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REGULARITIES OF VIBRATION FINISHING AND GRINDING PROCESSING AND DIRECTIONS OF IMPROVEMENT OF ITS INTENSITY AND QUALITY

Abstract. *The data on the labor intensity of manufacturing engineering products and the share of finishing and grinding operations in the total labor costs of their manufacture are presented. The list and the degree of mastering the technological operations of finishing and grinding processing, performed in the conditions of machine-building industries during the last years are given. The grounds are given for highlighting the method of vibration processing as the most promising for ensuring complete mechanization of the process of finishing and cleaning, as well as achieving high technological characteristics of the surface roughness of parts. An assessment was made of the influence of modes, the trajectory of the movement of the reservoir and the grain size of the granules of the abrasive medium on metal removal. It is indicated that the intensity and quality of vibration treatment is estimated quantitatively by the weight removal of metal and qualitatively by the roughness of the processed surface. It is indicated that the determining factor in this case is the speed of the oscillating movement of granules and parts, the difference of which represents the speed of vibration processing, depending on the speed of the oscillating movement of the medium. It is noted that in order to increase the productivity of the process, it is necessary to increase the speed of the medium by increasing the frequency and amplitude of the reservoir oscillations. The layer-by-layer transmission of a force impulse from the bottom of the reservoir to the bulk medium is considered. The physical meaning of increasing productivity by increasing the amplitude of the reservoir oscillations is indicated. The conditions for obtaining metal removal are indicated, which provide increased efforts for the interaction of granules with parts at high micro-cutting speeds. Experimental studies are described to determine the influence of the amplitude and frequency of oscillations on the results of vibration finishing and grinding. Graphic dependences of metal removal were obtained for various ratios of the sample weight to the weight of the medium granule. The dependence of metal removal on the ellipticity coefficient and the amplitude of the reservoir oscillations was obtained in a similar way. It is noted that the vertical component of the amplitude during in-plane oscillations of the reservoir is the determining factor of the complex influence of the parameters of the ellipse coefficient of the trajectory of the reservoir and its amplitude of oscillations. It has been established that when using a coarse-grained abrasive, the penetration of grains into the metal of the part occurs to a greater depth and larger metal chips are removed with a large metal removal. With a small grain size of the abrasive, small chips are removed with a small metal removal and a decrease in the height of micro-roughness.*

Keywords: *vibration treatment; technological capabilities; intensity and quality; amplitude and frequency of oscillations; trajectory of the reservoir; metal removal; ellipse coefficient; granularity of the medium material.*

With the growth of production volumes and the requirements for the quality of products of mechanical engineering and instrumentation, there is a constant increase in the volume of finishing and grinding processing.

It is known from domestic and foreign experience that at the present stage, the share of finishing and grinding processing reaches 10 ... 20 % of the total labor intensity of manufacturing parts. In some cases, for example, in the manufacture of parts from materials that are difficult to machine by cutting and pressure processes, the labor intensity of finishing and grinding operations can reach 40 – 70 % of the labor costs for manufacturing the part [1].

The technological operations of finishing and grinding processing include: deburring; removal of flash and grata; edge rounding; surface cleaning from scale, corrosion; molding sand residues; grinding and polishing to give shade and shine, etc. [2].

Studies of various types of finishing and grinding processing have made it possible to establish the degree of their development in the metalworking industry in the recent period. These data are as follows: vibration treatment – 23 %; jet-abrasive – 18 %; belt grinding – 11 %; tumbling – 6 %; polishing wheels and metal brushes – 5 %; treatment with a stream of compacted abrasive – 2 ... 3 %.

An analysis of technological capabilities and experience in practical application made it possible to single out the vibratory processing method from the variety of industrial methods of finishing and cleaning, as the most effective from the position of mechanization of manual labor while achieving high technological characteristics of surface roughness and ensuring complete mechanization of the process of vibration finishing and grinding.

Further, in order to improve the intensity and quality of vibration finishing and cleaning processing, we will evaluate the influence of the modes and trajectory of the reservoir movement, as well as of the material grain size of the abrasive medium granules on the resulting metal removal.

It is accepted that the intensity and quality of vibration treatment is estimated quantitatively by the weight metal removal from a unit surface area per unit time and qualitatively by the roughness of the processed surface [3,4].

The determining factor in this case is the speed of the oscillating movement of abrasive granules and parts, the difference of which represents the speed of vibration processing. The latter depends on the damping coefficient of the bulk medium, which in its urn is determined by its elastic properties, the thickness of the medium layer, the size and shape of the granules, the relative content of the chemically active solution in the reservoir, the internal friction in the medium, its air permeability and a number of other factors, the influence of which should be taken into account almost impossible analytically.

Obviously, to increase the productivity of the process, it is necessary to increase the speed of the oscillating movement of the medium by increasing the frequency and amplitude of the reservoir oscillations. Usually, the oscillation frequency is in the range of 1500 ... 3000 vpm and its increase is limited by the design capabilities of the vibrating machine units. Running at lower frequencies causes significant performance degradation. The amplitude of oscillations during vibration processing is selected within the range of 0.5 ... 6.0 mm. Increasing it more than 6.0 mm causes a sharp decrease in the service life of bearing assemblies of inertial vibration exciters.

The transfer of a force impulse from the bottom of the reservoir to the bulk medium is carried out in layers – from one layer to another. During vibration processing, a phase lag is observed in the movement of various layers. There may be a mode of operation in which the inner or upper layers are in suspension state, and the lower layer, falling on the surface of the reservoir bottom, again receives and transmits an impulse to the upper layer, when it has not yet completed its upward movement. Such a transfer of motion reduces productivity, since layers of abrasive granules, which are far from the walls of the reservoir, practically stop removing metal from parts [5, 6].

In this case, the most effective measure to improve productivity is to increase the amplitude of the reservoir oscillations. The physical meaning of this lies in the fact that when the reservoir moves upwards, first there is a compaction and elastic compression of the medium layers with a thickness of δ located near the wall. When the reservoir wall is moved by an amount equal to the amplitude of A, the layer is compacted and decreases by an amount Δ.

Thus, it is shifted by an amount of $A-\Delta$. The next layer will not receive an impulse if the compaction and compression of the first layer by Δ is greater than A. The same will happen with the n-th layer, when $\Delta_n \geq A$.

The force F_n of the mutual pressure of the parts and the abrasive granule is determined by the expression:

$$F_n = \varepsilon\, MA\omega^2; \qquad (1)$$

where $\varepsilon = k^2/k_1$, k and k_1 – coefficients are not constant in value; k – takes into account the damping properties of the medium and the inertia of the part; k_1 – takes into account the decrease in amplitude due to the damping of the medium. Each point of the cross section of the reservoir has its own values k and k_1, which vary depending on the distance of parts from the reservoir walls and some other reasons.

By increasing the oscillation amplitude, it is possible to transfer the force impulse to a layer of much greater thickness. According to dependence (1) at $A = 2.5$ mm we have $F_n = \varepsilon\, 2.5 \cdot 43600 = 109000$ grams.

Increasing the amplitude from $A = 1.5$ mm to $A = 2.5$ mm makes it possible to obtain a greater force than it is achieved by increasing the frequency by 1000 rpm. With an increase in amplitude to $A = 4.0$ mm,

$F_n = \varepsilon\, 4 \cdot 43600 \approx 175000$ grams, that is, the force increases by 1.7 times compared to the first case.

Thus, for the vibration grinding process, when it is necessary to remove a defective metal layer from the surface to be treated, as well as for cleaning operations, large amplitudes should be used, providing increased interaction forces between granules and parts, as well as high micro-cutting speeds along with high values of the parameters of the elastic-plastic deforming.

For finishing operations, on the contrary, large vibration amplitudes are unacceptable, since in this case it is not required to remove a significant layer of metal from the surface to be treated, but to increase its purity with a decrease in the height of micro-roughness., Therefore, the designs of vibrating machines that allow changing the amplitude and frequency of processing in a wide range receive all greater distribution [7].

It is extremely difficult to analytically determine the influence of the amplitude and frequency of vibrations on the results of grinding and polishing due to the large number of factors that affect the results of processing. This can be done more simply and accurately experimentally. The corresponding experiments were carried out on cylindrical samples of steel 45 DSTU 7809:2015 (steel 45C DIN EN 10083-2) weighing 25, 50, 100 and 300 grams. Mineral-ceramic plates weighing 10 grams were used as an abrasive medium for all experiments.

Obtained as a result of the experiment, the dependence of metal removal from 1 cm^2 of the surface of the samples on the oscillation frequency at a different ratio of the weight of Q sample to the weight of q granules of the medium is presented graphically (Fig. 1).

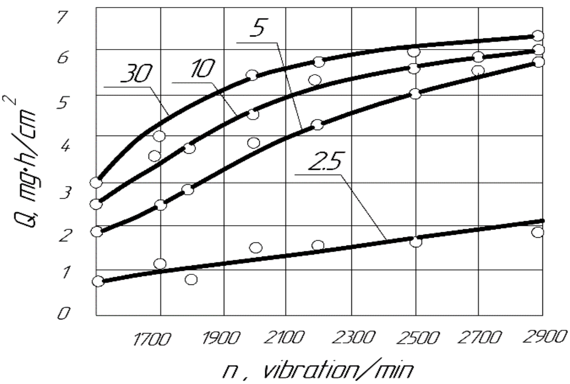

Figure 1 – Dependence of metal removal on the oscillation frequency and relationships $Q/q = 2.5; 5; 10; 30$

The difference in the removal of metal from the samples when the ratio Q/q changes from 2.5 to 30 is explained by a large decrease in the speed of movement of heavy parts when they are removed from the reservoir walls compared to light ones. This leads to an increase in the relative speed between the part and the granules and, therefore, to an increase in the efficiency of the operation.

As the frequency increases, metal removal increases rapidly at first, then slows down. This can be explained as follows. With an increase in the oscillation frequency, the impulse from the walls and bottom of the reservoir is transmitted only to the layers located near these surfaces, with a frequency corresponding to the oscillation frequency of the reservoir. The layers, however, remote from the walls and the bottom, receive an impulse of the opposite sign even before the end of the movement in the original direction. So their movement is damped [8].

The dependence of metal removal on the ellipse coefficient K_A and the amplitude A of the reservoir oscillations has been obtained in a similar way (Fig. 2). It can be considered linear within $A = 0.5...6.0$ mm.

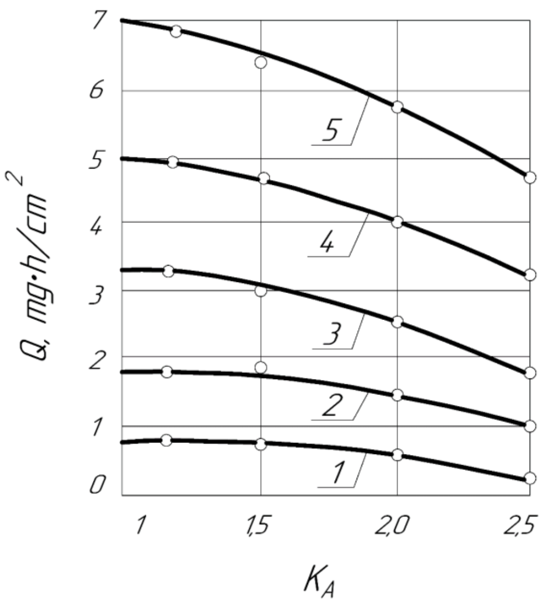

Figure 2 – Dependence of metal removal on the ellipse coefficient and the amplitude of the reservoir oscillations: 1 – $A_y = 1$ mm; 2 – $A_y = 2$ mm; 3 – $A_y = 3$ mm; 4 – $A_y = 4$ mm; 5 – $A_y = 5$ mm

The results of experiments to determine the removal of metal, depending on the grain size of the material of the granules of the abrasive medium, are presented graphically (Fig. 3).

The greatest removal of metal at all investigated amplitudes is observed at $K_A = 1.0...1.5$, and within these limits of fluctuations K_A the removal of metal changes insignificantly. This allows you to adjust the trajectory of the reservoir motion with less accuracy, which speeds up and simplifies the adjustment of vibrating machines.

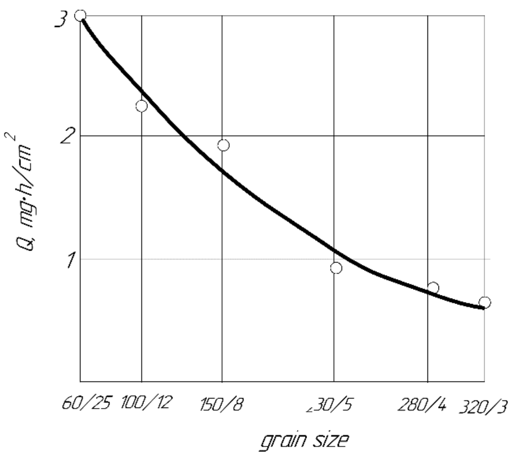

Figure 3 – Dependence of metal removal on the grain size of the material of the granules of the abrasive medium

At a value of $K_A = 2.0...2.5$, an increased number of micro-nicks are observed on the processed surfaces of parts, the depth of which reaches 0.1 mm. For grinding, the most productive modes will be those that have K_A close to unity.

The removal of metal is decreased with a decrease in the material grain size of the abrasive medium granules. This is especially noticeable in the grain size range of 2.5 ... 5.0 µm. An increase in the grain size of grinding powders in the range from 5.0 to 7.0 µm also leads to a decrease in metal removal. However, the use of fine-grained abrasive media allows to obtain a higher surface quality.

Conclusions

1. An analysis of the theoretical and experimental studies carried out showed that an increase in the frequency of oscillations, depending on the accepted ranges of its change, has a different effect on the intensity and quality of the process. However, in all cases, there is a clear tendency to increase the productivity of vibration processing with an increase in the frequency of vibrations of the vibrating machine reservoir.

2. The amplitude of the reservoir oscillations, as well as its frequency, has a significant impact on the intensity of the vibration treatment process, where the fundamental effect on the medium is the vertical component of the amplitude during in-plane oscillations of the reservoir. The conducted studies have a general tendency to increase the intensity of vibration treatment with an increase in the amplitude of vibrations of the vibrating machine reservoir.

3. Experimental studies have established that when using a coarse-grained abrasive, the number of grains in contact with the processed surface decreases. In this case, the penetration of grains into the metal occurs to a greater depth and larger metal chips are removed with a significant metal removal. With a small grain size of the abrasive, the number of contacts with the processed surface increases. This contributes to the removal of small chips and a decrease in the height of the micro-roughness of the processed surface with a small metal removal.

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ЗАКОНОМІРНОСТІ ПРОЦЕСУ ВІБРАЦІЙНОЇ ОЗДОБЛЮВАЛЬНО-ЗАЧИЩУВАЛЬНОЇ ОБРОБКИ І НАПРЯМКИ ВДОСКОНАЛЕННЯ ЇЇ ІНТЕНСИВНОСТІ ТА ЯКОСТІ

Анотація. *Наведено дані трудомісткості виготовлення виробів машинобудування та частки оздоблювально-зачищувальних операцій у загальних трудовитратах їх виготовлення. Дано перелік та ступінь освоєння технологічних операцій оздоблювально-зачищувальної обробки, що виконуються в умовах машинобудівних виробництв за останній період. Наведено підстави для виділення методу вібраційної обробки як найбільш перспективного для забезпечення повної механізації процесу оздоблювально-зачищувальної обробки, а також досягнення високих технологічних характеристик шорсткості поверхні деталей. Здійснено оцінку впливу режимів, траєкторії руху резервуара та зернистості гранул абразивного середовища на зйом металу. Вказано, що інтенсивність та якість вібраційної обробки оцінюється кількісно за ваговим зйомом металу і якісно за шорсткістю оброблюваної поверхні. Вказано, що визначальним фактором при цьому є швидкість осциляційного руху гранул і деталей, різниця яких представляє швидкість вібраційної обробки, яка залежить від швидкості осциляційного руху середовища. Відзначено, що підвищення продуктивності процесу слід шляхом збільшення частоти та амплітуди коливань резервуара збільшити швидкість руху середовища. Розглянуто пошарову передачу силового імпульсу від днища резервуара до насипного середовища. Вказано фізичне значення підвищення продуктивності шляхом збільшення амплітуди коливань резервуара. Вказано умови отримання зйому металу, що забезпечують підвищені зусилля взаємодії гранул з деталями на високих швидкостях мікрорізання. Описано проведення експериментальних досліджень щодо визначення впливу амплітуди та частоти коливань на результати вібраційної оздоблювально-зачищувальної обробки. Отримано графічні залежності зйому металу при різному співвідношенні ваги зразка до ваги гранули середовища. Аналогічним чином отримана залежність зйому металу від коефіцієнта еліпсності та амплітуди коливань резервуара. Зазначено, що вертикальна складова амплітуди при площинних коливаннях резервуара є визначальним фактором комплексного впливу параметрів коефіцієнта еліпсності траєкторії руху резервуара та його амплітуди коливань. Встановлено, що при використанні крупнозернистого абразиву проникнення зерен у метал деталі відбувається на велику глибину та видаляється більша металева стружка з великим зйомом металу. При малій зернистості абразиву відбувається видалення дрібної стружки з малим зйомом металу та зменшенням висоти мікронерівностей.*

Ключові слова: *вібраційна обробка; технологічні можливості; інтенсивність та якість; амплітуда та частота коливань; траєкторія руху резервуара; зйом металу; коефіцієнт еліпсності; зернистість матеріалу середовища.*