DOI: https://doi.org/10.33216/1998-7927-2025-295-9-59-62

УДК 621.9.048

THE INFLUENCE OF RESERVOIR LINING MATERIAL ON THE PERFORMANCE OF PROCESSING OF PARTS WITH A COMBINED WORKING MEDIA UNDER THE INFLUENCE OF OSCILLATIONS

Romanchenko O.V. Ivchenko A.G.

ВПЛИВ МАТЕРІАЛУ ФУТЕРУВАННЯ РЕЗЕРВУАРУ НА ПРОДУКТИВНІСТЬ ПРОЦЕСУ ОБРОБКИ ДЕТАЛЕЙ КОМБІНОВАНИМ РОБОЧИМ СЕРЕДОВИЩЕМ ПІД ДІЄЮ КОЛИВАНЬ

Романченко О.В., Івченко А.Г.

This work examines the effect of the lining material of a reservoir used for processing combined free working media under the action of oscillations on the overall productivity of the surface finishing process. The method is based on the transmission of pulses from the oscillating walls of the reservoir to the working media, which creates a stable circulating flow of the abrasive media, chemical solutions, and workpieces. The relative movement of the media elements determines the metal removal rate, and the presence of passive zones within the reservoir significantly affects the uniformity of the finish processing. While the parameters of the oscillation process have been thoroughly studied in the scientific literature, the influence of the abrasive properties of the reservoir walls remains understudied, despite the widespread use of rubber coatings in industrial equipment.

This paper presents the results of an experimental study conducted on equipment with a 25-liter reservoir. Two lining configurations were investigated: a traditional lining with a rubber surface and a surface lined with silicon carbide plates. Porcelain balls and a sodium bicarbonate solution were used as the working medium. Before the main machining operation, a cleaning step was performed using a continuous water supply. After the main operation, a repeat cleaning step was performed. After machining, the mass of metal removed from the samples was assessed in a series of ten parallel tests for each lining configuration.

The data obtained showed that changing the reservoir wall roughness did not significantly affect the circulation of the working media. The use of an abrasive silicon carbide lining significantly increased process productivity – the average metal removal rate increased by 40%. The possibility of intensifying oscillating machining by using wall materials with abrasive properties without compromising the stability of the working media was experimentally confirmed. The study demonstrates the potential of using abrasive coatings to improve the machining efficiency in equipment designed for finishing with abrasive tools without a rigid kinematic connection.

Key words: *combined working media, reservoir lining, abrasive coatings; circulation motion, metal removal.*

Introduction. As is well known, the process of machining with a combined working media under oscillation involves the sequential application of multiple micro-impacts by working media granules to the surface of the workpiece. The key conditions necessary for the machining process are contact between the workpiece and the working media granules and the transfer of a force impulse from the reservoir walls to the contact zone. As a result of the transfer of impulses from the oscillation source, the reservoir oscillates, which are transmitted to the working media. As a result, a stable circulatory movement of the working media and the workpiece occurs within the reservoir. The relative movement of the workpiece and granules, therefore, determines the machining intensity. Circulatory movement occurs under certain conditions due to the effect of oscillational transport.

A large number of studies have been devoted to these issues. Theoretical models have been proposed and experimental studies have been conducted to evaluate the influence of various process parameters [1, 2].

At the same time, there are currently virtually no studies devoted to assessing the impact of reservoir wall surface characteristics on the efficiency of process operations. However, indicators characterizing the material used are used in many theoretical studies [1, 3].

This is due to the fact that in the most common and widely used equipment in production, the reservoir walls are coated with a layer of rubber, 5 to 100 mm thick 10 мм, resistant to the acidic and alkaline solutions used during processing. Studies of the geometric parameters of the reservoir wall surfaces are known, but the properties of the coating have not been considered [4].

Theoretical studies of the influence of the characteristics of the wall surface material, including the use of surface materials with abrasive properties as an additional tool, are difficult because, to date, there is no mathematical model capable of adequately describing the characteristics of the movement of the part and tool in the reservoir.

Due to the complexity and multifactorial nature of the processes being studied, significant differences in the results obtained are evident in both theoretical and experimental data. This is due to the more practical nature of the experiments.

In most studies, circulation of the working media is considered a process that ensures the movement of the part through zones with varying machining performance, thereby achieving uniform machining across the entire surface of the part. The walls of the reservoir act as a means of influencing the tool or as an additional means of limiting the movement of the part (in cases where the part is fixed using additional fixtures) [5].

However, unlike classical vibration machining, machining with a combined working media under oscillation is a more complex method. Its integrated approach allows for consideration of the shape and abrasive characteristics of the tool walls and/or additional deflectors, which influence the direction of the working media and workpiece flows. It should be noted that stable movement of the entire load during machining with a combined working media under oscillation is essential for ensuring high productivity and process determinacy. With this method, the working media movement is essentially circulatory, with additional flows that can be achieved through the use of deflectors, additional oscillation sources, or the reservoir wall parameters.

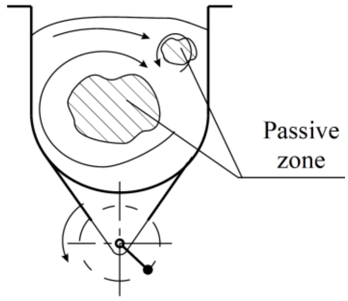

Fig. 1. Passive zones arising during processing with a combined working environment under the influence of oscillations

Ensuring uniform processing of parts throughout the entire volume of the reservoir is a complex task due to the presence of passive zones, in which the processing intensity is reduced [4]. The location of such passive zones in the center of the reservoir and its upper section is shown in Figure 1. This arrangement of these zones occurs due to a reduction in the transmitted impulse from the oscillation source to the working media, which is especially characteristic of the zone in the upper section, as well as due to a decrease in the speed of granule movement, which has a greater impact on granules in the center of the reservoir. Obviously, the angular velocity of the granules will decrease as they approach the center of the reservoir.

The dynamic trajectories of the workpiece(s), individual granules, and all granules have not yet been fully explored. Most researchers agree that the movement of the working media elements follows a spiral curve (Fig. 2, a). The workpieces also follow a spiral curve and, upon reaching the reservoir wall, move along it toward the free loading surface. They then slide toward the opposite wall and are again immersed in the working media, continuing their movement [5]. There are also studies in which the movement of granules during processing follows a trajectory resembling centroids (Fig. 2, b) [6]. As a result, under the action of inertial forces, the workpieces and granules are pressed against each other, making relative loop-like movements, gradually approaching the center of the reservoir and thus the workpieces are drawn into the passive zone.

It is necessary to take into account that the characteristics of the equipment, its operating mode and the parameters of the tool play an important role, which, as already mentioned above, are different in most studies.

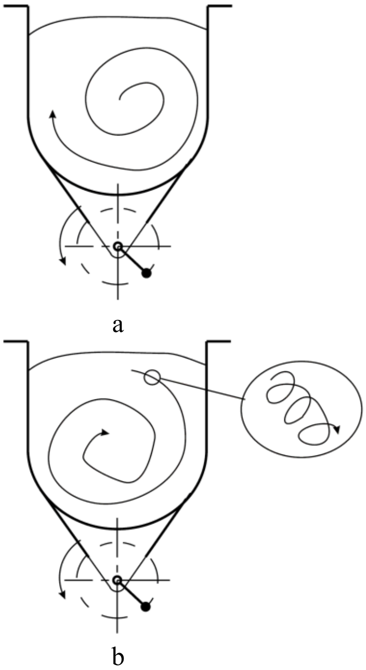

Fig. 2. Trajectories of movement
of the loading mass in the volume of the reservoir:
a – movement along a trajectory in the form of a spiral;
b – movement along a trajectory in the form of a centroid

The objective. Determining the influence of the use of abrasive material for lining the walls of a reservoir of equipment for processing a combined working medium under the influence of oscillations on the movement of the working media and metal removal.

Research results. There is insufficient research into the degree of influence of the surface characteristics of the reservoir walls, namely its abrasive properties and geometric parameters, on the processing process.

In response to the above questions, experimental studies were conducted to assess the influence of reservoir wall surface characteristics on the amount of metal removed from the workpiece surface and the movement of the working media. This study assessed the influence of the abrasive properties of the reservoir surface, using identical geometric parameters.

The studies were conducted on a UVI-25 laboratory setup in a 25-liter reservoir. The HFAA (heat-frost-acid-alkali resistant) rubber was used as the original material for the reservoir walls, and silicon carbide plates were used as the new material. The amplitude and frequency of oscillations during the study were 4 mm and 75 Hz, respectively. The combined working environment included porcelain balls with a diameter of 10 mm as an abrasive tool and a 5% solution of sodium bicarbonate ($NaHCO_3$) as a chemical component. At the beginning of the treatment, primary rinsing was carried out by continuously feeding and draining water for 5 minutes, then the main solution was fed. At the end of the treatment, the rinsing operation was repeated. Cylindrical samples with a diameter of 14 mm and a length of 30 mm were used as parts. The material of the studied samples is copper-zinc alloy LS 59-1L (0,97% Pb, 58,52% Cu, other - Zn), an analogue according to the ISO system - CuZn39Pb1. Ten samples were processed simultaneously; after processing, the process efficiency was assessed based on the mass of metal removed.

The study included two series of 10 tests each, ensuring that the metal removal rate dispersion field was estimated within a 90% confidence interval using the Student's t-test. The experimental results are presented in Table.

Table

Results of experimental studies of the influence of the surface material of the reservoir walls on the efficiency of the processing

Sample number	Average metal removal rate in a reservoir with a traditional lining	Average metal removal rate in a silicon carbide lined reservoir
1.	0,0621	0,1114
2.	0,0625	0,1074
3.	0,0634	0,1138
4.	0,0618	0,1157
5.	0,0619	0,1064
6.	0,0782	0,1176
7.	0,0628	0,1135
8.	0,0613	0,1144
9.	0,0646	0,1153
10.	0,0811	0,1179

The speed of the working media's surface layer was determined by the speed of a specially designed "turntable" device. This device consists of a hub with four blades mounted crosswise. The hub's axle is mounted in bearings to ensure free rotation and is secured to a fixed platform so that the working media exerts a constant force on the blades.

During the studies in both series, the flow pattern of the working media was stable and deterministic, and the circulation speed was 10 rpm. Consequently, changes in the surface roughness of the reservoir walls do not significantly affect the flow pattern of the working media.

However, the results of evaluating the process performance based on metal removal rate, as one of the key performance indicators, presented in Table 1, were predictably high when using reservoir walls with an abrasive component. The use of an abrasive coating allowed for an average increase in metal removal rate of 40%.

Thus, the possibility of intensifying the process of treatment with a combined working media under the action of oscillations by using an abrasive coating on the walls of the reservoir, as well as the absence of a significant influence of the roughness of the surface of the lining on the nature of the movement of the working media, was experimentally demonstrated.

Conclusions. Based on the experimental studies conducted, it was established that the abrasive properties of the reservoir surface do not have a significant impact on the circulation of the working media; the nature of the movement remains stable and deterministic.

The lining material of the reservoir directly affects the amount of metal removed, which in turn affects the overall performance of the process of processing a combined working media under the influence of oscillations.

The use of silicon carbide as a lining increases the efficiency of the process by 40%, which is explained by the additional abrasive effect of the walls on the surface of the part, which in this case act as an abrasive tool.

References

1. Malkin S., Guo C. Grinding Technology: Theory and Application of Machining with Abrasives. 2nd ed. New York: Industrial Press Inc., 2008. 372 p.
2. Blekhman I.I. Vibrational Mechanics: Nonlinear Dynamic Effects, General Approach, Applications. Singapore: World Scientific, 2000. 509 p.
3. Babichev A.P. Dynamics of vibrational processing systems with free abrasive media. Kharkiv: NTU “KhPI”, 2019.
4. Mitsyk, V.Ya. Intensification of processing of parts in vibrating reservoirs with counter-moving flows of the working media Dissertation … candidate of technical science: Voroshilovgrad, 1986. 246 p.
5. Pshenichnyy, I.N. Expanding of the technological capabilities of processing of parts in vibrating reservoirs Dissertation … candidate of technical science: Lugansk. 2005. 265 p.
6. Branspiz, E.V. (2001). Increasing the efficiency of vibro-abrasive machining by rationally selecting its main parameters. Dissertation … candidate of technical science: Lugansk. 2005. 265 p.

Романченко О.В. Івченко А.Г. Вплив матеріалу футерування резервуару на продуктивність процесу обробки деталей комбінованим робочим середовищем під дією коливань.

В роботі досліджується вплив матеріалу футеровки резервуару обладнання для обробки комбінованим вільним робочим середовищем під дією коливань на загальну продуктивність процесу фінішної обробки поверхні деталей. Принцип методу заснований на передачі імпульсів від стінок резервуара, що коливаються, робочому середовищу, що формує стійкий циркуляційний рух абразивного середовища, хімічних розчинів і оброблюваних деталей. Відносний рух елементів середовища визначає інтенсивність знімання металу, а наявність пасивних зон усередині резервуара істотно впливає на рівномірність обробки. У науковій літературі докладно досліджено параметри вібраційного процесу, проте вплив абразивних властивостей стінок резервуару вивчено недостатньо, незважаючи на широке застосування гумових покриттів у промисловому устаткуванні

У роботі представлені результати експериментального дослідження, проведеного устаткуванні з резервуаром об'ємом 25 літрів. Досліджувалися дві конфігурації футеровки: традиційна з облицюванням поверхні резервуара гумою та поверхня фанерована пластинами карбіду кремнію. Як робоче середовище використовувалися фарфорові кулі та розчин гідрокарбонату натрію. Перед основною операцією обробки проводилася операція очищення із застосування безперервної подачі води. Після завершення основної операції проводилася повторна операція очищення. Після обробки оцінювалася маса знятого металу із зразків при серіях з десяти паралельних дослідів кожної конфігурації футеровки.

Отримані дані показали, що зміна шорсткості стінок резервуара не помітно впливає на циркуляційний рух робочого середовища. Застосування абразивного футерування з карбіду кремнію забезпечило значне збільшення продуктивності процесу – середній знімання металу зріс на 40%. Експериментально підтверджено можливість інтенсифікації вібраційної обробки за рахунок використання матеріалів стінок з абразивними властивостями, без порушення стабільності руху робочого середовища. Дослідження показує перспективність застосування абразивних покриттів підвищення ефективності обробки деталей в устаткуванні, призначеному для фінішної обробки абразивним інструментом без жорсткого кінематичного зв'язку.

Ключові слова: *комбіноване робоче середовище, футерування резервуара, абразивні покриття; циркуляційний рух, знімання металу.*

Романченко О.В. – к.т.н., доц., завідувач кафедри машинобудування та прикладної механіки Східноукраїнського національного університету ім. В. Даля, alexvromanchenko@snu.edu.ua

Івченко А.Г. – Phd., доцент кафедри машинобудування та прикладної механіки Східноукраїнського національного університету ім. В. Даля, ivchenko_ag@snu.edu.ua

Стаття подана 15.10.2025