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Micrometric research results of vacuum dough divider components[*]

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Результаты микрометражных исследований деталей тестоделительных машин вакуумного типа[***]

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Introduction. Nowadays, vacuum-type dough dividers are used in industries with a production volume of up to 4,000 loaves per day. In the dough divider operation, due to wear of the working surfaces of the piston, chamber, and drum, the gap between them goes beyond the value equal to 50 microns, which provides vacuum in the suction chamber. As a result, the suction process becomes unstable; the dough divider disturbs the weight accuracy of bakery goods. Repair of such equipment is carried out mainly through a full or partial replacement of worn parts and assemblies with new ones. To increase their durability, there is a need to develop a new highly efficient technology with the restoration of worn part surfaces using the welding and surfacing methods.
Materials and Methods. A new technique of determining the number of objects for research using the “STATISTICA” program is presented. Wear surfaces of the vacuum dough divider parts are determined.
Research Results. Micrometric studies of the dough divider components were carried out. They showed the presence of appreciable size distortions due to the local wear of the working surfaces. In this case, a side gap between the suction chamber and the main piston and between the drum and the suction chamber is 6 times higher than the permissible one, and a vertical gap between the division box and the piston exceeds the permissible gap by more than 10 times. Wear of the working surfaces of the dough divider parts is local in nature, while the range of values is as follows: for the main piston, it is 10-200 microns; for the gaging piston, it is 250-900 microns; for the suction chamber and division box, it is 300-400 microns; for the drum surfaces, it is 280-300 microns.

Введение. В настоящее время на производствах с объемом выпуска до 4 000 булок в день используются тестоделительные машины вакуумного типа. В процессе эксплуатации тестоделительного устройства из-за износов рабочих поверхностей поршня, камеры, барабана зазор между ними выходит за величину, равную 50 мкм, при которой обеспечивается вакуум во всасывающей камере. В результате этого процесс всасывания становится нестабильным, тестоделительное устройство нарушает точность развесовки хлебобулочных изделий. Ремонт такого оборудования проводится в основном с использованием полной или частичной замены изношенных деталей и узлов на новые. Для повышения их долговечности возникает потребность в разработке новой высокоэффективной технологии с восстановлением изношенных поверхностей деталей сварочно-наплавочными методами.
Материалы и методы. Представлена новая методика определения количества объектов для исследования с использованием программы «Статистика». Определены поверхности износа деталей тестоделительных машин вакуумного типа.
Результаты исследования. Проведены микрометражные исследования деталей тестоделительных устройств, которые показали наличие у них значительных искажений размеров из-за локального износа рабочих поверхностей. При этом боковой зазор между всасывающей камерой и главным поршнем, барабаном и всасывающей камерой в 6 раз превышает допустимый, а вертикальный зазор между мерной камерой и поршнем превышает допустимый зазор более чем в 10 раз. Износы рабочих поверхностей деталей тестоделительных машин носят локальный характер, при этом диапазон значений составляет: для главного поршня — 10–200 мкм; мерного поршня — 250–900 мкм; всасывающих и мерных камер — 300–400 мкм; поверхностей барабана — 280–300 мкм.

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Discussion and Conclusions. The conducted micrometric studies showed the presence of appreciable size distortions due to the local wear of the working surfaces. Based on the results obtained, it can be argued that the most productive and economically viable technique for the restoration of worn surfaces of dough divider parts is, for example, the electrospark machining.

Обсуждение и заключения. Проведенные микрометражные исследования деталей тестоделительных устройств показали наличие у них значительных искажений размеров из-за локального износа рабочих поверхностей. Основываясь на полученных результатах, можно утверждать, что наиболее технологичным и экономически целесообразным для восстановления изношенных поверхностей деталей тестоделительных машин является метод электроискровой обработки.

Keywords: dough divider, dough weight distribution, wear of dough divider parts, measurement diagram, gaps in mobile interfaces of dough divider.

Ключевые слова: тестоделительное устройство, развесовка теста, износы деталей тестоделительного устройства, схема измерения, зазоры в подвижных сопряжениях тестоделительных устройств.

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Introduction. Bread baking holds a specific place in the food industry. Products of enterprises of this specialization are top requested. However, despite high demand for bread and bakegoods, in some cases, such production may be wasteful. This is due to the insufficient mechanization of the baking process and the complexity of its maintenance. To make an enterprise of such specialization profitable, it is necessary to use high-tech equipment in the process of making bread, which includes, for example, dough-dividing machines **[**1].

Dough dividers are designed for mechanical processing of dough through dividing it into portioned pieces of a certain weight and shape. Dough dividers are most often used in bakeries that supply bread, loaves, rolls, etc. to the market.

At the bread factories and in bakeries, dough-making machines of domestic production “*Voskhod*”, “*GORIZONT*” and of foreign manufacture - “*PARTA U2*”, “*Kumkaya*”, “*CRV*” are mostly often used [2, 3]. Imported equipment is although more functional than domestic analog models, but, it costs 1.5–2.5 times as much.

The main unit of the dough divider that performs the key function is a dividing device (Fig. 1) which consists of hopper *A*; bin hopper *B*; suction chamber body *C*; dividing knife *D*; main piston *E;* suction chamber *F*; measuring piston G; drum-type tail gate *I* (hereinafter referred to as the drum) with division box *H* [4].

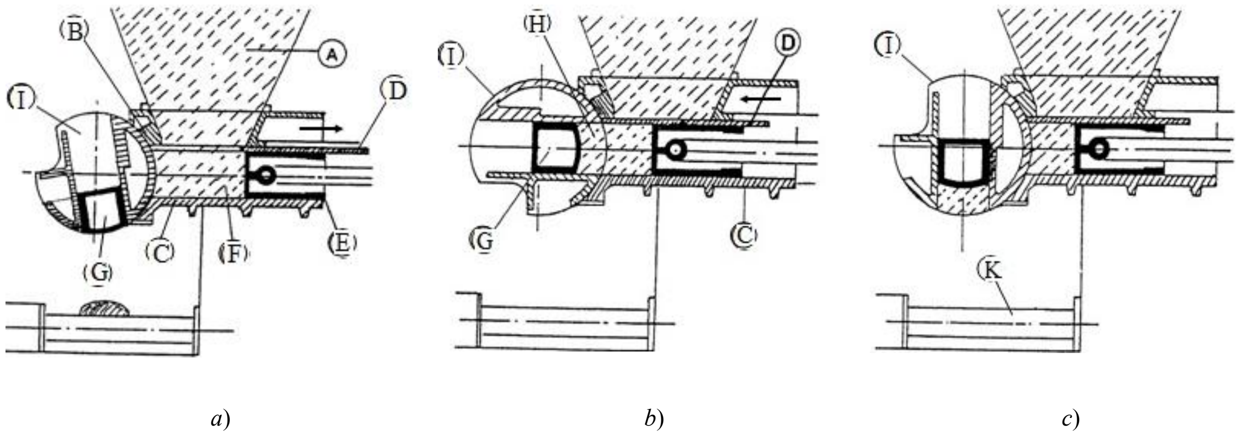

Fig. 1. Structure diagram of vacuum-type dough divider: *A* is hopper; *B* is bin hopper; *C* is suction chamber body; *D* is dividing knife; *E* is main piston*;* *F* is suction chamber; G is measuring piston; *H* is division box; *I* is tail gate (drum); *K* is conveyer belt.

When in operation, the working surfaces of the main piston (Fig. 2 a), the suction chamber body (Fig. 2 b), the drum (Fig. 2 c), etc., wear out.

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a) *b*) *c*)

Fig. 2. General view of dough divider components: (A is maximum wear region): *a* is measuring piston; *b* is suction chamber body; *c* is drum

As a result, gaps between them go beyond the value at which vacuum is maintained in the suction chamber; the suction process goes out of control, and the dough divider disturbs the weight distribution accuracy of bakery goods [5].

Till now, repair of such equipment is carried out by 70–80% using spare parts priced from 200 to 300 thousand rubles. The component parts of foreign equipment are particularly expensive [6].

At a number of technical service enterprises, the restoration of components is carried out through the building-up of cast iron, stainless steel and non-ferrous metal on worn surfaces, and then through machining according to the allowance and technical requirements of the maker [6, 7]. However, this technique is unsustainable, time-consuming, and it has high cost.

To increase the durability of such machines, a new highly efficient technology is needed, which provides restoring components through coating with the desired physical and mechanical properties. One of the main criteria for selecting a technique of restoring worn parts is evaluation of the part surface wear that determines the required thickness of metal coatings.

In this regard, the work objective is to assess average values of gaps and wear of dough divider components according to the micrometric study results.

Materials and Methods. The number of dough dividing devices for micrometric studies was selected using the *chi*-square test. When using this criterion, the critical power value $p_{кр}$ = 0.80 [8] and the value of the one-sided probability belief $p_{д} = 0.80$ [9] were set.

The determination of the number of objects is carried out according to the hypothesis: for a given value of the significance level α = 0.05. According to the null hypothesis, the number of objects is enough for research, according to the alternative one, it is not enough. If the significance level of the current value α_i is higher than the accepted value of 0.05 and the current value of the *chi*–square p_{xi} criterion power is higher than the critical value of 0.80, then the null hypothesis is valid, and vice versa.

For the accepted parameter values, the dependency graph of the number of objects N and the one-sided confidence probability $p_{д}$ of the *chi*-square criterion is shown in Fig. 3.

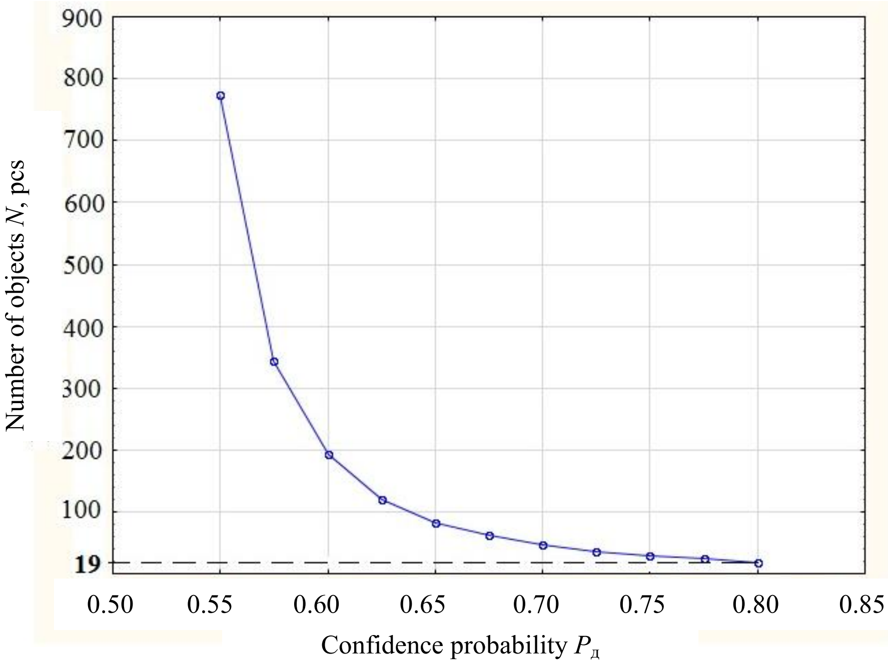


Fig. 3. Dependency graph of number of objects *N* and the one-sided confidence probability of *chi*-square criterion

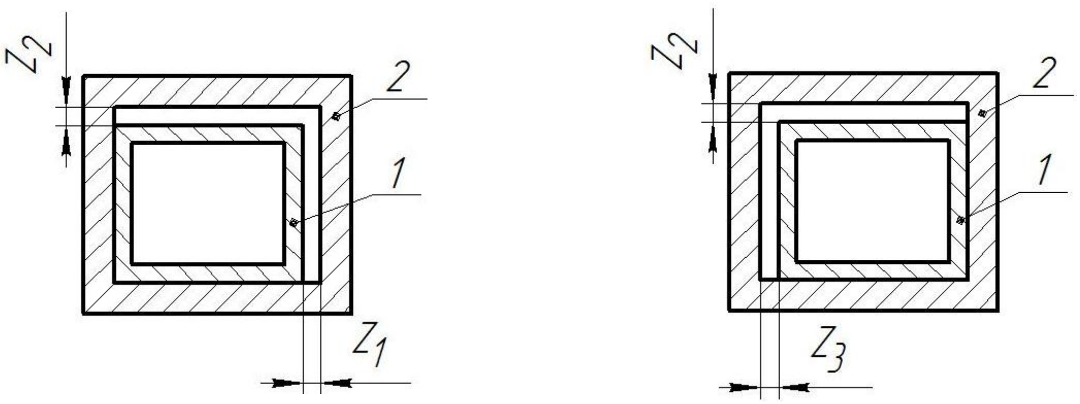
The graph shows that for the accepted one-sided confidence probability $p_д = 0.80$, the number of objects for the experiment is $N = 19$ pcs.

The calculation results in the *STATISTICA* program show that the design value of the significance level of the *chi*-square test $\alpha_i = 0.064$ is higher than the accepted 0.05, and the actual power of the criterion $p_{xi}= 0.84$ is higher than the critical value 0.80 [8]. The results obtained validate the null hypothesis with a certain number of dough divider devices $N = 19$ pcs.

Under the micrometric studies at the first stage, gaps in the interfaces were measured.

According to Fig. 1, a divider consists of a suction chamber and a division box, inside which the main piston and the measuring one, respectively, are moving.

When measuring the gap in the horizontal plane of these joints, the piston 1 is shifted all the way to the fixed chamber 2 and, on the opposite side, the gap Z_1 is measured in different sections (Fig. 4,a). Also, in this position of the piston 1, the gap Z_2 in the vertical plane is measured.



a) *b*)

Fig. 4. Measurements of gap in sliding joints of dough dividers

Then piston 1 is shifted to the opposite direction (Fig. 4, b), and the measurement algorithm is repeated. Such measurements were carried out in the extreme and middle working position of the main and measuring piston 1 (Fig. 1).

The tail gate-drum coupling is structurally made of two parts — a housing with a division box and a faceplate. The gap in this coupling is measured between the drum and the suction chamber.

If a gap in the joints is more than 0.05 mm, the wear of the part working surfaces is measured. When the dough divider is operating in the joints, the main piston is a suction chamber, the measuring piston is a division box, and the drum is a suction chamber (Fig. 1). The unworn surface of the parts is absent, their relative wear is measured according to [10, 11].

The relative wear of the outer part surfaces in the i-th section is calculated from the formula

$$U_{\mathrm{i}}^{\mathrm{H}} = d_{\max} - d_{\mathrm{i}},$$

where $d_{\max}$ is maximum part size, microns; d_{i} is the part size in the i-th section, microns.

The relative wear of the internal part surfaces in the i-th section is calculated from the formula

$$U_{\mathrm{i}}^{\mathrm{B}} = D_{\mathrm{i}} - D_{\min},$$

where D_{i} is the part size in the i-th section, microns; $D_{\min}$ is the minimum part size, microns.

When measuring, the sections of the chamber parts of the dough dividers are selected according to the working stroke of the pistons in those places where the working surfaces are in contact (Fig. 1).

The relative wear of the drum surface is measured through radial deviation of the fixed points of the drum surface relating to the center holes of the bearing trunnions. A measurement circuit of the drum working surface is shown in Fig. 5.

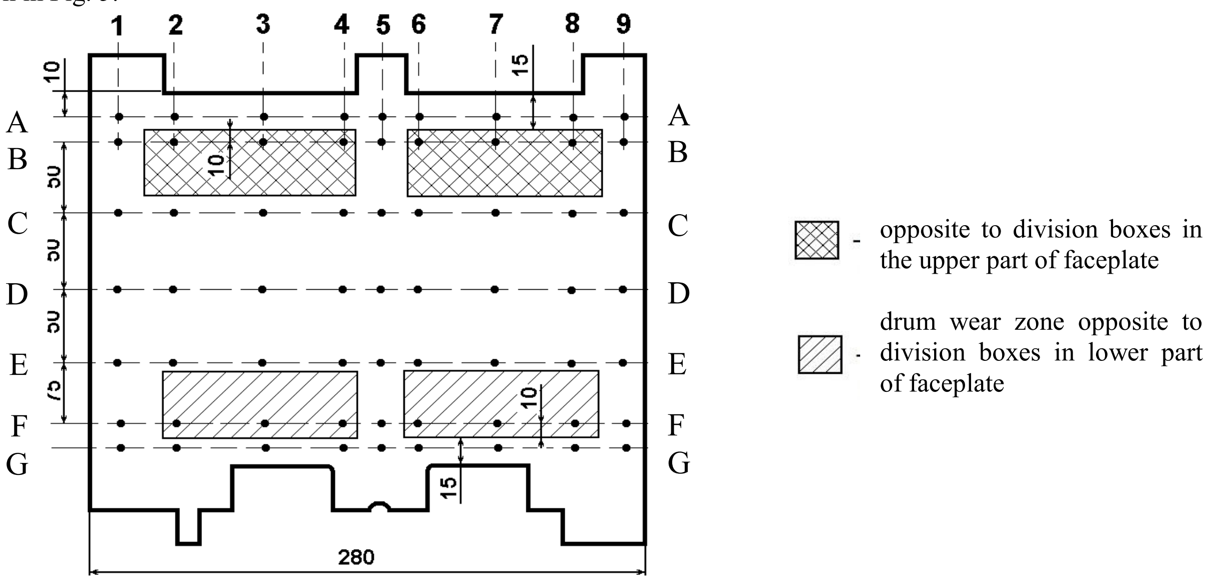


Fig. 5. Measurement circuit of the drum working surface

For measurements, the drum is installed in the centers of the lathe. Measurements during a longitudinal movement are made by the detecting head along the drum in different planes, but without changing the position of this head in the radial direction.

To measure the external components of the dough dividers, MP02102 micrometer with an accuracy of 0.003 mm in 0.002 is used. For internal parts –GOST 868 indicating hole gage NI-100M, whose measurement error is 0.015 mm, with GOST 577 ICh10 mercer clock gauge head, 1 accuracy class in 0.01 mm.

Research Results. The average values of the gaps between the pistons and chambers of the dough divider according to Fig. 3 are shown in Tables 1 and 2.

Table 1

Average values of the gap between suction chamber and main piston

Distance from front chamber edges, mm	Gap average value, mm (±0.02)		
	Z_1	Z_2	Z_3
0	0.02	0.20	0.12
25	0.18	0.22	0.18
50	0.30	0.22	0.20
75	0.25	0.20	0.20
100	0.30	0.25	0.20
150	0.25	0.25	0.20
200	0.25	0.20	0.20

Table 2

Average values of the gap between division box and piston

Distance from front chamber edges, mm	Gap average value, mm (±0,02)		
	Z_1	Z_2	Z_3
Left chamber			
5	0.50	0.35	0.30
25	0.50	0.45	0.35
50	0.55	0.50	0.35
75	0.50	0.35	0.30
Right chamber			
5	0.10	0.40	0.10
25	0.10	0.45	0.15
50	0.05	0.45	0.15
75	0.05	0.40	0.15

Tables 1 and 2 show that the side gap between the worn-out suction chamber and main piston reaches 300 µm in some areas. Given the increased wear of the output part of the lower plane of the chamber, the vertical clearance is at least 400-500 µm. Values of the lateral and vertical gaps between worn division boxes and pistons also far exceed the permissible value and reach 550 µm.

The average values of the gap between the drum and the suction chamber are shown in Table 3.

Table 3

Average values of the gap between drum and suction chamber

Sections	Clearance in mm (±0.02) at points								
	1	2	3	4	5	6	7	8	9
A	0.06	0.15	0.15	0.13	0.10	0.20	0.18	0.21	0.07
B	<0.05	0.26	0.30	0.30	0.08	0.25	0.25	0.28	<0.05
C	<0.05	0.17	0.15	0.18	0.07	13	0.15	0.15	0.05
D	<0.05	0.09	0.10	0.08	<0.05	0.12	0.11	0.10	<0.05
E	0.05	0.07	0.08	0.08	0.05	0.05	0.06	0.08	<0.05
F	<0.05	0.16	0.14	0.15	0.09	0.15	0.15	0.13	<0.05
G	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

As follows from Table 3, the gap between the drum and the suction chamber in 300 µm far exceeds the permissible value.

Tables 4–5 show the measurement schemes and average wear values of the part surfaces that determine the performance of the dough dividers.

Table 4

Results of micrometric measurements of main piston

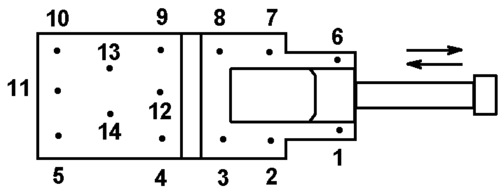
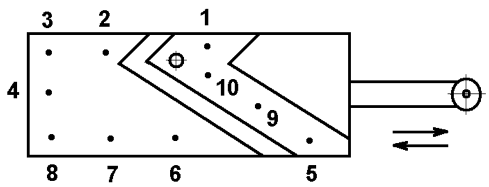
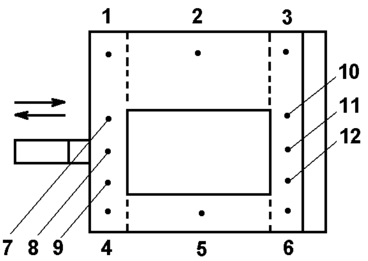
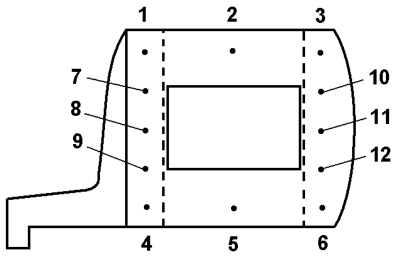
<table>
<tr><td>Sections</td><td>Average measurements, mm</td><td>Observations</td></tr>
<tr><td>1</td><td>2</td><td>3</td></tr>
<tr><td colspan="3">Sectional piston height measurements, ±0.01 mm</td></tr>
<tr><td colspan="2">Average measurements, mm</td><td>
</td></tr>
<tr><td>1</td><td>99.95</td><td rowspan="2">In zones 1-2 on the bottom surface, wear is up to 0.2 mm deep, 20 mm long, and 5-6 mm wide</td></tr>
<tr><td>2</td><td>99.93</td></tr>
<tr><td>3</td><td>99.90</td><td rowspan="12">On the total area of bottom and top surfaces of zones 3-14, there is tearing and furrows up to 0.1 mm in depth, some dents</td></tr>
<tr><td>4</td><td>99.86</td></tr>
<tr><td>5</td><td>99.82</td></tr>
<tr><td>6</td><td>99.95</td></tr>
<tr><td>7</td><td>99.96</td></tr>
<tr><td>8</td><td>99.92</td></tr>
<tr><td>9</td><td>99.89</td></tr>
<tr><td>10</td><td>99.87</td></tr>
<tr><td>11</td><td>99.80</td></tr>
<tr><td>12</td><td>99.82</td></tr>
<tr><td>13</td><td>99.84</td></tr>
<tr><td>14</td><td>99.80</td></tr>
<tr><td colspan="3">Sectional measurements of piston width, ±0.05 mm</td></tr>
<tr><td colspan="2">Average measurements, mm</td><td>
</td></tr>
<tr><td>1</td><td>189.80</td><td rowspan="9">There is tearing and furrows up to 0.1 mm in depth over the total area of the side surfaces</td></tr>
<tr><td>2</td><td>189.65</td></tr>
<tr><td>3</td><td>189.60</td></tr>
<tr><td>4</td><td>189.60</td></tr>
<tr><td>5</td><td>189.80</td></tr>
<tr><td>6</td><td>189.80</td></tr>
<tr><td>7</td><td>189.70</td></tr>
<tr><td>8</td><td>189.60</td></tr>
<tr><td>9</td><td>189.80</td></tr>
<tr><td>10</td><td>189.80</td><td>In this area, on the right side, there is longitudinal tearing up to 0.3 mm in depth</td></tr>
</table>

Table 5

Results of micrometric measurements of measuring pistons

Sections	Measurement results, mm (±0.01 mm)	Observations
1	2	3
Average measurements, mm		Sectional measurement scheme of piston width 
PISTON No. 1 (left), sectional measurements of piston height		
1	99.88	On the bottom surface in zones 1-3, there is tearing up to 0.3 mm in depth
2	99.88	
3	99.78	
4	99.80	
5	99.78	
6	99.69	
7	99.58	
8	99.57	
9	99.60	
10	99.42…60	On the top surface (half the area) in zones 10-12, there is fatigue wear, on the rest area, there is tearing up to 0.2 mm in depth
11	99.40…50	
12	99.55	
PISTON No. 1 (left), sectional measurements of piston width		
1	82.33	
2	82.33	
3	82.27	
4	82.38	
5	82.36	
6	82.31	
7	81.92	In zones 7-9, there is uniform wear, the amount of wear on the left surface is greater than of the right one
8	82.00	
9	82.15	
10	81.80…90	In zone 10, there is fatigue wear up to 3.5 cm^2 in area
11	82.00	
12	82.14	

PISTON No. 2 (right), sectional measurements of piston height		
1	99.78	On the bottom surface in areas 1-6, there is tearing and furrows
2	99.77	
3	99.68	
4	99.80	
5	99.83	
6	99.75	
7	99.50	
8	99.48	
9	99.47	
10	99.22…53	On the top surface in zones 10-12, there is fatigue wear up to 90% in area
11	99.22…49	
12	99.20…50	
PISTON No. 2 (right), sectional measurements of piston width		
1	82.29	
2	82.31	
3	82.18	
4	82.38	
5	82.41	
6	82.28	
7	81.66	
8	81.98	
9	82.22	
10	81.49…75	On both surfaces in zones 10-11, there is fatigue wear up to 50% in area
11	81.58…92	
12	82.10	

As follows from Table 4, the height of the main piston wear along the sections is uneven. It is minimal at the rear part of the piston (10–20 µm) and gradually increases to a maximum value up to 150 µm to its front face. The nature of the change in the size of the piston width is similar, in which the maximum value of wear of at least 200 µm is also located at its front face. Grooves of various depths (from 100 to 300 µm), furrows, some dents are visible on the total frictional area. Piston wear is caused by mechanical abrasion.

The inspection results of a measuring piston (Table 5) show that wear along the height and width is maximum in its front part (Table 3) and it can reach 800–900 microns. However, there is a feature caused by the presence of vertical and horizontal gates. The areas of friction surfaces opposite these gates are worn out more – by an average of 250-300 µm. Besides, in the fore piston lead-in, opposite the gates, on the top and side surfaces, there are sections of increased wear. This is clearly seen in Fig. 2, a.

The wear monitoring of the components of the suction chamber and division box shows that a long-term operation has also affected their size variation. As in the case with pistons, they are worn unevenly over sections along the total length of the working stroke. A characteristic feature of the suction chamber is increased wear (300–400 µm) of the bottom plane at the outlet part over all sections (Fig. 2, b). The width of the increased wear stripe of the suction chamber is 25–30 mm.

The measurement results of the radial deviation of the drum working made according to the scheme of Fig. 4 are shown in Table 6.

Table 6

Average values of radial deviation of drum working surface[1]

Sections	Sectional measurement results					
	→			←		
	1	3	5	5	7	9
A	–0.03	–0.11	–0.06	–0.05	–0.13	–0.04
B	0	–0.28	–0.03	–0.03	–0.22	–0.02
C	0.01	–0.16	–0.04	–0.05	–0.11	–0.03
D	0	–0.05	–0.02	–0.03	–0.06	0.01
E	–0.02	–0.06	–0.02	–0.02	–0.04	–0.01
F	–0.01	–0.09	–0.05	–0.04	–0.10	0.01
G	0	–0.02	–0.01	–0.02	0	0

[1]Note.
1) → and ← are directions of the longitudinal movement of detecting head;
2) points G1 and G9 are basic

Along with measuring the radial deviation of fixed surface points, it is possible, using the data from Table 3, to determine the boundaries of worn sections and the values of wear. The most worn sections of the drum working surface are in the sections opposite the division boxes in the upper and lower parts of the faceplate (Fig. 2c, 4)

As follows from Table 3, maximum wear on the most worn sections of the drum working surface reaches 280-300 µm.

To restore worn surfaces of dough divider components in the modern repair production, the most productive and economically viable technique is the electrospark machining [12].

Electrospark treatment is the process of transferring electrode material to a surface to be treated through the spark electric discharge. A feature of this method is a localization of worn areas, the absence of heating the components and the possibility of applying any conductive materials that provide high tribological properties of friction couples with minimal surface preparation.

Conclusion. Thus, the micrometric studies of dough divider parts show that they have appreciable distortions due to local wear of the working surfaces.

The investigation of gaps in the dough divider joints shows the following: the lateral gap between the suction chamber and the main piston is 6 times higher than the permissible one and reaches an average value of 300 µm; lateral and vertical gaps between the division box and the piston are 550 µm, which is more than 10 times the allowable gap; the gap between the drum and the suction chamber is 6 times the permissible gap and reaches an average value of 300 µm.

Wear of the working surfaces of the dough divider parts are local in character. The range of values for the main piston is 10-200 µm; for the measuring piston, it is 250-900 µm; for the suction chamber and division box, it is 300-400 µm; for the drum surfaces, it is 280-300 µm.

Based on the results obtained, it can be argued that the electrospark machining is the most productive and economically viable technique for restoring worn part surfaces of the dough dividers.

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