regular microrelief (Tynchenko, et. al., 2023; Tynchenko, et. al., 2023; Tynchenko, et. al., 2024).

Consider an example: Imagine two surfaces with regular microrelief. Both surfaces have the same relative area occupied by regular irregularities ($F_H$). However, on one surface the irregularities are more densely spaced and on the other surface they are more loose. In this case, the $F_H$ parameter does not reflect the differences in the microrelief structure and does not allow an accurate assessment of the functional properties of the surfaces (Golik, 2022; Volneikina, 2023; Malozyomov, 2023).

This emphasises the need for further development of standards and methods for describing surface microgeometry, taking into account all important parameters and characteristics.

**Optimisation of partially regular microrelief parameters.** According to

GOST 24773, the parameter $F_H$ represents the expressed percentage of the area occupied by regularly spaced irregularities to the area of the treated surface. This parameter is an important indicator of surface quality and reflects the degree of regularity of microrelief. However, the determination of the $F_H$ parameter may not be as simple as it seems at first glance (Martyushev, et. al., 2023; Kachurin, et. al., 2021; Kozlova , et. al., 2023).

It is particularly important to take into account the special features of the $F_H$ parameter determination for parts of mining and industrial equipment. For more accurate determination of the $F_H$ parameter it is necessary to take into account the size of the measurement site and the axial pitch of regular irregularities. It is of interest to determine the $F_H$ parameter on a site of size $T*2A$ within the boundaries of a microrelief element at different values of the axial pitch S of regular irregularities. $T$ is the width of the microrelief element. $2A$ - length of the microrelief element. $S$ - axial pitch of regular irregularities.

By changing the value of the axial step S, it is possible to obtain different values of the $F_H$ parameter even on the same surface. This is due to the fact that at different step of irregularities the number of regular irregularities falling into the measurement area will change.

Thus, for a more accurate and unambiguous determination of the $F_H$ parameter it is necessary to take into account the size of the measurement site and the axial pitch of regular irregularities. This will allow to obtain more accurate information about surface microgeometry and provide more effective quality standardisation of mining and industrial equipment parts.

Let us consider the elements of partially regular microrelief formed by vibration rolling presented in Fig. 2 (Katryuk, et al., 2018).

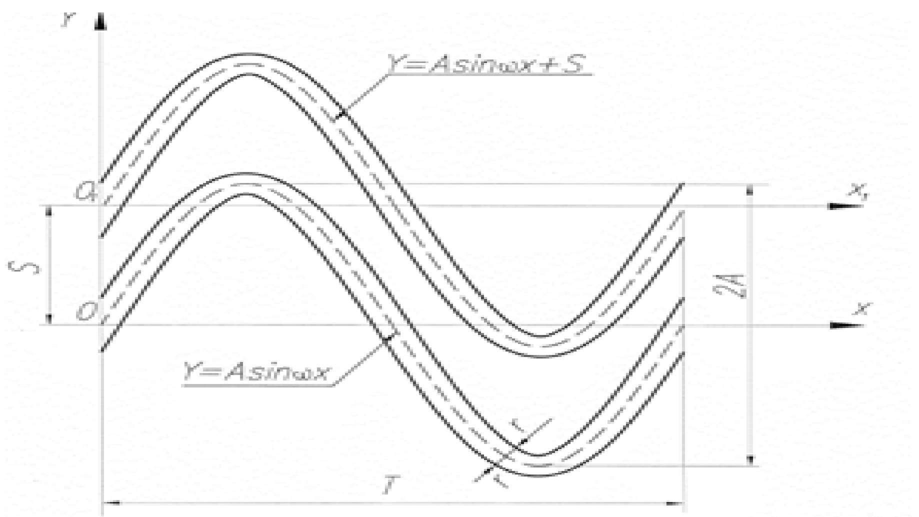


Fig.2. Elements of partially regular relief

The trajectory of the centre of the deforming element is described by the equation

$$y = A \cdot Sin\omega x$$

In order to simplify the calculation, let us assume that the upper and lower boundaries of the sinusoidal groove are described by the equation

$$y = A\sin\omega x \pm r$$

where *r* – the radius of the imprint of the deforming element on the plane.

For a neighbouring sinusoidal groove displaced by the cross feed *S*, the trajectory of the centre of the deforming element has the following form

$$y = A\sin\omega x \div S$$

Let's fix the coordinate system XOY, then the equations of trajectories of the deforming element centre are written in the form

$$y_j = A\sin\omega x + js, \quad j=0; \pm 1; \pm 2$$

Let's consider the parameter $F_H$ *on the* sites of size *T 2A,* where *T=2π/ω* at different values of cross feed *S*. Let us first have a pad

$$\Pi_0 = [(0, -A), (0, A), (T, A), (T, -A)]$$

$$S = 2\,A/k\,, k = 1,2, \ldots, [A - r] \qquad (1)$$

On the site $\Pi_0$ there are exactly to sinusoidal grooves and due to symmetry on each site

$$\Pi\tau =, (0, A + \tau), (T, A + \tau), (T, -A + \tau)$$

Hence, as a consequence, the constancy of the parameter $F_H$ at any of the sites $\Pi_\tau$.

At $2\,A/(k + 1) < S < 2\,A/k$ the symmetry is broken.

Consider this situation at *k = 2,*

$$S = \frac{4A}{2k+1} = \frac{4A}{S}$$ for sites $\Pi_0$ and $\Pi_{-0,4A}$.

Thereare two complete sinusoidal grooves and arcs of subsequent sinusoidal grooves at site $\Pi_0$

$$s - A\sin\omega x + r < A, \text{ around } x=0$$

$$A - 0{,}4A < A\sin\omega x + s < A, \text{ around } \omega x=\pi$$

$$A - 0{,}4A < A\sin\omega x + s < s\,, \text{ around } \omega x= 2\pi$$

$$A\sin\omega x + 2s < A\,, \text{ around } \omega x=3\pi/2$$

$$-A < A\sin\omega x - 2x, \text{ around } \omega x=\pi/2$$

Similarly, two complete sinusoidal grooves and the arcs of subsequent sinusoidal grooves are arranged on the $\Pi_{-0,4A}$ site.

$$-A - 0{,}4A < A\sin\omega x - 2s < -A, \text{ at } 0<\omega x<\pi$$

$$-A - 0{,}8A < A\sin\omega x + s < A - 0{,}4A \text{ at } \pi< \omega x < 2\pi$$

Taking into account the symmetry, we obtain that the area of sinusoidal grooves located on the site $\Pi_0$ is equal to

$$2r \cdot 2T + 2 \cdot 2r(2arcsin0{,}2) \cdot \omega^{-1} + 2 \cdot 2r(\pi - 2arcsin0{,}2) \cdot \omega^{-1} + \\ +2 \cdot 2r(\pi - 2arcsin0{,}6)\omega^{-1};$$

The area of sinusoidal grooves located on the site $\Pi_{-0,4A}$ is equal to

$$2r \cdot 2T + 4 \cdot 2r(arcsin0{,}6 - arcsin0{,}2)\omega^{-1}$$

Thus:

$$F_H(\Pi_0) = \frac{2r}{T \cdot 2A}(3T + T\,(2\arcsin0{,}2 - 2\arcsin0{,}6)/\pi) = \frac{r}{A}\left[3 - \frac{2}{\pi}\left(\frac{37}{300} \cdot 2\pi - \frac{11,5}{300} \cdot 2\pi\right)\right] \\ = \frac{r}{A} \cdot 2{,}71 F_H(\Pi_{-0,4A}[2T + 2T(\arcsin0{,}6 - \arcsin0{,}2) \cdot \pi^{-1}] = \frac{r}{A} \cdot 2{,}29$$

In particular, in *r=0,3 mm* и *A =2,5 mm* $F_H(\Pi_0) = 0{,}3252$

$$FH(\Pi - 0{,}4A) = 0{,}2748$$

Let us also consider the case $k = 1$ $S = 4A/3$ for sites $\Pi_0$ and $\Pi_{-2A/3}$

There is one complete sinusoidal groove and arcs of neighbouring sinusoidal grooves on pad $\Pi_0$.

$$A sin\omega x - S \leftarrow A, \qquad \text{around } x > 0$$

$$-A - \frac{2A}{3} < A sin\omega x - S \leftarrow A, \text{around } \omega x = \pi$$

$$-A - \frac{2A}{3} < A sin\omega x - S\ , \qquad \text{around } \omega x \le 2\pi$$

Hence, the area of sinusoidal grooves located on the site $\Pi_0$ is equal to

$$2\,r\,(T + 2 \cdot 2\,\frac{\pi}{2} - \arcsin\frac{1}{3}) \cdot \omega^{-1},$$

and on the playground $\Pi_{-2A/3}$

$$2r\left(T + 2 \cdot 2 \cdot \frac{1}{\omega}\arcsin 1/3\right)$$

Thus:

$$F_H(\Pi_0) = \frac{2r}{2AT}\left(2T - \frac{2T}{\pi}\arcsin\frac{1}{3}\right) = \frac{r}{A}2\left(1 - \frac{1}{\pi}\arcsin\frac{1}{3}\right) = \frac{r}{A}1{,}784$$

$$F_H(\Pi_{-2A/3}) = \frac{2r}{2AT}\left(T + \frac{2T}{\omega}\arcsin\frac{1}{3}\right) = \frac{r}{A}\left(1 + \frac{2}{\omega}\arcsin\frac{1}{3}\right) = \frac{r}{A} \cdot 1{,}216$$

In particular, in $A = 4{,}5\ r$; $F_H(\Pi_0) = 0{,}4$; $F_H(\Pi_{-2A/3}) = 0{,}266$

Based on the above calculations, we can conclude that the parameter $F_H$, reflecting the relative area occupied by regular irregularities, is one of the key parameters in describing the microgeometry of surfaces. It largely determines almost all operational properties of surfaces and affects their performance and durability. It is especially important to take into account the peculiarities of $F_H$ parameter determination for parts of mining and industrial equipment operating in extreme conditions. Precise microrelief increases strength, reduces friction and improves lubrication, which extends the life of parts.

One of the key factors affecting wear on mining equipment parts is the actual surface contact area. $F_H$ directly affects this area. The higher the $F_H$ value, the greater the contact area between the parts, which increases the strength of the joint and reduces stress concentrations in the contact areas. Another important factor affecting wear is the oil capacity of the surface. Regular micro-relief with a high $F_H$ value allows for more effective 'lubrication pockets' that retain lubricant and provide a more uniform distribution of lubricant across the contact surface. This reduces friction, prevents overheating and component wear, and increases component life.

In addition, micro-relief affects the surface's ability to keep foreign particles such as dust, sand and other abrasive particles from being carried to the contact surface. Regular micro-relief with a high $F_H$ value creates more effective 'traps' for foreign particles, which reduces abrasion and increases part life.

However, despite the importance of the parameter $F_H$, it cannot always unambiguously describe the microgeometry of a regular microrelief at the ratio of the amplitude parameter $A$ and the axial pitch $S$. This is due to the fact that the same parameter $F_H$ can be achieved with different combinations of amplitude and axial pitch.

Therefore, for a more complete description of the microgeometry of regular microrelief, it is necessary to take into account not only the parameter $F_H$, but also other characteristics, such as the shape and periodicity of regular irregularities.

**Conclusion and recommendation.**

1. The parameter $F_H$ of a partially regular microrelief most fully determines almost all operational properties of surfaces and, first of all, the actual area of contact between the surface of a solid body and another surface, the oil capacity of the surface, the ability to keep foreign particles from being carried to the contact surface

2. Such an important parameter as $F_H$ - relative area occupied by regular irregularities of an ambiguous, describes the microgeometry of a regular microrelief at the ratio of the amplitude parameter A and axial pitch.

3. To ensure unambiguous description of the microgeometry of regular microrelief by the parameter $F_H$ it is necessary to observe the multiplicity of the ratio of amplitude $A$ and axial step $S$.

**References**

Balanovsky A.E., Shtayger M.G., Grechneva M.V., Kondrat'ev V.V., Karlina A.I. Comparative metallographic analysis of the structure of St3 steel after being exposed to different ways of work-hardening. // IOP Conference Series: Materials Science and Engineering. – 2018. – 411(1). – 012012

Balanovsky A.E., Shtayger M.G., Kondrat'ev V.V., Nebogin S.A., Karlina A.I. Complex metallographic researches of 110G13L steel after heat treatment. // IOP Conference Series: Materials Science and Engineering. – 2018. – 411(1). – 012014

Bosikov I.I., Martyushev N.V., Klyuev R.V., Tynchenko V.S., Kukartsev V.A., Eremeeva S.V., Karlina A.I. Complex Assessment of X-ray Diffraction in Crystals with Face-Centered Silicon Carbide Lattice. // Crystals. – 2023. – 13. – 528. doi: 10.3390/cryst13030528

Brigida V., Golik V.I., Voitovich E.V., Kukartsev V.V., Gozbenko V.E., Konyukhov V.Y., Oparina T.A. Technogenic Reservoirs Resources of Mine Methane When Implementing the Circular Waste Management Concept. Resources. – 2024. – 13(2). – 33. https://doi.org/10.3390/resources13020033

Gladkov A., Kukartsev V., Kozlova A., Grigorev D. Development of Requirements for AIS Aimed at Controlling High Turnover. 2023 IEEE International Conference on Computing (ICOCO), 2024. https://doi.org/10.1109/ICOCO59262.2023.10397670

Gladkov A., Kukartsev V., Kozlova A., Grigorev D. Development of Requirements for AIS Aimed at Controlling High Turnover. 2023 IEEE International Conference on Computing, ICOCO 2023. https://doi.org/10.1109/ICOCO59262.2023.10397670

Gladkov A., Kukartsev V., Yarkova A., Kuzmich R., Nizameeva A. Development of an automation system for personnel monitoring and control of ordered products. // E3S Web of Conferences. – 2023. – 458. – 01007. https://doi.org/10.1051/e3sconf/202345801007

Golik V.I., Kachurin N.M., Stas G.V., Liskova M.Yu. To Nature-and Resource-saving Technologies for Underground Mining of the Complex Structure Deposits. // Bezopasnost' Truda v Promyshlennosti. – 2022. – 2022(9). – pp. 22–27. https://doi.org/10.24000/0409-2961-2022-9-22-27

Gutarevich V.O., Martyushev N.V., Klyuev R.V., Kukartsev V.A., Kukartsev V.V., Iushkova L.V., Korpacheva L.N. Reducing Oscillations in Suspension of Mine Monorail Track. // Appl. Sci. – 2023. – 13. – 4671. doi: 10.3390/app13084671

Ilyushin Y.V., Pervukhin D.A., Afanaseva O.V. Application of the theory of systems with distributed parameters for mineral complex facilities management // ARPN Journal of Engineering and Applied Sciences. – 2019. - 14 (22). - pp. 3852-3864.

Kachurin N.M., Stas G.V., Kachurin A.N. Dynamics of gas emission from exposed surface of gas-bearing coal seams having medium thickness. // Sustainable Development of Mountain Territories. – 2021. – 13(3). – pp. 441–448. https://doi.org/10.21177/1998-4502-2021-13-3-441-448

Klyuev S.V., Kashapov N.F., Radaykin O.V., Sabitov L.S., Klyuev A.V., Shchekina N.A. Reliability coefficient for fibreconcrete material. // Construction Materials and Products. – 2022. – 5 (2) . – P. 51 – 58. https://doi.org/10.58224/2618-7183-2022-5-2-51-58

Konstantinova M.V., Olentsevich A.A., Konyukhov V.Y., Guseva E.A., Olentsevich V.A. Automation of failure forecasting on the subsystems of the railway transport complex in order to optimize the transportation process as a whole. // IOP Conference Series: Materials Science and Engineering. – 2021. – 1064(1). – 012020

Konyuhov V.Y., Gladkih A.M., Semenov V.V. Measures to the improvement of efficiency of a repair enterprise. Journal of Physics: Conference Series. – 2019. – 1353(1). – 012046

Konyuhov V.Yu., Gladkih A.M., Galyautdinov I.I., Severina Y.D. Economic aspects of green technologies. IOP Conference Series: Earth and Environmental Science. – 2019. – 350(1). – 012036

Konyuhov, V.Y., Konstantinova, M.V., Gladkih, A.M. Determination of restored units spectrum of equipment and development of the assembly unit repair method at industrial enterprises. Journal of Physics: Conference Series. – 2019. – 1353(1). – 012047

Kozlova A., Kukartsev V., Melnikov V., Kovalev G., Stashkevich A. Finding dependencies in the corporate environment using data mining. // E3S Web of Conferences. – 2023. – 431. – 05032. https://doi.org/10.1051/e3sconf/202343105032

Kravtsov K., Tynchenko V., Semenova E., Shalaeva D., Pinchuk I. Workflow automation and performance improvement based on PostgreSQL. // E3S Web of Conferences. 2023. – 458. – 09022. https://doi.org/10.1051/e3sconf/202345809022

Malozyomov B.V., Martyushev N.V., Kukartsev V.A., Kukartsev V.V., Tynchenko S.V., Klyuev R.V., Zagorodnii N.A., Tynchenko Y.A. Study of Supercapacitors Built in the Start-Up System of the Main Diesel Locomotive. // Energies. – 2023. – 16. – 3909. doi: 10.3390/en16093909

Martyushev N.V., Bublik D.A., Kukartsev V.V., Tynchenko V.S., Klyuev R.V., Tynchenko Y.A., Karlina Y.I. Provision of Rational Parameters for the Turning Mode of Small-Sized Parts Made of the 29 NK Alloy and Beryllium Bronze for Subsequent Thermal Pulse Deburring. // Materials. – 2023. – 16. – 3490. doi: 10.3390/ma16093490

Sokolov A.A., Orlova L.G., Bashmur K.A., Kuzmich R.I., Kukartsev V.V. Ensuring uninterrupted power supply to mining enterprises by developing virtual models of different operation modes of transformer substations. // Mining Informational and Analytical Bulletin. – 2023. – 11. – 278-291. https://doi.org/10.25018/0236_1493_2023_111_0_278

Tynchenko V., Kukartsev V., Shalaeva D., Zdrestova-Zaharenkova S., Dzhioeva N., Moiseeva K. Development of Automated Control System of Electron-Beam Welding Process. // Lecture Notes in Networks and Systems. – 2023. – 596. – 484-490. https://doi.org/10.1007/978-3-031-21435-6_42

Tynchenko V.S., Tynchenko Y.A., Rogova D.V., Leonteva A.A., Seregin Y.N., Bocharov A.N. Energy distribution computation for induction soldered construction elements. // AIP Conference Proceedings. – 2023. – 2700. – 070017. https://doi.org/10.1063/5.0125008

Tynchenko Ya.A., Kukartsev V.V., Gladkov A.A., Panfilova T.A. Assessment of technical water quality in mining based on machine learning methods. // Sustainable Development of Mountain Territories. – 2024. – 16(1) . – 56-69. https://doi.org/10.21177/1998-4502-2024-16-1-56-69

Volneikina E., Kukartseva O., Menshenin A., Tynchenko V., Degtyareva K. Simulation-Dynamic Modeling Of Supply Chains Based On Big Data. 2023 22nd International Symposium INFOTEH-JAHORINA, INFOTEH 2023. https://doi.org/10.1109/INFOTEH57020.2023.10094168

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