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EXPERIMENTAL INVESTIGATION OF THE HANDLING PROCESS OF POLYMERIC UNITS IN A MACHINE WITH A COMPACTED SPACE MOVEMENT OF WORKING CAPACITY

Purpose. *An experimental determination of the main technological parameters of polishing small polymer parts with a free abrasive in the form of granules in containers that perform a complex spatial movement.*

Methodology. *An experimental investigation of the processing of small polymeric parts by abrasive in the form of free granules in a machine whose working capacities performs a complex spatial movement to determine rational polishing conditions.*

Results. *On the basis of experimental research of the processing of small polymer parts in a machine with a complex spatial motion of a working tank, a rational mode of motion of a friable working medium is established that provides the highest intensity of polishing of parts. The intensity of execution of technological polishing operations during the implementation of cascade and waterfall modes of the friable working environment is shown. The mode of motion of a friable working environment is established, in the implementation of which the intensity of polishing parts will be the smallest. It has been experimentally established that in a capacity with proportional greater geometric parameters processing will take less time.*

Scientific novelty. *The regularities of the influence of the geometric parameters of the working capacity, which performs the complex spatial motion and the modes of motion of a friable working medium, are determined on the intensity of the process of polishing small polymer parts by abrasive in the form of free granules.*

Practical significance*. The instructions for realization of the corresponding mode of movement of a friable working medium, which provide intensive polishing of small polymer parts with a free abrasive in the form of granules, are obtained in a machine whose working capacities performs a complex spatial movement.*

Keywords: *polishing, working capacity, free abrasive in the form of granules, polymeric units.*

Introduction. Formation of a large number of small polymer parts of various industries, including fittings of light industry, is caused by mechanical processing or casting. After that, the surface of the products has significant microniness and lack of gloss. Such parts are subjected to finishing, the essence of which is grinding and polishing their surface with a free abrasive in the form of granules, usually in the middle of the rotational capacity [1, 2] or in the capacities of vibrating machines [3]. These operations take up to 80% of the technological time [4]. Such processing in machines whose working capacities perform low-performance rotary motion [5] and require a lot of time.

Setting problem. educing the processing time can be due to the use of equipment in which the working capacity performs a complex spatial movement, due to the fact that the working environment in the processing process moves very rapidly.

However, to date, there are practically no guidelines for the processing of fine polymeric parts (grinding, polishing) with a free abrasive in the form of granules in a machine which working capacity is complicated by spatial motion [6], there is no scientifically substantiated information about the choice of rational mode of the working environmen friable motion.

Thus, the definition of the rational mode of movement of a friable working environment, as well as the prediction of technological result at the design stage in the execution of the relevant technological operations, is an urgent task to date.

Results of the study. The analysis of published works on tools and methods for processing parts with free abrasive in the form of granules showed that the work of foreign scientists [7 – 9] on the study of the processes of blending of friable substances in similar equipment with the complex spatial movement of the working capacity. However, the processes of mixing friable substances and processing small polymer parts in the same type of equipment have radically different technological characteristics. That is why, when performing the technological processes of polishing small parts, it is not rational to use the instructions on the processes of blending of friable substances.

In [10], mathematical dependencies between the corresponding motion regime of the friable medium, the angular velocity of the driving shaft and the dimensional parameters of the working capacity, which performs a complex spatial motion, are established, however, there are no guidelines on how the friable working medium motion regime should be applied at polishing of the surface of polymeric parts.

There are dry and wet polishing abrasive small parts free in the middle of working capacity. During the experiment of processing of polymer parts, a method of wet polishing was used, in which the capacity with a friable working medium was poured water to the required level.

The time taken to perform the processing operations of grinding and polishing small polymer parts with a free granule abrasive depends on a large number of factors, the main of which are: the movement of a friable working medium, the level of filling of the working tank, the volume ratio of the abrasive components and the machined parts , the level of filling with bulk solids water, geometric parameters of the working capacity, the force influence of the abrasive components on the machined parts, the geometric shape and material, as treated products, and abrasive components, etc.

At the same time, it is impossible to take into account all the factors, therefore most of them were accepted according to previous researches of scientists and technological regulations of enterprises, namely: the level of filling of the working capacity was accepted by 40%, as treated products used the workpieces of buttons made of polyester resin in diameter of 28 mm and 16 mm. As abrasive material, ceramic triangular prisms with a length of all faces of 5 mm (Fig. 1) and fine-grained pumice were used. The volume ratio between the abrasive material and the buttons was 2,5: 1, the level of filling with water did not exceed the level of the bulk solid. The bulk density of the abrasive material was 1500 kg / m^3.

The experiment was carried out at the facility with the possibility of changing the working capacity. Thus, two capacities of different sizes were used.The lower working capacity with the following geometric parameters: the volume of the container is 0,0021 m^3 (2,1 l), the length of the container between the opposite ends $l_Ц$ = 0,17 m, the diameter of the container d = 0,13 m. For such a capacitance was introduced conditional scale factor n=1,54.

The greater working capacity with the following geometric parameters: the volume of the container is 0.0082 m^3 (8,2l), the length of the container between the opposite ends $l_Ц$ = 0,26 m, the diameter of the container d = 0,2 m. For such a capacity was introduced conditional scale factor n=1,54.

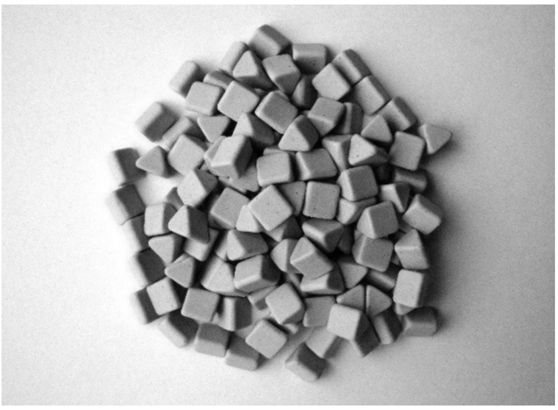


Fig. 1. **Abrasive material in the form of ceramic triangular prisms**

During the experiment, the following factors varied: the operating modes of the friable working environment, the size of the working capacity, and also took into account the force influence of the abrasive components on the workpieces. The processing of the buttons was carried out on the experimental installation of the machine, whose working capacity is made by a complex spatial motion, the photo of which is presented in Fig. 2.

Fig.2. **Photo of the experimental facility**

In the first part of the experiment, the effect of changing the modes of motion of a friable working medium on the intensity of the processing of polymer buttons was determined. Thus, the polishing of three separate batches of polyester buttons was carried out during the implementation of the waterfall, cascade and mixed modes of the friable working environment in the following sequence: in the lower working capacity (n = 1), unprocessed buttons and abrasive filler were loaded in the above ratios, the contents were flooded with water without special characteristics, the driving shaft of the machine provided angular velocity, which is necessary for the implementation of the corresponding mode of movement of the working environment. The angular velocity required for the implementation of the corresponding motion regime of a friable working medium in the middle of a capacitance of an appropriate size that performs a complex spatial motion can be calculated from the already known equations presented in [6].

For each mode of motion the total processing time was 42 hours. During this time, the machine stopped 7 times, samples of the buttons were taken at the 6th, 9th, 14th, 21st, 24th, 32nd and 42nd hours of processing. It was obtained 14 samples of two types of buttons for each mode of motion. The roughness of the surface of all 42 samples, as well as 2 unprocessed buttons and 2 control buttons, which passed the complete cycle of processing at the company Polyplast LLC (Ukraine, Lviv) in an ordinary rotary tumbler, (a processing time was 30 hours), was determined in Laboratory of Measuring Equipment MMI NTUU "KPI named after Igor Sikorsky". The roughness of the surface was determined by two parameters: the arithmetic mean deviation of the profile R_a and the highest height of the profile inequalities R_{max}. Each measurement of the roughness parameter on one button was duplicated 7 times.

Next, for each roughness parameter measured on one button, an arithmetic mean value was determined, after which, with the help of Microsoft Excel, the graphic dependences of the surface roughness on the corresponding parameter from the processing time in the form of approximated curves were constructed, and the laws of the change of these curves were determined.

The roughness of the surface of the control raw samples and buttons, which have passed the complete cycle of processing at the company Polyplast LLC, in two parameters is presented in Table 1.

Table 1

Control sample	R_a, mkm	R_{max}, mkm
Unprocessed button Ø28	3,624	25
Unprocessed button Ø16	1,771	12,6
Processed button Ø28	0,092	1,8
Processed button Ø16	0,07	1,38

Graphic processing time dependencies of the surface roughness of the buttons for three motion modes of working medium are shown in fig. 3 (a – d).

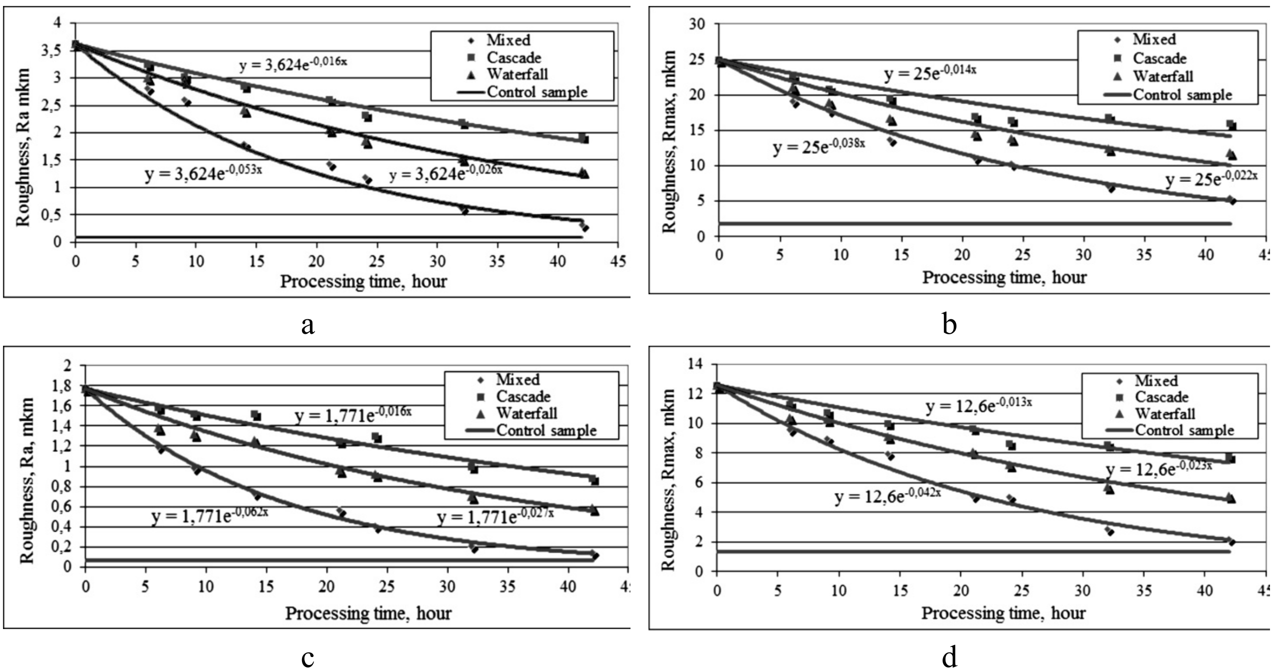


Fig. 3. **Processing time dependency of the surface roughness of the buttons for three motion modes of working medium (a – the buttons with a diameter of 28 mm by the parameter R_a, b – the buttons with a diameter of 28 mm by the parameter R_{max}, c – the buttons with a diameter of 16 mm by the parameter R_a, d – the buttons with a diameter of 16 mm by the parameter R_{max})**

Having analyzed the graphs of dependence, presented in Fig. 3 it is established that the greatest intensity of the processing of buttons occurs in the implementation of the mixed mode of motion, less intensive processing occurred in the waterfall mode of motion and the smallest - at cascade mode. According to the presented laws of changes in the approximated curves for different modes of motion of a friable working environment have been found that the time spent on processing polyester buttons in the waterfall mode will be one and a half times greater during the processing of products in a mixed mode, as well as the time spent on processing at cascade mode - three to four times greater than the time of processing in mixed mode.

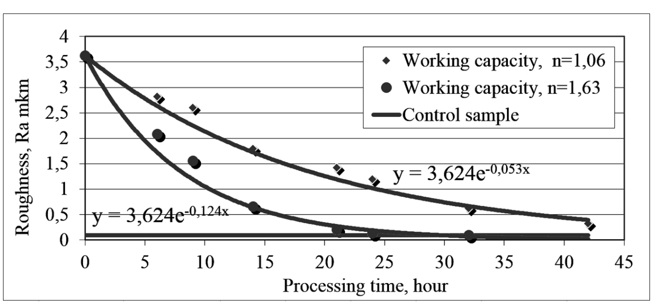
Such a pattern can be explained by the fact that during the waterfall mode of motion, due to the fact that there is free flight of particles, the time of contact between the processed products and the abrasive material decreases, as a result, time increases and the processing intensity decreases. A similar situation ocures during the implementation of the cascade mode of motion, especially at very low angular velocities of the driving shaft. In this case, though there is a constant contact between the processed products and the abrasive material, however, the friction path that is passed by one product over the appropriate period of time is significantly reduced.

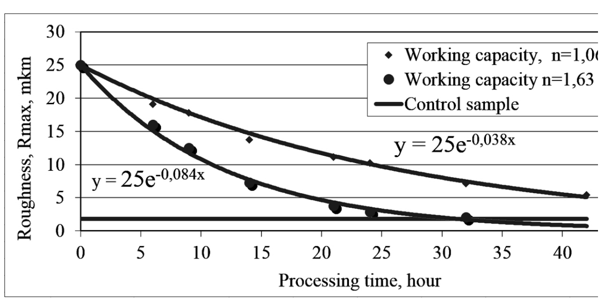
Thus, further polishing of small polymer products with a free abrasive in the form of granules should be performed in the implementation of a mixed mode of motion of friable working media.

In the second part of the experiment, the influence of the geometric parameters of the working capacity on the intensity and quality of the buttons processing was determined, as well as the time required for the performance of the processing operations of the buttons. Thus, the polishing of an additional party of buttons in a larger working capacity was carried out (*n=1,54*).

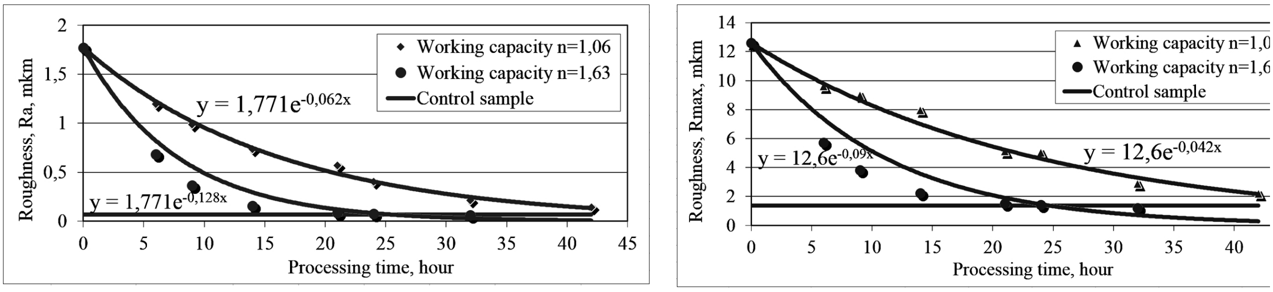
The processing of 2 types of buttons performed during 32 hours. During this time the machine stopped 6 times, samples of the buttons were taken at the 6th, 9th, 14th, 21st, 24th and 32nd hours of processing. We received 12 samples of two types of buttons. The roughness of their surface was determined in the laboratory of the NTUU "KPI named after Igor Sikorsky" in two parameters the arithmetic mean deviation of the R_a profile and the greatest height of the profile inequalities $R_{max.}$ Each measurement of the roughness parameter on one button was duplicated 7 times after that, using Microsoft Excel, graphic dependences of surface roughness were constructed with the corresponding parameter from the processing time obtained as a result of the approximation of the experimental data. The laws of curve change are determined and compared on one coordinate plane with a graph of the dependence of surface roughness from the time the buttons are processed in a working capacity with lower geometric parameters.

Graphic dependencies of the change of the buttons surface roughness from the processing time in two working capacities of proportional different sizes during the implementation of the mixed mode of motion of a friable working medium are presented in Fig. 4 (a – d).





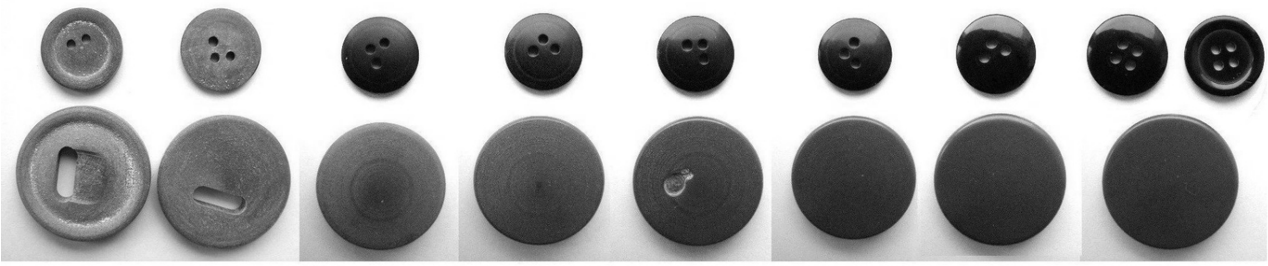
a b



c d

Fig. 4. **Processing time dependency of the surface roughness of the buttons for three motion modes of working medium (a – the buttons with a diameter of 28 mm by the parameter R_a, b – the buttons with a diameter of 28 mm by the parameter R_{max}, c – the buttons with a diameter of 16 mm by the parameter R_a, d – the buttons with a diameter of 16 mm by the parameter R_{max})**

The photo of the raw buttons, as well as the buttons that have passed the appropriate processing time, are shown in Fig. 5.



unprocessed buttons 6 hours 9 hours 14 hours 21 hours 24 hours 32 hours

Fig. 5. **The photo of the raw buttons, as well as the buttons that have passed the appropriate processing time**

Having analyzed the graphs of dependence, presented in Fig. 4 it is confirmed that the intensity of processing of polymer parts will be greater in working capacity with proportionally larger sizes. Compare among themselves the Microsoft Excel equations of the roughness curves defined on the graphs by the processing of products in working tanks with larger (*n=1,54*) and smaller (*n=1,0*) geometric parameters, it can be noted that the processing time of the buttons at *n = 1,0* will require about 2.5 to 3 times more time than the time of processing at *n = 1.54* according to the parameters according to the roughness parameters on which the quality of the processed surface was evaluated.. In addition, the time spent on processing buttons with a diameter of 16 mm to achieve this value of roughness Ra, which corresponds to the roughness of the surface of the button treated at the company Polyplast LLC (0,771 microns), will be approximately 25-27 hours, which is already 3 - 5 hours less during processing in a machine with rotating capacity.

In addition, when using a machine with a flexible working capacity to perform grinding or polishing operations on the surface of the parts and simultaneously reducing power consumption, it is not necessary to simultaneously process two or more types of parts, including buttons, with distinct geometric parameters. It is recommended that only one type of detail be processed in one machine.

If there are insignificant quantities of batch products, the processing should be carried out in a machine having a capacity with a smaller volume.

Conclusions:

1. The influence of modes of movement of a friable working medium in the middle of the tank on the intensity and quality of processing of small polymer parts is investigated. It has been experimentally established that the most intense polishing of parts by abrasive in the form of free granules occurs when the mixed mode of motion of the working medium in the middle of the capacity, performing a complex spatial movement, occurs.

2. The influence of geometric parameters of the working capacity on the intensity and quality of processing of small polymer parts is investigated. It has been experimentally established that in a capacity with proportional greater geometric parameters processing will take less time.

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ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ПРОЦЕСУ ОБРОБКИ ДРІБНИХ ПОЛІМЕРНИХ ДЕТАЛЕЙ В МАШИНІ ЗІ СКЛАДНИМ ПРОСТОРОВИМ РУХОМ РОБОЧОЇ ЄМКОСТІ

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Мета. *Експериментальне визначення основних технологічних параметрів полірування дрібних полімерних деталей вільним абразивом у вигляді гранул у ємкостях, що виконують складний просторовий рух.*

Методика. *Проведено експериментальне дослідження процесу обробки дрібних полімерних деталей абразивом у вигляді вільних гранул в машині, робоча ємкості якої виконує складний просторовий рух, для визначення раціональних умов полірування, результати експерименту систематизовано за допомогою програмного забезпечення Microsoft Excel-2016, побудовано відповідні графіки на основі апроксимації даних.*

Результати. *На основі проведеного експериментального дослідження процесу обробки дрібних полімерних деталей в машині зі складним просторовим рухом робочої ємкості встановлено раціональний режим руху сипкого робочого середовища, який забезпечує найбільшу інтенсивність полірування деталей. Показано інтенсивність виконання технологічних операцій полірування при реалізації каскадного та водоспадного режимів руху сипкого робочого середовища. Встановлено* *режим руху сипкого робочого середовища, при реалізації якого інтенсивність полірування деталей буде найменшою. Експериментально встановлено, що в ємкості, яка має пропорційно більші геометричні параметри, процес обробки займатиме менше часу.*

Наукова новизна. *Встановлені закономірності впливу геометричних параметрів робочої ємкості, що виконує складний просторовий рух та режимів руху сипкого робочого середовища на інтенсивність процесу полірування дрібних полімерних деталей абразивом у вигляді вільних гранул.*

Практична значимість. *Отримані настанови щодо реалізації відповідного режиму руху сипкого робочого середовища, що забезпечують інтенсивне полірування дрібних полімерних деталей вільним абразивом у вигляді гранул в машині робоча ємкості якої виконує складний просторовий рух.*

Ключові слова: *полірування, робоча ємкість, вільний абразив у вигляді гранул, полімерні деталі.*

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ПРОЦЕССА ОБРАБОТКИ МЕЛКИХ ПОЛИМЕРНЫХ ДЕТАЛЕЙ В МАШИНЕ СО СЛОЖНЫМ ПРОСТРАНСТВЕННЫМ ДВИЖЕНИЕМ РАБОЧЕЙ ЕМКОСТИ

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Цель. *Экспериментальное определение основных технологических параметров полирования мелких полимерных деталей свободным абразивом в виде гранул в емкостях, выполняющих сложное пространственное движение.*

Методика. *Проведено экспериментальное исследование процесса обработки мелких полимерных деталей абразивом в виде свободных гранул в машине, рабочая емкость которой выполняет сложное пространственное движение, для определения рациональных условий полирования.*

Результаты. *На основе проведенного экспериментального исследования процесса обработки мелких полимерных деталей в машине со сложным пространственным движением рабочей емкости установлено рациональный режим движения сыпучей рабочей среды, который обеспечивает наибольшую интенсивность полирования деталей. Показано интенсивность выполнения технологических операций полирования при реализации каскадного и водопадного режимов движения сыпучей рабочей среды. Установлен режим движения сыпучей рабочей среды, при реализации которого интенсивность полировки деталей будет наименьшей. Экспериментально установлено, что в емкости, которая имеет пропорционально большие геометрические параметры, процесс обработки будет занимать меньше времени.*

Научная новизна. *Установлены закономерности влияния геометрических параметров рабочей емкости, выполняющей сложное пространственное движение и режимов движения сыпучей рабочей среды на интенсивность процесса полировки мелких полимерных деталей абразивом в виде свободных гранул.*

Практическая значимость. *Полученные установки по реализации соответствующего режима движения сыпучей рабочей среды, обеспечивающие интенсивное полирование мелких полимерных деталей свободным абразивом в виде гранул в машине, рабочая емкость которой выполняет сложное пространственное движение.*

Ключевые слова: *полирование, рабочая емкость, свободный абразив в виде гранул, полимерные детали.*