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

INTERACTION OF THE ABRASIVE MEDIUM WITH THE TREATED SURFACE AND THE PROCESS OF METAL REMOVAL DURING VIBRATION TREATMENT IN THE PRESENCE OF A CHEMICALLY ACTIVE SOLUTION

Abstract. *Interaction of working medium granules with the processed surface of the part is considered. It is noted that the processing methods are characterized by the dynamic interaction of the abrasive medium with the processed surface. It is indicated that during vibration treatment there is an impact contact of the abrasive granule with the surface of the part, which leads to the formation of characteristic traces during the formation of the surface relief. The types of impact of abrasive grains of working medium granules on the surface of the processed part are identified. It is indicated that the effect of abrasive grains depends on the geometric parameters of the tops of the grains and the working contour of the granule as a whole. The alternation of the operation of abrasive grains in the connection with the nature of the motion of the granule over the surface of the part is shown. The interaction of surfaces of bodies during vibration treatment is considered. The distinctive features of the vibration treatment method from other analogs are indicated. The conditions for the formation of the surface layer of the part during vibration processing are given. The analysis of the mechanical-physicochemical model of the micro-cutting process in the presence of a chemically active solution is carried out and a comparison of the intensity of technologies for vibration treatment of steel parts is given.*

Keywords: *abrasive medium; types of medium action; surface layer; mechanical-physicochemical model; metal removal; chemically active solution; vibration treatment technologies.*

Introduction. Processes of treatment in abrasive media are characterized by a wide range of mechanical-physicochemical phenomena caused by various technological schemes of interaction between the medium and the treated surface, the variety of characteristics of processing media, technological chemically active solutions, and parameters of processing modes [1].

The interaction of the medium with the surface to be treated is accompanied by plastic deformation and micro-cutting, friction, thermal phenomena, chemical interaction, the manifestation of the action of electromagnetic and electric fields, and adhesion processes.

The peculiarities of the interaction of the abrasive medium and the processed parts make it possible to assess the technological capabilities of the applied processing method and its regularities. In the study of the processing of parts in abrasive media, a significant influence is given to the contact interaction of the processing medium with the processed surface, that is, to local contact and their integral manifestation in the form of deformation processes and micro-cutting, to the properties of materials contacting during processing [2].

Interaction of medium granules with the processed surface. Despite the variety of processing methods in abrasive media, there is sufficient generality in the assessment of the mechanism of interaction of medium granules with the processed surface. Most of the processing methods under consideration are characterized by the dynamic interaction of the abrasive medium with the processed surface, in which there is an impact contact of the medium granule with the surface of the part (jet-abrasive, turbulence processing, tumbling, etc.), the formation of characteristic traces of processing and the formation of the surface.

So, for example, during vibration processing, the analysis of the phenomena in the zone of the working medium granules collision with the processed surface shows that during vibration action there is an impact contact of the abrasive granule with the surface of the part. In this case, the abrasive grains of granules in contact with the processed surface carry out micro-cutting, plastic and elastic flow around the material, and the formation of many traces of processing [3].

Considering a single granule moving relative to the processed surface, it can be noted that its profile consists of grains that carry out micro-cutting, plastic and elastic repression, and grains that are not involved in the operation.

Types of action of abrasive grains on the processed surface. The nature of the action of abrasive grains on the metal depends on the geometric parameters of their tops and the working contour of the granule as a whole. Depending on the orientation of the cutting edges of the abrasive grains relative to the forming granules, there are three main types of action of the abrasive grain on the surface to be processed: cutting; plastic repression; friction. In this case, each abrasive grain in the process of treatment over time can first produce only friction, then plastic repression; and, finally, carry out cutting, and vice versa.

This alternation of operation performed by the abrasive grains of the granule is associated with the nature of its movement over the surface of the processed part. High-speed filming of the process has shown that granules can leave on the contact surface complex traces of processing, which differ in depth and location on the surface. The depth of the track changes in the direction of movement of the granule and is determined by the speed of its movement, the force and frequency of penetration during the contact time, and other factors.

Interaction of surfaces of bodies during vibration treatment. During vibration treatment, the surfaces of two bodies interact, that is, the working surfaces of an individual granule and the processed part. The nature of mechanical and physical-mechanical processes is determined by: physical and mechanical properties of cutting grains, their sizes, shape, quantity and location on the surface of the granules; characteristics of the processed material; its physical and mechanical properties, process parameters, depending on the technological mode of processing.

The vibration treatment process depends on the nature of the local contact of the "working grains" of the abrasive granule with a thin surface layer of the processed part. In the contact of parts with a mass of abrasive granules oscillating and moving along their surface, mutual intensive destruction of the surfaces of the contacting solids occurs, that is, the mutual running-in process occurs.

The nature of the dynamic loads in the contact zones of the working medium granules and parts distinguishes the vibration treatment method from other known methods [4]. The distinctive features include the following:

– grains of abrasive granules are loaded more evenly, and the depth of penetration of each of them is stable;

– the alternation of deforming and cutting grains is ensured due to the discontinuity of their interaction with the surface of the part;

– the presence of oscillations ensures a decrease in friction forces on the contact surfaces of the "granule-part" system;

– the abrasive granule, due to its small size, is reliably impregnated with a chemically active solution and ensures its supply to the zone of mutual contact of the abrasive granule with the processed surface;

– provides a decrease in micro-cutting forces and contact temperature.

Conditions for the formation of the surface layer of the part after vibration treatment. Most of the listed distinctive features are due to the self-regulation process characteristic for vibration processing, which allows a moving granule with grains embedded in the metal surface to occupy an optimal position, uniformly apply elementary traces to the surface, displaced relative to each other. This creates conditions for the formation of a more uniform surface layer, eliminates the possibility of coarse traces of destruction. It is noted that a complex spectrum of stresses arises at the points of actual contact of the bodies, micro-cutting, elastic-plastic deformation with a significant increase in the dislocation density and the formation of active dislocation-vacancy centers occur.

Due to specific patterns of vibration processing, the noted effects are distributed fairly evenly over the entire surface of the part. In general, micro- and sub-micro-relief is formed as a result of the presence of smooth areas with oxide films, rough areas formed during the destruction of the film and adhered to the surface of the smallest metal particles, as well as transition areas from smooth to rough.

It should also be noted the peculiarity of the course of the process in time. It is observed that the destruction of the material begins only after a certain period, during which preparatory processes occur, namely the formation of traces of processing, surface hardening, the initiation of micro-cracks, etc. The duration of this period depends on the physical and mechanical properties of the material and processing conditions.

In connection with the presence of the effects of multiple elastic-plastic deformation and re-deformation of sections of the processed surface, along with the process of direct fracture, the process of high-cycle plastic deformation and fracture is manifested. The processes of micro-cutting, elastic-plastic deformation, activation of the surface layer of the metal, the formation and destruction of secondary structures, poly-deformational destruction are repeated with the frequency of collision of the medium granules with the processed surface.

Mechanical-physicochemical model of the micro-cutting process in the presence of a chemically active solution and comparison of the intensity of vibration treatment technologies for steel parts. The analysis makes it possible to construct a mechanical-physicochemical model of the process of destruction of the processed surface, that is, the process of micro-cutting the material of a part, which ensures the metal removal in the presence of a chemically active solution. This model relates the parameters of metal removal and surface micro-roughness with factors affecting them and includes the following:

– shock mechanical contact, on which there is elastic, plastic, elastic-plastic deformation and destruction of the surface layer with the removal of metal particles;

– the formation of a loosened layer of active metal;

– interaction of the active metal layer with the environment, that is characterized by the formation of weakened secondary structures;

– destruction of secondary structures by subsequent impacts of medium granules;

– the formation of a specific sub-micro-relief, which is a layer of finely divided particles.

Fig. 1 shows a comparison of technological processes of vibration treatment of steel parts to high classes of surface cleanliness.

The technological process of vibration treatment of parts of carbon steels [5], as shown by curve *1* of the graph, consists of five transitions, for which the processing modes and the used abrasive material are indicated.

For example, for technological process *1*, the first transition is performed under the conditions of 25КЧ25, ВТ1, 1,5А3, where 25 is the size of the granules of the working medium, КЧ is the grain material, 25 is the granularity of the granules, BT1 is the hardness of the bond, 1.5 is the vibration frequency of the vibrating machine reservoir, thousand counts / min., A3 – vibration amplitude, mm (Ukrainian standard).

In this case, obtaining a micro-roughness of $R_a = 0.32...0.16$ μm with an initial $R_a = 20...10$ μm is achieved in 12 ... 16 hours of processing in the medium of abrasive granules of a certain granularity for each transition. The reservoir is flushed with a soap and soda solution. The final finishing of the processed surfaces is carried out with felt wads, caricatured with polishing paste.

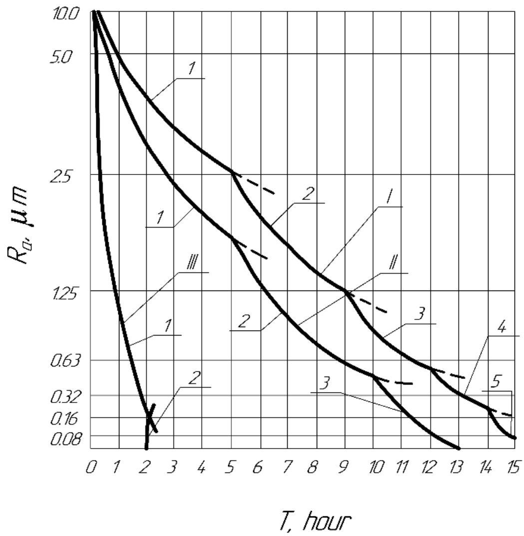

Figure 1 – Comparison of technological processes of vibration processing of parts of carbon steel: *I* – technological process of NIITM, 1, 2, 3, 4, 5 – technological transitions; *II* – ENIMS technology; *III* – technology of V. Dahl EUNU

Technology [6] offers a range of vibration grinding and polishing processes for ferrous metal parts. To obtain a surface with a micro-roughness of $R_a = 0.32$ μm with an initial $R_a = 20...10$ μm, the parts should be processed in the following sequence:

– first, in the medium of abrasive granules with a grain size of 12 ... 40 in the presence of an aqueous solution to a purity of $R_a = 2.5...1.25$ μm;

– then, in the medium t of abrasive granules with a grain size of 6 ... 10 in the presence of an aqueous solution to a purity of $R_a = 1.25...0.63$ μm;

– finally, in the medium of a special molded filler and an aqueous solution to a purity of $R_a = 0.16$ μm.

The total processing time is 12 ... 14 hours. Naturally, such complex multistage technological processes of vibration treatment have not found wide application in mechanical engineering.

The chemically active solution [7] allows to eliminate multistage overloading of the reservoir contents and to obtain a cleanliness of the treated surface of $R_a = 0.32$ μm at the initial $R_a = 20...10$ μm in one operation in the medium of abrasive granules АН-2 ТУ 2-036-02211899-007-97 (Ukrainian standard).

The second stage of processing is required only if it is necessary to obtain a purity of $R_a = 0.16...0.08$ μm.

Conclusions

1. The process of metal removal during vibration processing is characterized by the intensity of mechanical and chemical actions and the ability of the material of the processed part to resist the effects of these processes.

2. In connection with the considered model of destruction of the surface layer of the processed part the ratio of micro-cutting and elastic-plastic deformation processes is 30 ... 35 %.and 70 ... 65 %, respectively.

3. Unlike abrasive granules used as a working medium in vibration grinding operations, the interaction of metal balls used in vibration polishing operations is accompanied by elastic-plastic deformation and the formation of many processing traces.

4. The use of chemically active solutions in vibration treatment contributes to a more intensive metal removal due to the formation of loose films on the surface of parts, which are easily removed by an abrasive during processing and favorably affects the formation of the micro-relief of the processed surface. In addition, the chemically active solution has anti-corrosion properties and helps to brighten the processed surface.

References: 1. *Mitsyk A.V* Rozvytok procesiv obrobky vil'nym abrazyvnym seredovyshhem v kolyvnyh rezervuarh i formuvannja i'h fizyko-tehnologichnyh mozhlyvostej. Visnyk SNU im. V. Dalja. Sjevjerodonec'k, SNU im. V. Dalja, 2020. № 4 (260). pp. 55 – 65. DOI: https://doi.org/10.33216/1998-7927-2020-260-4-55-65. **2.** Instrumental'noe obespechenie processov obrabotki detalej v granulirovannyh sredah: monografija / A.P. Babichev, P.D. Motrenko, S.A. Kostenkov, O.A. Rozhnenko, M.A. Tamarkin, V.Ja. Shumjacher; Donskoj gos. tehn. un-t. Rostov-n/D: 2011. 267 p.

3. *Mitsyk A.V., Fedorovich V.O., Grabchenko A.I.* Mehano-fizyko-himichne modeljuvannja procesu rujnuvannja poverhni detali u vil'nomu abrazyvnomu seredovyshhi. Rizannja ta instrumenty v tehnologichnyh systemah. Kharkiv, NTU «KhPI», 2020. № 92. pp. 62 – 67. DOI: http://doi.org/10.20998/2078–7405.2020.92.08. **4.** *Babichev A.P.* Osnovy vibracionnoj tehnologii / A.P. Babichev, I.A. Babichev. Rostov-n/D: Izdatel'skij centr DGTU, 2008. 694 p. **5.** *Babichev A.P.* Vibracionnaja obrabotka detalej v abrazivnoj. M.: Mashinostroenie, 1968. 92 p. **6.** Ob'emnaja vibracionnaja obrabotka / I.E. Burshtejn, V.V. Balickij, A.F. Duhovskij, M.Ja. Dubova i dr.; pod red. I.E. Burshtejna. Moskva: JeNIMS, 1977. 108 p. **7.** *Kartashov I.N.* Obrabotka detalej svobodnymi abrazivami v vibrirujushhih rezervuarah / I.N. Kartashov, M.E. Shainskij, V.A. Vlasov. Kiev: Vishha shkola, 1975. 188 p.

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

ВЗАЄМОДІЯ АБРАЗИВНОГО СЕРЕДОВИЩА З ОБРОБЛЮВАНОЮ ПОВЕРХНЕЮ ТА ПРОЦЕС ЗНЯТТЯ МЕТАЛУ ПРИ ВІБРООБРОБЦІ В ПРИСУТНОСТІ ХІМІЧНО-АКТИВНОГО РОЗЧИНУ

Анотація. *Розглянуто взаємодію гранул робочого середовища з оброблюваною поверхнею деталі. Відзначено, що методи обробки характеризуються динамічним взаємодіям абразивного середовища з оброблюваною поверхнею. Зазначено, що при віброобробці відбувається ударний контакт абразивної гранули з поверхнею деталі, що призводить до утворення характерних слідів при формуванні рельєфу поверхні. Виділено види впливу абразивних зерен гранул робочого середовища на поверхню оброблюваної деталі. Зазначено, що вплив абразивних зерен залежить від геометричних параметрів їх вершин і робочого контуру гранули в цілому. Показано, що глибина сліду від абразивної гранули змінюється в напрямку її руху і визначається швидкістю переміщення, силою і частотою проникнення за час контакту та іншими динамічними факторами. Дано три види впливу абразивного зерна на оброблювану поверхню. Встановлено, що кожне абразивне зерно в процесі обробки з плином часу виконує тільки тертя, потім пластичне відтиснення і далі різання. Показано, що чергування роботи абразивних зерен пов'язано з характером переміщення гранули по поверхні деталі. Розглянуто взаємодію поверхонь тіл при віброобробці. Вказані відмінні ознаки способу віброобробки від інших аналогів. Дано умови утворення поверхневого шару деталі при віброобробці. Проведено аналіз механо-фізико-хімічної моделі процесу мікрорізання в присутності хімічно-активного розчину і наведено порівняння інтенсивності технологій віброобробки сталевих деталей. Показано порівняння технологічних процесів віброобробки сталевих деталей до високих класів чистоти поверхні. Визначено, що хімічно-активний розчин дозволяє усунути багатостадійні перевантаження вмісту резервуару та отримати необхідну чистоту обробленої поверхні за одну операцію віброобробки. Відзначено, що хімічно-активний розчин має корозійні властивості й сприяє освітленню обробленої поверхні.*

Ключові слова: *абразивне середовище; види впливу середовища; поверхневий шар; механо-фізико-хімічна модель; зняття металу; хімічно-активний розчин; технології віброобробки.*