UDC 621.9.048 **doi: 10.20998/2078-7405.2022.96.14**

A. Mitsyk, V. Fedorovich, A. Grabchenko, Kharkiv, Ukraine

MAIN TECHNOLOGICAL FACTORS DETERMINING THE EFFICIENCY AND QUALITY OF THE VIBRATION PROCESS

Abstract. *The factors that determine the efficiency and quality of vibration treatment are indicated. Characteristic cases of interaction of abrasive granules with the processed surface are noted. The influence of the hardness of the processed part material and the shape of its surface, as well as the influence of chemically active solutions on the efficiency and quality of vibration processing, is substantiated. The characteristics of abrasive granules and their volume ratio with the processed parts are given. It is indicated that the underestimation of the possibilities of vibration processing technologies is explained by their insufficient studies. It has been established that vibration processing, depending on the characteristics and composition of the processing medium, is a mechanical or mechanochemical removal of the smallest particles of metal or its oxides and plastic deformation of microroughness due to mutual collisions of the medium granules with the processed surface, caused by vibrations of the reservoir in which the processing medium and, the processed parts are placed. It is noted that, according to the classification, vibration treatment refers to mechanical processing methods and, in particular, to the group of mechanical-chemical processing methods or to combined methods when chemically active solutions are introduced into the working medium, It is also noted that vibration treatment refers to dynamic, and for technological purposes – to dimensionless processing methods, according to the type of tool used - to the group of processing methods with a free abrasive. It has been established that the efficiency of vibration processing depends on the oscillation modes of the vibrating machine, the mass of the processed parts and abrasive granules, the hardness of the parts material and the shape of their treated surfaces, the characteristics of the abrasive medium, the volume ratio of the parts and abrasive granules, as well as on the composition of the chemically active solution. The characteristic cases of interaction of abrasive granules with the processed surface are given. The situations of the highest processing productivity for performing the operations of vibration grinding, vibration polishing, washing and descaling have been established. It is noted how the hardness of the processed part and the shape of their surface affects the performance and quality of vibration processing operations. The characteristics of the working medium, which affects the efficiency and quality of vibration treatment, are given, including the influence of grain size and hardness of the material of abrasive granules. The volume ratios of abrasive and processed parts are considered. The types of actions on the vibration treatment processes are given.*
Keywords: *vibration treatment; processed parts; vibration machine reservoir; abrasive granules; the hardness of the granule material; abrasive grain size, chemically active solution.*

Introduction.

Vibration treatment, depending on the characteristics and composition of the processing medium, is a mechanical or mechanochemical removal of the smallest particles of metal or its oxides and plastic deformation of microroughness due to mutual collisions of the granules of the medium with the processed surface, caused by oscillations of the reservoir in which the working medium and the processed parts are placed.

In accordance with the existing classification, vibration treatment refers to mechanical processing methods, and when chemically active solutions are introduced into the working medium, to combined methods, in particular, to the group of mechanical processing methods. Vibration treatment refers to dynamic processing methods, and according to the type of tool used, vibration processing belongs to the group of processing methods with a free abrasive [1].

Despite the widespread application of vibration treatment, its implementation until recently was limited to such simple operations as cleaning parts, removing burrs, and rounding sharp edges. The underestimation of the possibilities of this technological process is explained by its insufficient knowledge.

Factors affecting the efficiency and quality of vibration treatment.

The last studies carried out have included solving particular problems to identify the influence of one or a small number of factors on the processing efficiency. Comprehensive studies have shown that the effectiveness of vibration treatment depends on many factors, the main of which are:

1. Processing mode and mass of processed parts and abrasive granules.
2. The hardness of the material and the shape of the processed surfaces.
3. Characteristics of the abrasive material.
4. Volumetric ratio of processed parts and abrasive granules in the vibrating machine reservoir.
5. The composition of the chemically active solution that intensifies the processing.

Microchips are removed from the part processed surface in oscillating reservoirs, during the relative movement of parts and granules. Therefore, it is natural that the mode indicators of processing (frequency and amplitude of oscillations of the reservoir, the trajectory of its movement) have a great influence on the nature of the interaction of the mass elements loaded into the reservoir [2].

Typical cases of interaction of abrasive granules with the part processed surface.

Let us consider three most characteristic cases of the interaction of abrasive granules with the processed surface.

1. Abrasive granules and parts move in the same direction with the oscillating movement of the reservoir parallel to the surface to be processed.

In this case, the relative slip speed of the abrasive granule and the processed part, that is, the speed of processing $V_{\text{proc.}}$ will be equal to $V_{\text{proc.}} = V_{\text{p}} \pm V_{\text{gr}}$, where V_{p} is the speed of the processed part, V_{gr} is the speed of the abrasive granule.

2. Abrasive granules and parts move, as in the first case, but their relative movement is perpendicular to the processed surface. In this case, the abrasive granule collides with the processed surface at a speed of $V_{\text{proc.}}$, that is, $V_{\text{proc.}} = V_{\text{p}} + V_{\text{gr}}$.

3. The abrasive granule and the part move along a curved path, in particular, along a circle. In this case, the abrasive granule meets the processed surface at an angle or tangentially.

As can be seen from the above formulas, the relative sliding speed, which is one of the main factors for increasing the efficiency of processing, depends on the absolute values of the speeds of movement of abrasive granules and processed parts [3].

In its turn, these speeds depend on the frequency and amplitude of oscillations, the trajectory of the reservoir, as well as on the ratio of the masses of the processed parts and abrasive granules. The greater the difference in these masses, the greater the speed of mutual slippage will be. With a small difference in the masses of parts and abrasive granules, and, accordingly, a slight difference from inertia, the slip speed between them will be low, which, all other conditions being equal, will lead to a decrease in efficiency of treatment. Therefore, the efficiency of vibration treatment of parts with low mass and dimensions can be ensured by increasing the speed of the reservoir motion [4, 5].

From the analysis of the considered schemes of interaction of granules with the processed surface, the following conclusions can be drawn:

1. In the first case, the minimum amount of metal is removed, since the pressure of the granule to the part is very small and is created only by the static pressure of the medium. Obviously, such an interaction, associated with the use of the energy of the vibrational and centrifugal actions of the working medium, will be the best for performing vibration grinding and vibration polishing operations [6].

2. In the second case, the granule collides with the processed surface, as a result of which imprints of abrasive grains, chips or tearing of metal appear on it. This nature of the interaction of abrasive granules with the processed surface will be the most productive for cleaning parts with using the shock wave effect, as a result, removing scale and a defective metal layer in rough cleaning operations with a large metal removal [7].

3. In the third case, when the abrasive granule and the processed part move along a curved path, an intermediate nature of the interaction takes place.

The hardness of the processed part material.

The hardness of the processed part material affects the productivity and quality of machined surfaces. The higher it is, the shallower the abrasive grains will be introduced into the part. This reduces the removal of metal from the processed surface while reducing its microroughness [8, 9].

The shape of the processed part surface.

The shape of the surface to be processed also affects the efficiency of the process. Collisions of abrasive granules with complex elements that form grooves and recesses in parts of various types do not always occur at optimal angles. This causes a sharp decrease in productivity. Moreover, there are cases when the shape of the processed surface is such that it is impossible for abrasive granules to collide with it [10].

Characteristics of abrasive granules that affect the efficiency and quality of vibration treatment.

The most important characteristics of abrasive granules that affect the efficiency of vibration treatment include the mass, size, shape and hardness of the granules [11].

During the interaction of the medium elements in the reservoir, when a direct blow is applied by a granule to the processed surface, its force is proportional to the mass of this granule. Therefore, an increase in the latter leads to an increase in the amount of metal removed. A significant increase in the mass of the abrasive granule can cause a deterioration of the quality of processing, as well as a decrease in the slip speed. A detailed study of this issue made it possible to draw a general conclusion: abrasive granules with an extremely large mass should be used for rough cleaning operation, and for finishing operations, with a relatively small mass.

The dimensions of the granules are related to their weight. Therefore, in the general case, the recommendations for their choice are similar to the previous ones. However, often the sizes of abrasive granules are chosen so as to ensure their access to closed or semi-closed surfaces to be processed. In addition, there are cases when the processing of individual surfaces is undesirable. Then the sizes of the granules are chosen so that they do not collide with such surfaces.

The forms of abrasive granules do not have a noticeable effect on the efficiency of vibration treatment. But with difficult access of abrasive granules to the processed surfaces, it becomes necessary to select a rational form of granules in order to ensure processing [12].

Grain size of the abrasive material.

The grain size of the abrasive material is largely reflected in both the quality and productivity of processing. When using a coarse-grained abrasive, the number of grains in contact with the processed surface is significantly reduced. In this case, other things being equal (in particular, at the same pressure), the penetration of grains into the metal occurs to a greater depth and larger metal chips are removed.

With a small grain size, the number of contacts with the surface increases sharply, but the penetration of grains occurs at a shallow depth. This contributes to the removal of small chips and a decrease in the height of micro-roughness [13].

The hardness of the abrasive granules material.

The hardness of abrasive granules is one of the main characteristics that have a significant impact on the efficiency of the vibration process. During vibration processing, the volume of the abrasive filler loaded into the reservoir, as a rule, exceeds the volume of the processed parts. In this regard, the granules in the process of treatment come into contact with each other more often than with parts. This causes increased wear of the abrasive due to its abrasion and chipping of the grains.

The appearance of wear products in the abrasive mass clogs the pores between the grains of the granules and leads to the "loading" of the abrasive, and as a result, to a decrease in its cutting properties. The flaking large abrasive grains, falling between the granule and the processed surface, leave deep imprints on the latter [14].

Volume ratio of abrasive and processed parts.

The volume ratio of abrasive and processed parts in the reservoir is largely reflected in the productivity of vibration treatment. If the number of parts in the vibrating machine reservoir is large, then the abrasive granules will be in contact with the processed surfaces of only individual parts. In this case the treatment process is implemented slowly. If the number of processed parts is small compared to the loaded mass of the abrasive, then the possibilities of the vibrating machine will not be fully used [2].

Chemically active solutions.

Chemically active solutions have different effects on the vibration treatment process. In some cases, chemical solutions, reacting with the surface layer of the metal, change its properties and thereby change the intensity of processing. Under other conditions, the components of the solution, entering into chemical reactions with the metal, form films on the processed surfaces, which are easily removed by abrasive granules. Sometimes the solutions may include additives that help restore the cutting properties of the abrasive, remove processing waste, etc. [15].

Chemically active solutions should not be complex in composition, safe for maintenance personnel and medium ally friendly when descending into industrial effluents without sludge and neutralization. The dosage of the applied solution has a great influence on the quality of processing and the productivity of the treatment. Both its insufficient and excessive amount has a negative effect on the treatment process. The use of chemically active solutions in the cutting process produces a cooling, lubricating, dispersing and washing effect.

Chemically active solutions with an acidic medium are designed for cleaning steel parts, destroying and removing scale, and intensifying grinding. Chemically active solutions with an alkaline medium are designed for rounding sharp edges and polishing. Entering into a chemical reaction with the surface of the part, they facilitate micro-cutting and plastic deformation. Solutions with a neutral medium, having a cleaning and washing ability, are intended for washing and removing wear products.

In all cases, the use of chemically active solutions of the required compositions leads to an increase in productivity and an increase in the quality of vibration processing.

Conclusions.

The development and perfection of existing technological processes of vibration treatment requires comprehensive research, taking into account the variety of factors affecting its efficiency and quality. The lack of such data is the main reason for the insufficient implementation of the vibration treatment process in the metalworking branches of mechanical engineering and instrument making.

References: 1. *Babichev A.P.* Osnovy vibracionnoj tehnologii / A.P. Babichev, I.A. Babichev. Rostov-n/D: Izdatel'skij centr DGTU, 2008. 694 p. **2.** *Kartashov I.N.* Obrabotka detalej svobodnymi abrazivami v vibrirujushhih rezervuarah / I.N. Kartashov, M.E. Shainskij, V.A. Vlasov. Kyiv: Vishha shkola, 1975. 188 p. **3.** *Mamalis, A.G., Grabchenko, A.I., Mitsyk, A.V., Fedorovich, V.A., Kundrák, J.* Mathematical simulation of motion of working medium at finishing – grinding treatment in the oscillating reservoir. The International Journal of Advanced Manufacturing Technology 70, pp. 263 – 276 (2014). https://doi.org/10.1007/s00170-013-5257-6 **4.** *Politov I.V., Kuznecov N.A.* Vibracionnaja obrabotka detalej mashin i priborov. Leningrad: Lenizdat, 1965. 125 p. **5.** *Mitsyk A.V., Fedorovich V.O.* Osoblivosti tehnologij vidalennja zadirok, skruglennja i poliruvannja gostrih kromok pri vibracijnij ozdobljuval'no-zachishhuval'nij obrobci detalej. Vazhke mashinobuduvannja. Problemi ta perspektivi rozvitku: tezi dopovidej XIX mizhnar. nauk.-tehn. konf. (m. Kramators'k, 1 – 4 chervnja 2021 r.). Kramators'k, DDMA, 2021. pp. 105 – 106. **6.** *Kundrák J., Mitsyk A.V., Fedorovich V.A., Markopoulos A.P., Grabchenko A.I.* Simulation of the Circulating Motion of the Working Medium and Metal Removal during Multi-Energy Processing under the Action of Vibration and Centrifugal Forces. Machines Vol. 9 (6) 118, pp. 1 – 22, (2021). https://doi.org/10.3390/machines9060118 **7.** *Mitsyk A.V., Fedorovich V.A., Grabchenko A.I.* The effect of a shock wave in an oscillating working medium during vibration finishing-grinding processing. Cutting & Tools in Technological System. Kharkiv, NTU «KhPI», 2020. № 93. pp. 62 – 67. http://doi.org/10.20998/2078-7405.2020.93.06 **8.** Instrument dlja obrobki detalej vil'nimi abrazivami: monografija / M.O. Kalmykov, T.O. Shumakova, V.B. Strutins'kij, L.M. Lubens'ka; Kyiv – Luhans'k: «Noulidzh», 2010. 214 p. **9.** *Lubens'ka L.M., Strutins'kij V.B., Jasunik S.M., Kalmykov M.O.,* Ozdobljuval'no-abrazivni metodi obrobki: pidruchnik. Luhans'k – Kyiv: Vid-vo «Noulidzh», 2011. 268 p. **10.** *Venckevich Gzhegozh* Vlijanie nekotoryh parametrov abrazivnogo napolnitelja na jeffektivnost' processa shlifovanija v vibrirujushhih rezervuarah: dis. … kand. tehn.

nauk: 05.02.08 / OPI. Odessa, 1986. 175 p. **11.** Obrobka u vil'nih abrazivah: monografija / Branspiz O.V., Kalmykov M.O., Jasunik S.M. Luhans'k: «Noulidzh», 2010. 318 p. **12.** Primenenie vibracionnyh tehnologij na operacijah otdelochno-zachistnoj obrabotki detalej (ochistka, mojka, udalenie obloja i zacsencev, obrabotka kromok): monografija / Babichev A.P., Motrenko P.D., Gillespi L.K. i dr.; pod red. A.P. Babicheva. Rostov-na-Donu: Izd-vo DGTU, 2010. 289 p. **13.** Otdelochno-uprochnjajushhaja obrabotka detalej mnogokontaktnym vibroudarnym instrumentom / A.P. Babichev, P.D. Motrenko, I.A. Babichev i dr.; pod red. A.P. Babicheva. Rostov n/D: Izdatel'skij centr DGTU, 2003. 213 p. **14.** Primenenie vibracionnyh tehnologij dlja povyshenija kachestva poverhnosti i jekspluatacionnyh svojstv detalej / A.P. Babichev, P.D. Motrenko, V.A. Lebedev i dr.; pod red. A.P. Babicheva. Rostov n/D: Izdatel'skij centr DGTU, 2006. 213 p. **15.** *Bereshhenko A.A.* Vibrohimicheskaja obrabotka uglerodistyh i legirovannyh stalej: dis. … kand. him. nauk: 05.17.03 / Institut obshhej i neorganicheskoj himii AN USSR. Kyiv, 1980. 132 p.

Андрій Міцик, Володимир Федорович, Анатолій Грабченко, Харків, Україна

ОСНОВНІ ТЕХНОЛОГІЧНІ ФАКТОРИ, ЩО ВИЗНАЧАЮТЬ ЕФЕКТИВНІСТЬ І ЯКІСТЬ ПРОЦЕСУ ВІБРАЦІЙНОЇ ОБРОБКИ

Анотація. *Вказані фактори, що визначають ефективність та якість вібраційної обробки. Відзначено характерні випадки взаємодії абразивних гранул з оброблюваною поверхнею. Обґрунтовано вплив твердості матеріалу оброблюваної деталі та форми її поверхні, а також вплив хімічно-активних розчинів на ефективність та якість вібраційної обробки. Дана характеристика абразивних гранул та їх об'ємне співвідношення з оброблюваними деталями. Вказано, що недооцінка можливостей технологій віброобробки пояснюється їхньою недостатньою вивченістю. Встановлено, що віброобробка в залежності від характеристики та складу оброблювального середовища являє собою механічний або механохімічний зйом дрібних частинок металу або його окислів і пластичного деформування мікронерівностей внаслідок взаємних зіткнень гранул середовища з оброблюваною поверхнею, викликаних коливаннями резервуара, в якому розміщені оброблювальні деталі. Зазначено, що згідно з класифікацією віброобробка належати до методів механічної обробки, а при введенні до складу робочого середовища хімічно- активних розчинів до комбінованих методів, зокрема до групи механохімічних методів обробки. Також зазначено, що віброобробка відноситься до динамічних, а за технологічним призначенням – до безрозмірних методів обробки, за видом інструменту, що застосовується – до групи методів обробки вільним абразивом. Встановлено, що ефективність віброобробки залежить від режимів коливань віброверстата, маси оброблюваних деталей та гранул абразиву, твердості матеріалу деталей та форми їх оброблюваних поверхонь, характеристики абразивного середовища, об'ємного співвідношення деталей та гранул абразиву, а також складу хімічно-активного розчину. Наведено характерні випадки взаємодії абразивних гранул з оброблюваною поверхнею. Встановлено ситуації найбільшої продуктивності обробки для виконання операцій віброшліфування, віброполірування, миття та очищення від окалини. Відзначено, як твердість оброблюваної деталі та форма її поверхні впливає на продуктивність та якість операцій віброобробки. Дано характеристику робочого середовища, що впливає на ефективність та якість віброобробки, у тому числі оцінено вплив зернистості та твердості матеріалу абразивних гранул. Розглянуто об'ємні співвідношення абразиву та оброблюваних деталей. Наведені види впливу на процеси віброобробки.*

Ключові слова: *віброобробка; оброблювані деталі; резервуар; абразивні гранули; твердість матеріалу гранули; зернистість абразиву; хімічно-активний розчин.*