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PURPOSE AND TECHNOLOGICAL PROPERTIES OF GRANULAR MEDIA FOR VIBRATION FINISHING AND GRINDING PROCESSING

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Abstract. *The purpose and characteristics of granular working media used in vibration processing operations are given. It is indicated that the purpose of granular media is their contact interaction with the processed part surface under conditions of various energy parameters. This interaction is accompanied by elastic-plastic deformation, micro-cutting, adhesion and mechanic-chemical processes. Indicators of technological and operational properties for various types of granular media are given, including the intensity of material removal from the processed surface, cutting ability, wear resistance and achieved surface roughness. The physical and technological parameters of granular media have been established, including deformability, hardness during finishing and hardening operations and surface roughness of the media granules. The influence of the parameters of processing media granules on the productivity of vibration treatment has been determined. It is shown that such parameters are the binding of the granules material, its wear resistance, grain material, granulation and the shape of individual granules. It is noted that the choice of granule sizes depends on two main factors such as: the necessity to obtain a given roughness and high productivity of vibration operations. It was revealed that to ensure high surface cleanliness, the use of small granules of the medium is required, but to obtain high productivity, the use of large granules is required. Approximate dependencies have been determined that relate the size and weight of granules of the processing medium and the processed parts. It is indicated that the best results in achieving high quality of the processed surface and sufficient productivity are provided by granular media with a shape close to a sphere. It is noted that granules in the form of cones, pyramids, prisms and other forms are used for the successful processing of hard-to-reach places in the form of small holes, straight and sharp angles in the interface of the surface of parts, niches or pockets. Such granules are specially manufactured from a mixture of grinding powders of various grain sizes and an inorganic binder based on clays. The features of the physical and technological parameters of processing media are given.*

Key words: *vibration treatment; granular medium; processed parts, physical and technological parameters; productivity of vibration processing.*

1. GENERAL PROVISIONS

In metalworking industries, the granular media are used for finishing and grinding processing of various range parts during various types of vibration treatment [1, 2]. The technological operations include cleaning, washing, finishing-grinding, polishing, hardening and drying ones. Table 1 provides some examples of the use of granular media for various vibration finishing and grinding operations in production processes for the manufacture of parts [3].

2. PURPOSE AND CHARACTERISTICS OF GRANULAR MEDIA

The general purpose of granular media is to carry out contact interaction with the processed surface of parts under conditions of various energy parameters, accompanied by elastic-plastic deformation, micro-cutting, as well as adhesive and mechanic-chemical processes [4].

Table 1

Application of Granular Media for Vibratory Finishing-grinding Operations

№	Vibratory finishing and grinding operations	Composition and characteristics of processing medium granules, granulation
1	Cleaning castings from molding materials, removing flash and scale	Steel and cast iron sprockets, 15...50 mm
		Steel die-cut, 5...20 mm
		Mixture of sprockets and steel die-cuts with grinding wheels, 15...25 mm
		A mixture of scrap grinding wheels of various hardness
		Cast sprockets
		A mixture of mineral ceramic granules TsM-332 with grinding powder
		Mixture of steel balls and abrasive powder, 3...8 mm
2	Deburring with a base thickness of 0.15...0.2 mm, rounding of sharp edges, rough and fine grinding to $R_a = 0.32$ μm	Scrap waste from abrasive and grinding wheels, 8...40 mm
		Mineral ceramic grinding granules TsM-332, 8...25 mm
		Die cutting, chopped wire, needles, 3...15 mm
		Mixture of mineral-ceramic granules with abrasive powder, 8...25 mm

		Porcelain balls, 6...10 mm
		Glass balls, 2...14 mm
		Metal stamping with added abrasive materials
3	Polishing, glossing, finishing, hardening, stabilizing treatment	Polished steel balls 100Cr6 (DIN 17230), 3...6 mm
		Wooden cubes, felt wads, leather scraps, nut shells with the addition of polishing pastes
4	Washing parts from various types of contaminants	Rubber granules, 5...15 mm
5	Drying parts after cleaning and rinsing	Wood chips, crushed corn cobs

To carry out the mentioned technological operations, the granular medium must have certain technological properties. According to the above classification, each type of granular media is characterized by certain indicators of technological and operational properties. In particular, for abrasive granules hey are:

– intensity of material removal from the processed surface;

– cutting abilities;

– wear resistance;

– roughness of the processed surface.

The concept of “material removal rate” is measured in weight or volume units of material removal over a certain period of time [1–3].

Cutting ability is characterized by the ratio of the mass of material removed from a unit of surface per unit of time:

$$R = \frac{\sum_{i=1}^{S} Q_i}{t \sum_{i=1}^{S} S_{q_i}},$$

where Q_i – removal of material from the sample; S_{q_i} – sample surface area, cm^2; t – processing time, min.

The specific consumption of abrasive granules is the difference in mass or volume of consumed abrasive per unit time before and after processing, that is:

$$J_m = M_o - M_k ,$$

where J_m – mass of worn abrasive; M_o and M_k – mass of abrasive granules before and after treatment.

The processing coefficient (specific material removal) is characterized by the ratio of the mass of material removed from a unit surface of the sample to the mass of the consumed abrasive:

$$K_0 = \frac{\sum_{i=1}^{S} Q}{J_m \sum_{i=1}^{S} S_{q_i}} .$$

The wear resistance of abrasive granules is the ratio of the mass of worn material per unit time to the initial mass of the processed granules, expressed as a percentage:

$$J_{\text{sp.}} = \frac{J_m}{M_o} 100\% .$$

An important parameter of abrasive granules is the roughness of the processed surface, including the established roughness. It represents the surface roughness formed under constant processing conditions over a period of time, after which no change in roughness occurs [5].

3. PHYSICAL AND TECHNOLOGICAL PARAMETERS OF GRANULAR MEDIA

For metal granular media, important parameters are: deformability; hardness when performing finishing and hardening operations; roughness of the working surface of the medium granules [1].

When performing finishing operations, especially hardening ones, the durability of metal granules, maintaining the integrity of the working surfaces and their roughness, that is, the absence of chips, chipping, cracks, etc., becomes important. The presence of the mentioned defects may be accompanied by damage to the processed surface and deterioration of its relief.

For metal granules, the density of the material is essential. As the density of the granule material increases, the processing intensity increases due to an increase in the contact forces of interaction between the granules and the surface being processed. In addition to steel balls, granules from non-ferrous metals and alloys, as well as cast iron, are used as metal granules.

Depending on the material, non-metallic granular media are divided into polymer and organic. The polymer are used in washing operations, applying mechanic-chemical coatings, etc. The granules of these media must be oil- and water-resistant, acid- and alkali-resistant. They must have sufficient hardness and wear resistance under abrasion conditions. Examples include granules of polystyrene, fabric-based laminate, rubber, polyurethane and others. Granules made from materials of organic origin are used in the operations of washing, drying and lapping, fine surface finishing, and applying mechanic-chemical coatings. These media are often saturated with various types of pastes and powders in order to increase mass and impart polishing properties [6].

A distinctive feature of granules of organic origin is their low density, leading to a decrease in the intensity of the process. As a result, they resort to making the granules heavier by "interspersing" metal bodies of various shapes into them.

Pasty abrasive media is a flexible tool used for processing of complex surfaces, internal channels and grooves. In terms of content, it is a viscoelastic polymer filled with abrasive. The processing operations are carried out by moving the medium relative to the surface being treated.

The paste-like abrasive medium consists of a plastic semi-solid binder and abrasive grains. The pressure of the moving medium is 65 ... 2060 N/cm^2. Materials with different mechanical properties can be subjected to this treatment.

Silicon carbide, boron carbide, aluminum oxide, and diamond are used as abrasive grain materials. Grains ranging in size from 5 to 1525 μm are used. With the use of a large-grain abrasive, the processing intensity increases, while a smaller-grain abrasive helps reduce surface roughness and provides access to small-diameter holes.

The depth of micro-cutting when processing with abrasive paste depends on the applied pressure, the density of the paste and the size of the abrasive grains.

During the processing, the abrasive granules are destroyed and dulled, and the ground material becomes part of the abrasive medium.

The service life of the paste depends on a number of factors:

– initial amount of paste when loading;

– type and size of abrasive grains;

– paste flow speed;

– part configurations.

4. INFLUENCE OF GRANULAR MEDIUM PARAMETERS ON VIBRATION PROCESSING PRODUCTIVITY

In the practice of vibration treatment, it has been shown that its performance is influenced by such parameters of the granular medium as the binding of the granule material, its wear resistance, grain material, granulation and the shape of individual granules [3].

The bond of abrasive materials can be different - ceramic and made on the basis of organic binders (phenolic resin plastic, vulcanite, etc.).

Its effect on the vibration treatment process is similar to the effect of grinding wheels when grinding metal products on machine tools and consists in facilitating chipping of dull grains.

Research has shown that when using a ceramic binder, it is possible, by changing the size of the granules and processing modes, to obtain the necessary results, practically eliminating vibration processing with granules made on the basis of organic binders. This made it possible to use any high-performance chemically active solutions during all vibration operations [7]. When using granules only with a ceramic binder, the range of granular media used in vibration processing areas is significantly reduced, that makes it easier to organize the work of the workshop.

The hardness of the binder provides the necessary wear resistance of abrasive granules. With excessively soft ligaments, rapid destruction of granular media occurs and the accompanying clogging of the reservoir, which leads to a decrease in the productivity of vibrating machines.

From the point of view of wear of granular media, media with granule hardness VT and CT should be considered the most rational. However, when working with them, the surface may become greasy, which can be eliminated by using special working solutions [8].

Granular mineral ceramic media from the TsM-332 (microlite) brand are more resistant to abrasion. Their wear resistance compared to granules of hardness M is 200...350 times higher.

The material of the granular medium during vibration treatment has a relatively insignificant effect on both the metal removal and the resulting micro-roughness of the processed part. The interaction forces during vibration processing are insignificant, so there is practically no destruction of grains. The wear of the medium granules occurs mainly due to the chipping of grains from the binder. This effect ensures self-sharpening of the grinding bodies during processing.

The grain size of the granular processing medium has a great effect on metal removal and the micro-roughness of the obtaned surface in various vibration processing operations.

The granulation of the processing medium, in combination with the modes and its circulation in the vibrating machine reservoir, is one of the main factors determining the amount of metal removed from the surface of parts per unit of time. Metal removal depends not only on the size of the granules, their shape, weight and processing modes, but also on the design, sizes, material and weight of the processed part [9].

In many cases, it is possible to prescribe the required granulation of the processing medium with sufficient accuracy for practice without additional experiments. However, these decisions are often preliminary; they require redetermination when adjustment the technological process of vibration treatment, depending on the constructive features of the parts being processed. First of all, such features include the presence of pockets, small-diameter holes, grooves and other elements that make it difficult for granules to access the treated surfaces.

Therefore, when choosing the granulation of processing media, the shape and material of their granules, the type of technological process, the required productivity, design and final cleanliness of the surface of the processed parts are taken into account. The most widespread granulation of processing media is in the range of 3...50 mm [10].

The choice of granule sizes depends on two main factors: the need to obtain a given roughness and high productivity of vibration operations. To ensure high surface cleanliness, the use of small granules of the medium is required, and to obtain high productivity, large granulations are required. In addition, it is necessary to take into account that metal removal depends on the number of granules that are simultaneously placed on the processed part surface and strike it simultaneously or with a slight lag.

There is no direct proportionality between the size of the medium granules and metal removal. With small granulation, the number of impacts increases, while the force of interaction between the granules and the part decreases. In some cases, metal removal by medium-weight granules turns out to be higher than by heavy-weight granules.

It has been established that the dimensions and weight of the granules of the processing medium and the processed parts are interconnected by the following approximate dependencies:

$$\frac{P_{\text{part.}}}{P_{\text{gran.}}} > 30\,; \quad L_{\text{gran.}} = \frac{l_{\min}}{5}\,,$$

where $P_{\text{part.}}$ and $P_{\text{gran.}}$ – weight of the part and granules; $L_{\text{gran.}}$ – medium granule size; $l_{\min}$ – the smallest linear dimension of the part.

The shape of the granules of the processing medium is extremely diverse. It can vary from sharp-edged crap of grinding wheels and granules made of TsM-332 (microlite) material with sharp edges to well-rolled granules of spherical or elliptical shape. In the initial stage of work, when the granules still have sharp edges, marks and nicks may appear on the parts. To achieve high grades of surface cleanliness of the processed part, it is necessary to use either granules that have worked in rough operations for a time sufficient to round off sharp edges, or to specially process them until the sharp spots are rounded off.

The best results in achieving high quality of the processed surface and sufficient productivity are provided by granular media with a shape close to a sphere. The main disadvantage of such granules is the impossibility of processing hard-to-reach places in the form of small holes, straight and sharp corners in the mating surfaces of parts, niches, and pockets. In these cases, specially made granules are used in the form of cones, pyramids, prisms and other shapes. To improve their cutting properties, such granules are made from a mixture of grinding powders of various grain sizes and an inorganic binder based on clays.

5. CONCLUSIONS

1. An important condition for the implementation of the vibration treatment process is the presence of a granular processing medium. In domestic and foreign practice, it has been established that medium granules have a decisive effect on achieving surface quality and process productivity.

2. The choice of granular medium is made depending on the purpose of the operation being performed, the material and configuration of the processed part, as well as the vibration processing method used.

3. When choosing granular media, it is necessary to take into account the requirement for the quality of the surface being processed and the minimum cost of the treatment process, limiting the range of granular media for the purpose of ease of acquisition, preparation for use, as well as sorting and storage in metalworking production conditions.

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ПРИЗНАЧЕННЯ ТА ТЕХНОЛОГІЧНІ ВЛАСТИВОСТІ ГРАНУЛЬОВАНИХ СЕРЕДОВИЩ ДЛЯ ОЗДОБЛЮВАЛЬНО-ЗАЧИЩУВАЛЬНОЇ ВІБРАЦІЙНОЇ ОБРОБКИ

Анотація. *Наведено призначення та характеристика гранульованих робочих середовищ, що використовуються на операціях віброобробки. Вказано, що призначення гранульованих середовищ полягає в їхній контактній взаємодії з оброблюваною поверхнею деталі в умовах різних енергетичних параметрів. Така взаємодія супроводжується пружнопластичною деформацією, мікрорізанням, адгезійними та механохімічними процесами. Наведено показники технологічних та експлуатаційних властивостей для різних видів гранульованих середовищ, серед яких інтенсивність зйому матеріалу з оброблюваної поверхні, різальні здібності, зносостійкість, досягнута шорсткість поверхні. Встановлено фізико-технологічні параметри гранульованих середовищ, у тому числі деформаційну здатність, твердість при виконанні оздоблювально-зміцнювальних операцій, шорсткість поверхні гранул середовища. Визначено вплив параметрів гранул обробних середовищ на продуктивність вібраційної обробки. Показано, що такими параметрами є зв'язка матеріалу гранул, його зносостійкість, матеріал зерна, грануляція та форма окремих гранул. Зазначено, що вибір розмірів гранул залежить від двох основних факторів: необхідності отримання заданої шорсткості та високої продуктивності вібраційних операцій. Виявлено, що для забезпечення високої чистоти поверхні потрібно застосування гранул середовища малих розмірів, а для отримання високої продуктивності застосування гранул великої грануляції. Встановлено орієнтовні залежності, що зв'язують розміри та вагу гранул обробного середовища та оброблюваних деталей. Вказано, що найкращі результати досягнення високої якості обробленої поверхні та достатньої продуктивності дають гранульовані середовища за формою близькі до сфери. Зазначається, що для успішної обробки важкодоступних місць у вигляді дрібних отворів, прямих та гострих кутів у поєднанні поверхні деталей, ніш, кишень використовуються спеціально виготовлені із суміші шліфувальних порошків різної зернистості та неорганічної зв'язки на основі глин, гранули у вигляді конусів, пірамід, призм та інших форм. Надано особливості фізико-технологічних параметрів обробних середовищ.*

Ключові слова: *віброобробка; гранульоване середовище; фізико - технологічні параметри; продуктивність віброобробки.*