МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
Національний університет «Запорізька політехніка»

МЕТОДИЧНІ ВКАЗІВКИ

до лабораторних робіт з дисципліни
"Проектування технологічних процесів виробництва
електричних та електронних апаратів"
для студентів всіх форм навчання спеціальності
141 «Електроенергетика, електротехніка та електромеханіка»
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LABORATORY WORK №1
DETERMINATION OF THE PRODUCTION TYPE

Duration of scheduled study is 4 hours

1.1 The purpose of the work

Obtaining practical skills for determining the type of production according to its characteristics – the coefficient of fixation of technological operations.

1.2 General notes

The choice of one or another technological process depends on the type of production. Depending on the production program and the nature of the manufactured products, three types of production are distinguished – single, batch and mass. The type of production can be determined by two main methods – tabular and by calculating the coefficient of fixation of operations (*К*зо). To use the tabular method, it is necessary to know the volume of products production *Np* and one of the additional indicators – the weight of the product *M*, the labor intensity of assembly or the dimensions of the product. For example, when the mass of the product *M* < 10 kg, and the annual volume of production *Np* = 5000-50000 pcs the specified type of large-scale production (Table 1.1) [1].

Table 1.1 – Dependence of the production type on *Np* and *M*

Production type	Annual production volume of products *Np*, pcs		
	heavy *M* > 100 kg	medium 10 < *M* < 100 kg	**lightweight** ***M* < 10 kg**
Single production	up to 5	up to 10	**up to 100**
Small batch production	5 – 100	10 – 200	**100 – 500**
Medium batch production	100 – 300	200 – 500	**500 – 5000**
Large batch production	**300 – 1000**	**500 – 5000**	**5000 – 50000**
Mass production	more than 1000	more than 5000	more than 50000

If at the beginning of the design of technological process, the technologist has as a base the existing factory technological process with known time norms, then these norms can be used to determine *K*зо at this stage of the design. According to DSTU 2974-95, the operation consolidation coefficient is defined as the ratio of the number of all different technological operations to be performed within a month to the number of workplaces. Thus, the *K*зо coefficient characterizes the average number of various technological operations carried out at one workplace during a month.

1.3 The steps of work execution

The conditional number of the same type of operations $П_{oi}$ performed on one machine during a month under the condition of working in one shift is determined by the expression:

$$П_{oi} = \frac{\eta_н}{\eta_з},$$

where $\eta_н$ – the planned load factor of the machine by all operations of the same type, $\eta_н = 0{,}8$;

$\eta_з$ – the load factor of the machine by one operation specified during design.

$$\eta_з = \frac{T_{шт-к} \cdot N_M}{60 \cdot F_M \cdot K_B},$$

where K_B – compliance rate, $K_B = 1{,}3$;

$T_{шт-к}$ – piece-calculation time required to perform operations, min.;

N_M – monthly production program of this part when working in one shift, pcs.

$$N_M = \frac{N_p}{2 \cdot 12} = \frac{N_p}{24},$$

where N_p – annual production volume of a given part, pcs. / year.

F_M – monthly fund of equipment operation in one shift, hrs.

$$F_M = \frac{4055}{2 \cdot 12} = 169 \text{ hrs.}$$

The total number of various operations per month at one workplace, taking into account one shift supervisor:

$$\sum П_{O_i} = П_{O_1} + П_{O_2} + П_{O_3} + ... + П_{O_П},$$

where $1,2,...,n$ – numbers of workplaces.

The number of workers per machine, loaded to $\eta_н$ = 0,8 when working in one shift, is determined by the expression:

$$P_{яi} = \frac{N_i \cdot T_i}{К_В \cdot Ф \cdot 60} = \frac{П_{oi} \cdot N_M \cdot T_{шт-к_i}}{К_В \cdot Ф \cdot 60},$$

where $N_i = П_{oi} \cdot N_M$ – volume of production of parts, pcs/month;

$T_i = T_{шт-к_i}$ – piece-calculation time to perform a given operation, min;

$Ф$ – employee's monthly time fund for 22 working days per month, hrs.

$$Ф = 22 \cdot 8 = 176 \text{ hrs}$$

The actual number of workers when working in one shift is determined by adding up the values $P_{я_i}$:

$$\sum P_{я_i} = P_{я_1} + P_{я_2} + P_{я_3} + ... + P_{я_n}.$$

The value of the coefficient of fixation of operations is determined from the expression:

$$K_{з.о.} = \frac{\sum П_{O_i}}{\sum P_{я_i}} = \frac{K_в \cdot Ф \cdot \sum П_{O_i}}{\sum N_i \cdot T_i}$$

Values: Кзо ≤ 1 corresponds to mass production;
1 ≤ Кзо ≤ 10 – large batch production;
10 ≤ Кзо ≤20 – medium batch production;
20 ≤ Кзо ≤ 40 – small batch production;
Кзо > 40 – single production.

Individual tasks for performing the work are listed in the table. 1.2.

Table 1.2 – Output data for calculation

Variant No	No. of parts	Number of operations	$T_{шт-к}$ for operation No., min						*Np*
1	1	5	6	5	8	7	9	-	3000
	2	5	4	7	10	11	5	-	10000
2	3	4	3	7	8	5	-	-	2000
	4	4	5	8	9	6	-	-	8000
3	5	5	7	15	12	10	8	-	1000
	6	5	6	7	8	5	6	-	9000
4	7	6	3	4	3	5	2	4	12000
	8	6	6	7	7	5	6	4	2000
5	9	5	5	6	7	6	7	-	5000
	10	5	6	8	9	6	7	-	15000
6	11	4	3	4	6	5	-	-	7000
	12	4	5	6	7	8	-	-	1500
7	13	5	3	4	5	4	6	-	3500
	14	5	7	6	8	5	7	-	8000
8	15	6	6	7	5	8	5	4	1500
	16	6	8	9	10	7	6	9	5000
9	17	5	8	6	5	7	7	-	15000
	18	5	9	8	6	5	7	-	6000
10	19	4	4	5	5	6	-	-	2000
	20	4	8	10	9	7	-	-	5000

1.4 Control questions

1.4.1 Types of production and their characteristics?
1.4.2 Define the coefficient of fixation of operations? In what cases is it used?
1.4.3 Characteristics of the tabular method of determining the type of production?

LABORATORY WORK №2
CALCULATION OF THE BATCH SIZE IN BATCH PRODUCTION

Duration of scheduled study is 4 hours

2.1 The purpose of the work

Obtaining practical skills for determining the batch size in batch production using a differentiated method.

2.2 General notes

Batch production has become the most widely used in the electrical apparatus manufacturing. Depending on the size of the batches and the frequency of their repetition, small-batch, medium-batch and large-batch production are distinguished [2].

According to DSTU 2974-95, a production batch is defined as items of the same name and size, which are processed within a certain time for the same preparatory and final time for the operation.

The term batch refers to the number of parts, and the series refers to the number of apparatuses or machines that are put into production at the same time. The number of parts in a batch is determined based on production tasks. In batch and mass production, the number of parts in a batch is determined by the number of parts that can be produced between tool changes or material refills.

2.3 The steps of work execution

The differentiated method, which is considered in this laboratory work, involves the implementation of two stages.

During the first stage, two marginal permissible parameters of the batch are calculated – n_1 and n_2. The first parameter is determined from the expression:

$$n_1 = \frac{F_{E.M.} \cdot K_O \cdot K_B}{K_{З.О.} \sum_{i=1}^{K_O} T_i},$$

where $F_{E.M.}$ – effective monthly fund time plot, $F_{E.M.}$ = 10560 min;

K_O – the number of mechanical processing operations according to the technological process;

K_B – the average rate of compliance with the norms in the area, K_B = 1,3;

$K_{З.О.}$ – coefficient of consolidation of operations;

T_i – average labor intensity of one operation, standard minutes, $\sum_{i=1}^{K_O} T_i = T_i \cdot K_O$ – total labor capacity of the technological process.

Parameter n_1 reflects the level of job specialization achieved by the work area, indicators of labor productivity and cost of processing. Parameter n_2 is calculated by the expression:

$$n_2 = \frac{F_{E.M.} \cdot K_{СКЛ} \cdot K_B}{K_{M.O.} \sum_{i=1}^{K_O} T_i},$$

where $K_{СКЛ}$ – coefficient that takes into account the complexity and labor intensity of the part, $K_{СКЛ}$ = 1 for complex and labor-intensive parts and $K_{СКЛ}$ = 0,75 for parts of medium complexity and labor intensity;

$K_{M.O.}$ – coefficient that takes into account the costs of interoperational time.

The coefficient of $K_{M.O.}$ is accepted depending on the dimensions, complexity and number of mechanical processing operations of the part K_O:

1. Large complex parts $K_O > 12$; $K_{M.O.}$ = 0,75;
2. Medium-sized complex parts $4 < K_O < 12$; $K_{M.O.}$ = 1,5;
3. Small simple parts $1 < K_O < 3$; $K_{M.O.}$ = 2,5.

The second parameter n_2 takes into account and limits the permissible volume of unfinished production and binding of working capital.

At the second stage, the values of n_1 and n_2 are analyzed in order to meet the requirements of the technical and organizational order.

An important requirement is to ensure the multiplicity of the batch of parts to the size of the batch of products at the stage of assembly of the $n_{ск}$, as well as the monthly program of the release of N_M:

$$N_M = \frac{N_P}{24}$$

1. The multiplicity of a batch of parts to its size at the assembly stage is ensured by selecting an integer value of the multiplicity factor $n/n_{ск} = K_n = 1, 2, 3, ..., m$. At the same time, the minimum value n of the two previously found values of the batch parameters n_1 and n_2 $n=n_{min}$ is taken for calculation.

2. The multiplicity of the batch of parts to the monthly N_M production program is ensured by establishing for it the normal frequency of repetition of the production of $I_н$.

The production repetition period is the period of time between the launch and release dates of two adjacent batches of a product.

The estimated repetition frequency of the *i*-th details is found from the expression:

$$I_P = \frac{n' \cdot 22}{N_M}$$

The obtained calculated periodicity must be reconciled with its permissible normative values $I_н$:

months	1/22	1/8	1/4	1/2	1	2	3	4	6	8	12
days	1	2,5	5	11	22	44	66	88	132	176	264

The closest of the values of $I_н$ is taken as the accepted frequency of repetition of the production of *i*-th parts $I_{пр}$.

After that, a second batch size adjustment is performed, which is accepted according to the condition:

$$n'' = \frac{I_{np} \cdot N_M}{22} < n_{\max}$$

The size of a batch of products is calculated based on the entire nomenclature of parts of the site. At the same time, the obtained values of I_{np} periodicities within one district should not differ by more than 3-4 consecutive multiple values, for example $I_н$ = 2,5; 5 days etc.

The initial data for performing the work are given in table. 2.1.

Table 2.1 – Output data for calculation

Variant No	$K_{З.О.}$	K_O	N_M	$\sum_{i=1}^{K_O} T_i$	$n_{ск}$
1	4	10	530	50	20
2	7	9	220	63	15
3	2	11	990	58	10
4	2	10	314	168	5
5	2	38	2200	92	5
6	5	12	700	37	10
7	2	19	2000	50	10
8	24	21	40	230	4
9	12	10	150	61	10
10	25	9	60	63	10

2.4 Control questions

2.4.1 What is the significance of the parameters of the batch of products n_1 and n_2? Describe the parameters n_1 and n_2?

2.4.2 Define the production batch?

2.4.3 What is meant by production repetition period or batch rhythm?

LABORATORY WORK №3
DETERMINATION OF MANUFACTURABILITY OF PARTS

Duration of scheduled study is 4 hours

3.1 The purpose of the work

Acquiring practical skills of analysis and assessment of the manufacturability of the design of the part.

3.2 General notes

Manufacturability of the product is a set of properties that determine the possibility of achieving the minimum costs of funds, labor, materials and time in the technological preparation of production, manufacture, operation and repair of products in comparison with similar designs of the same purpose at a given level of quality and accepted conditions of production, operation and repair

A design that satisfies the given conditions is called technological, and work to improve the manufacturability of the product design is called testing the design for manufacturability.

At the same time, the *qualitative* assessment of the manufacturability of the product characterizes the manufacturability in general based on the experience of creating similar products, and the *quantitative* assessment is expressed by an indicator, the numerical value of which characterizes the level of satisfaction with the requirements for the manufacturability of the design.

The technological efficiency of parts of electrical apparatus that are subject to mechanical processing is expressed as follows:

1. The structural form of the parts should be simple, and the processed surfaces should have the shape of bodies of rotation or planes, which allows them to be processed in the most simple and productive ways.

2. The volume of mechanical processing of parts should be the smallest. This is achieved by reducing the number of processed surfaces and the amount of processing allowances.

3. The design of the parts must be rigid enough to exclude the influence of deforming forces on its accuracy when using increased cutting modes.

4. The design of the part should be such that it is convenient to process, fix and measure it.

5. The use of complex curved and shaped surfaces should be avoided, as they complicate processing and require the use of special equipment and tools.

6. The treated surfaces are made protruding above the untreated ones. This ensures the output of the cutting tool and reduces the size of the surface to be processed.

7. Surfaces to be processed should be placed on the same level if possible. This speeds up the production of the part because it does not require re-installation and readjustment of the part and the tool.

8. The surfaces adjacent to the processed areas are made perpendicular to the processed plane, if possible, so that the dimensions of the contours obtained during processing do not change.

9. Surfaces to be processed by drilling are provided with bosses and end planes, which must be perpendicular to the axis of the drill. This ensures the correct entry and exit of the tool and prevents it from breaking.

10. If the design does not provide for a free exit of the cutting tool, then the transition part must correspond to the shape and dimensions of the cutting tool.

11. When designing parts, it is necessary to ensure that the places where the cutting tool is processed are accessible for its entry and exit, with the exception of cases where a thread run-out is provided.

3.3 The steps of work execution

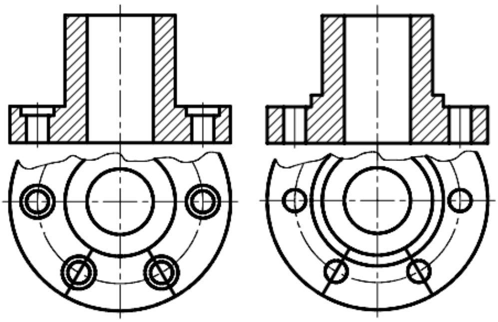
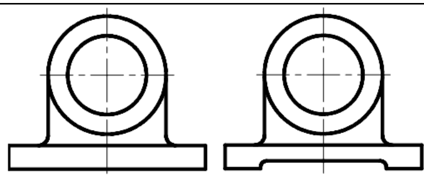
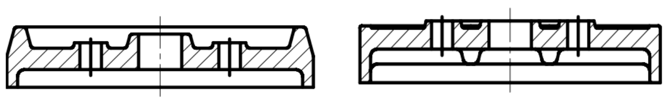
3.3.1 Qualitative analysis of the manufacturability

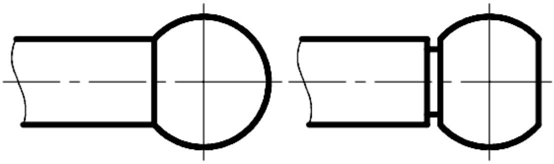
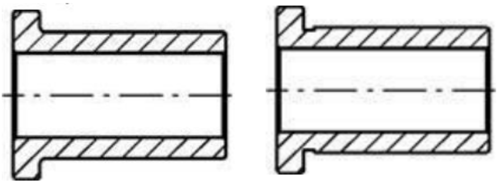
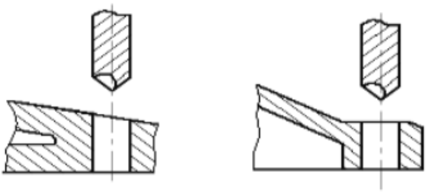
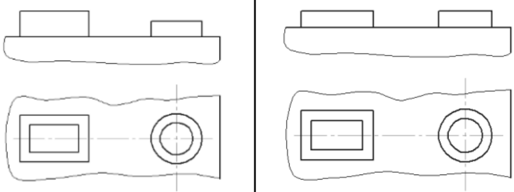
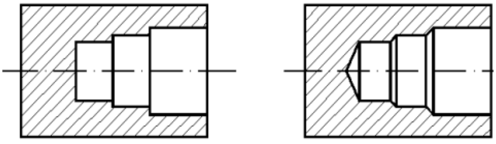
One and the same structural element of an electrical apparatus part may have a different design. Possible design options are presented by two figures in table 3.2. It is necessary to carry out a qualitative analysis of the compared designs for manufacturability and justify the choice of the design element of the part.

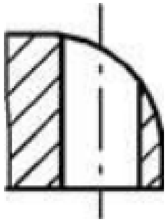
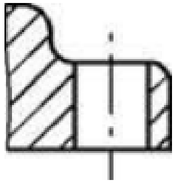
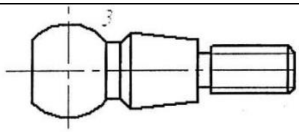
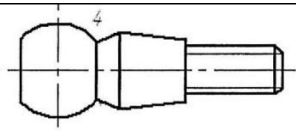
Table 3.1 – Input data for qualitative analysis of manufacturability

Variant No	Task
1	1,2,3
2	4,5,6
3	7,8,9
4	10,1,2
5	3,4,5
6	6,7,8
7	9,10,1
8	2,3,4
9	5,6,7
10	8,9,10

Table 3.2 – Designs of parts for qualitative analysis of manufacturability

№	Task
1	 a b
2	 a b
3	 a b

4	 a b
5	 a b
6	 a b
7	 a b
8	 a b

9	 a  b
10	 a  b

3.3.2 Quantitative analysis of the manufacturability of the part

It is necessary to determine the quantitative indicators of the manufacturability of the developed part and compare them with the indicators of the analogue part. The main characteristics of the developed part, the workpiece and the characteristics of the analogue part are given in Table. 3.3.

The main indicators of the manufacturability of the design include:

1. The level of manufacturability of the structure according to the labor intensity of production:

$$K_{у.п.} = \frac{T_i}{T_{б.а.}}$$

2. The level of manufacturability of the design according to the technological cost:

$$K_{у.с.} = \frac{C_т}{C_{б.т.}}$$

3. The level of manufacturability according to the coefficient of unification of the structural elements of the part:

$$K_{у.е.} = \frac{Q_{у.е.}}{Q_в}$$

The part is considered technological according to this feature if $K_{у.е.} \geq 6$.

4. The level of manufacturability according to the material utilization factor:

$$K_{в.м.} = \frac{m_д}{m_з}$$

Table 3.3 – Output data for quantitative analysis of manufacturability

Variant	The number of surfaces of the part Q_e	Number of unified elements $Q_{у.е.}$	Weight, kg		labor intensity, min		Cost, hryvnias	
			Part, $m_д$	Output workpiece, $m_з$	Part, T_i	Analog, $T_{б.а.}$	Part, C_m	Analog, $C_{б.т.}$
1	19	12	0,8	1,1	28	31	1,7	2,1
2	28	17	0,3	0,4	16	24	0,9	1,3
3	73	45	3,1	3,8	78	86	3,4	4,1
4	41	27	0,2	0,4	31	39	1,2	1,4
5	55	40	4,8	5,5	68	89	4,8	5,3
6	25	18	1,1	1,4	35	38	5,6	7
7	31	15	5,2	4,9	25	26	3,5	4,1
8	28	26	0,2	0,3	18	23	8,1	8,3
9	75	70	4,8	5,1	75	80	2,3	2,5
10	55	40	5,5	6	31	35	3,1	3,4

3.4 Control questions

3.4.1 What is the manufacturability of the part?

3.4.2 How is the qualitative analysis of the manufacturability of the product carried out?

3.4.3 According to what indicators is the quantitative assessment of the manufacturability of the product?

LABORATORY WORK №4
STUDY OF THE PROCESSING ROUTE OF ELEMENTARY PART SURFACES

Duration of scheduled study is 4 hours

4.1 The purpose of the work

Study of the theoretical and practical foundations for determining the methods and number of stages for processing the surfaces of parts.

4.2 General notes

Different surfaces have different requirements, which are provided by different processing methods, moreover, the same requirements can be satisfied with different sets of technological processing methods. Therefore, the development of surface treatment methods and routes is a difficult and responsible stage in the development of a technological process [3].

Currently, there is a fairly large number of various technological methods that allow you to achieve approximately the same processing results, however, they can differ significantly in cost of implementation and are therefore rational in different types of production [1].

Based on this, the technologist can develop several options for the processing route for each specific surface. The technological methods that make up these processing routes can differ significantly in cost and labor intensity of implementation, which indicates the multivariate technological design for one surface and even more so for the entire product as a whole.

In the process of transforming the surface of the workpiece into the finished surface of the part, a new surface with its own dimensions, roughness and dimensional relationships with other surfaces appears after each processing method.

This can be presented in the form of a graph or a table. The vertices of the graph symbolize the surfaces of the part, and the edges of the graph characterize the processing methods that are part of the surface processing route and transfer the surface from state i (number of the previous surface) to state j (number of the next state of the surface). The edges of the graph can be assigned both the names of the processing method (names of technological transitions) – the technological option of the graph, and the cost of their implementation – the economic option of the graph. There are two possible ways of finding a solution for the development of a surface treatment route: based on refinement calculations and by using typical surface treatment plans recommended by handbooks and technical literature [3].

4.3 The steps of work execution

The elementary external surface of rotation of the part with a diameter of $d_Д$ is made from a workpiece with a diameter of d_0.

It is necessary to analyze the raw data; determine the number of technological transitions to achieve the given degree size accuracy; set the accuracy of intermediate dimensions.

Table 4.1 – Output data for calculation

Variant	Type of initial workpiece	The diameter of the initial workpiece d_0, mm	The diameter of the part $d_Д$, mm
1	Forging on a radial forging machine	48js13	46n6
2	Casting in a shell mold	73js11	70f7
3	Casting	90±0,6	85s6
4	Stamped forging	$81{,}2^{+2{,}1}_{-1{,}1}$	75k6
5	Casting according to the molten model	35js10	33m7
6	Casting	150±3	142e8
7	Rolled hot-rolled steel	$90^{+0{,}5}_{-1{,}3}$	85r6
8	Free forging forging	184±3	160g6
9	Calibrated rolled metal	56h10	55f7
10	Mold casting	49js14	45n6

Example solution. The elementary surface of the shaft step with a diameter of $\varnothing 85^{+0{,}059}_{+0{,}037}$ is made from a stamped forging of increased accuracy with a diameter of $\varnothing 91{,}2^{+1{,}3}_{-0{,}7}$.

During the analysis, we establish that in the process of mechanical processing of the analyzed surface, the tolerance of the diameter of the initial workpiece T_{d0} = 2 mm decreases to the tolerance of the diameter of the part $T_{dД}$ = 0,022 mm (the size accuracy increases accordingly). At the same time, the overall gain of size accuracy is calculated by the expression:

$$K_{пос.розм.заг.} = \frac{T_{d0}}{T_D} = \frac{2}{0,022} = 90.$$

The number of necessary technological transitions is determined by the expression:

$$n = \frac{\lg K_{пос.розм.заг.}}{0,46} = \frac{1,9542}{0,46} = 4,2\ .$$

We take the value n=4. The workpiece diameter tolerance T_{d0} = 2 mm corresponds to approximately the 16 tolerance grade, and the part size tolerance corresponds to the 6 tolerance grade. Therefore, the accuracy increases by 16–6 = 10 tolerance grades. According to the accepted four technological transitions, we distribute it according to the law of progressive reduction: 10 = 4 + 3 + 2 + 1. The accuracy of the intermediate dimensions of the workpiece in the process of mechanical processing will correspond to:

after the 1st transition to the 12 tolerance grade (h12);
» 2nd" » 9th" (h9.);
» 3rd » 7th" (h7);
» 4th » 6th » (h6).

4.4 Control questions

4.4.1 Define the term "surfacing treatment route"?

4.4.2 The principle of determining the optimal route of surface treatment?

4.4.3 Name the two possible ways of determining the optimal route of surface treatment?

LABORATORY WORK №5
DETERMINATION OF THE CUTTING MODE FOR DRILLING, COUNTERING AND REAMING

Duration of scheduled study is 4 hours

5.1 The purpose of the work

Selection of a cutting tool and determination of cutting modes for drilling, countersinking and reaming.

5.2 General notes

The mode of processing the surfaces of the workpiece is the most important factor in the execution of the technological process, which directly affects the quality of the products [1].

The starting data for determining the cutting mode are [1, 3]:

– information about the workpiece – drawings and technical conditions, material and its characteristics (brand, condition, mechanical properties); allowances and the nature of their placement; the state of the surface layer (presence of a crust, scale, hardening, etc.);

– information about the part – working drawing and technical conditions; shape, dimensions and processing tolerances; permissible deviations from the geometric shape (ovality, conicity, cutting, etc.); permissible errors of mutual placement of individual surfaces; requirements for the condition of the surface layer, including the roughness of the surfaces;

– information about the cutting tools (material and geometry of the cutting part);

– passport data of machines regarding values of spindle rotation frequencies, feed values, etc.;

– information about the processing stage (rough, semi-finished, etc.).

5.3 The steps of work execution

On the vertical drilling machine 2H135, make a through hole with a diameter of 25H9 (Ra = 1,6 μm), l = 125 mm. The material of the workpiece is gray cast iron СЧ18, HB210.

Passport data of the vertical drilling machine 2H135

Engine power $N_д$ = 4,5 kW.

The efficiency factor of the machine 0,8.

Spindle rotation frequency, rpm:31,5; 45; 63; 90; 125; 180; 250; 355; 500; 710; 1000; 1440.

Feed rate, mm/rev: 0,1; 0,14; 0,2; 0,28; 0,4; 0,56; 0,8; 1,12; 1,6.

The maximum axial cutting force allowed by the feed mechanism of the machine P_{max} = 15000 H.

Selection of grinding wheel parameters for different grinding conditions (wheel speed V = 35 m/s).

The task consists in choosing a cutting tool, assigning cutting modes according to standard tables and determining the main time.

5.3.1 Selection of a cutting tool

According to the initial data, the operation is performed in three transitions – drilling, countersinking and reaming. Taking into account the allowance for drilling gray cast iron ЧЧ 18 HB 210, we choose drills D = 23 mm; for countersinking – one-piece countersink D = 24,8 mm, for reaming – one-piece countersink D = 25 mm (Table 5.1).

5.3.2 Selection of cutting mode

The first transition. Selection of drilling feed rate. For drilling cast iron HB 210 with a tool 23 mm in diameter, select the feed rate S = 0,47 - 0,54 mm/rev. Taking into account the correction factor for the drilling length K_{ls} = 0.9, we get the estimated feed rate values S = 0,42-0,48mm/rev (Table 5.2). According to the machine's passport, we set the nearest feed rate S = 0,4 mm/rev.

Selection of speed and number of revolutions.

$$V = \frac{C_V D^q}{T^m S^y} K_V$$

where C_V – the coefficient that determines the processing conditions, including the brand of the material of the cutting tool C_V = 17,1;

m = 0,125, *q* = 0,25, *y* = 0,4 – degree indicators (Table 5.3) – the average value of the stability of the cutting tool (the period of operation of the tool before blunting);

T = 75 (Table 5.4);

K_V – generalized correction factor that takes into account changes in processing conditions in relation to the tabular ones:

$$K_V = K_{M_V} \cdot K_{U_V} \cdot K_{l_V}$$

where K_{MV} – coefficient that takes into account the influence of the material of the workpiece, for cast irons.

$$K_{M_V} = \left(\frac{190}{HB}\right)^{n_v} = \left(\frac{190}{210}\right)^{1,3} = 0,87$$

where n_v = 1,3 according to Table 5.5.

For steel, the expression will look like this:

$$K_{M_V} = K_{\text{г}}\left(\frac{750}{\sigma_{\text{в}}}\right)^{n_v}$$

K_{U_V} =1 – coefficient that takes into account the material of the tool (Table 5.6)

K_{l_V} = 0,75 – coefficient that takes into account the length of the hole (Table 5.7)

$$K_V = 0,87 \cdot 1 \cdot 0,75 = 0,65$$

$$V = \frac{17,1 \cdot 23^{0,25}}{75^{0,125} \cdot 0,4^{0,4}} \cdot 0,65 = 20,45 \text{ m/min}$$

When setting up the machine, it is necessary to set the spindle rotation frequency, which provides the estimated cutting speed:

$$n = \frac{1000V}{\pi D} = \frac{1000 \cdot 20{,}45}{3{,}14 \cdot 23} = 283{,}2 \text{ rpm}$$

where V – estimated cutting speed, m/min;
D – diameter of the tool, mm.

We accept according to the passport of the machine n = 250 rpm
Actual cutting speed:

$$V = \frac{\pi \cdot D \cdot n}{1000} = \frac{3.14 \cdot 23 \cdot 250}{1000} = 18 \text{ m/min.}$$

Torque when drilling:

$$M_k = 10 \cdot C_м \cdot D^q \cdot S^y \cdot K_p =$$
$$= 10 \cdot 0{,}021 \cdot 23^2 \cdot 0{,}4^{0{,}8} \cdot 1{,}06 = 56{,}52 \text{ N·m}$$

where $C_м$ = 0,021; q = 2; y = 0,8 (Table 5.8).

$$K_p = K_{Mp} = \left(\frac{210}{190}\right)^{0{,}6} = 1{,}06$$

Axial force during drilling (Table 5.8):

$$P_o = 10 \cdot C_p \cdot D^q \cdot S^y \cdot K_p =$$
$$= 10 \cdot 42{,}7 \cdot 23 \cdot 0{,}4^{0{,}8} \cdot 1{,}06 = 4996{,}9H$$

According to the machine's passport, the maximum force allowed by the feed mechanism is 15,000 N.

Checking the selected mode for axial force and power.
The cutting power is calculated according to the expression:

$$N_e = \frac{M_{кр} \cdot n}{9750} = \frac{56{,}52 \cdot 250}{9750} = 1{,}45$$

where $M_{кр}$ – torque, N·m;
n – number of revolutions, rpm

According to the passport of the machine, the power on the spindle:
$N_э = N_д \cdot \eta = 4{,}5 \cdot 0{,}8 = 3{,}6$ kW
$N_э = 3{,}6 > N = 1{,}45$ kW
Therefore, the machine can provide the specified cutting mode.
The second transition. Cutting depth:

$$t = \frac{D-d}{2} = \frac{24{,}8-23}{2} = 0{,}9 \text{ mm}$$

Choice of feed (Table 5.9). For countersinking a hole in gray cast iron HB 210 with a countersink with a diameter of 24,8 mm, when the hole is subsequently processed with one sweep, it is recommended to feed rate S = 0.7 – 0.8 mm / rev.
$K_{OS} = 0{,}7$
$S = 0{,}7 \cdot 0{,}8 = 0{,}56$ mm / vol
The nearest application according to the passport of the machine S = 0,56 mm / vol

Selection of cutting speed and number of revolutions (taking into account the data of Table 5.10):

$$V = \frac{C_V D^q}{T^m t^x S^y} K_V = \frac{18{,}8 \cdot 24{,}8^{0,2}}{40^{0,125} \cdot 0{,}9^{0,1} \cdot 0{,}56^{0,4}} \cdot 0{,}65 = 29{,}28 \text{ m/min}$$

Machine spindle speed:

$$n = \frac{1000V}{\pi D} = \frac{1000 \cdot 29{,}28}{3{,}14 \cdot 24{,}8} = 376 \text{ rpm}$$

According to the passport of the machine, we take n = 355 rpm.

Actual cutting speed:

$$V = \frac{\pi \cdot D \cdot n}{1000} = \frac{3.14 \cdot 24.8 \cdot 355}{1000} = 27{,}64 \text{ m/min}$$

Torque when drilling:

$$M_k = 10 \cdot C_m \cdot D^q \cdot t^x \cdot S^y \cdot K_p =$$
$$= 10 \cdot 0{,}085 \cdot 24{,}8 \cdot 0{,}9^{0{,}75} \cdot 0{,}56^{0{,}8} \cdot 1{,}06 = 12{,}95 \text{ N·m}$$

where C_m = 0,085; x = 0,75; y = 0,8 (Table 5.8)

$$K_p = K_{Mp} = \left(\frac{210}{190}\right)^{0{,}6} = 1{,}06$$

Axial force during drilling

$$P_o = 10 \cdot C_p \cdot t^x \cdot D^q \cdot S^y \cdot K_p =$$
$$= 10 \cdot 23{,}5 \cdot 0{,}9^{1.2} \cdot 0{,}4^{0{,}4} \cdot 1{,}06 = 151{,}25$$

According to the machine's passport, the maximum force allowed by the feed mechanism is 15000 H.

Checking the selected mode for axial force and power.

The cutting power is calculated according to the formula:

$$N_e = \frac{M_{кр} \cdot n}{9750} = \frac{12{,}95 \cdot 376}{9750} = 0{,}5$$

According to the passport of the machine, the power on the spindle:

$N_э = N_д \cdot \eta = 4{,}5 \cdot 0{,}8 = 3{,}6$ kW

$N_э = 3{,}6 > N = 0{,}5$ kW

Therefore, the machine can provide the specified cutting mode.

The third transition. Cutting depth:

$$t = \frac{D-d}{2} = \frac{25-24{,}8}{2} = 0{,}1 \text{ mm}$$

Selection of feed rate (Table 5.3). For countersinking a hole in gray cast iron HB > 210 with a mechanical reamer with a diameter of 25 mm, the feed S = 2,2·0,8 = 1,76 mm / rev is recommended.

K_{OS} = 0,8

The nearest application according to the passport of the machine S = 1,6 mm / vol

Selection of cutting speed and number of revolutions (according to Table 5.4 and Table 5.10):

$$V = \frac{C_V D^q}{T^m t^x S^y} K_V = \frac{15{,}6 \cdot 25^{0,2}}{60^{0,3} \cdot 0{,}1^{0,1} \cdot 1{,}6^{0,5}} \cdot 0{,}65 = 5{,}7 \text{ m/min}$$

Machine spindle speed:

$$n = \frac{1000V}{\pi D} = \frac{1000 \cdot 5{,}7}{3{,}14 \cdot 25} = 72{,}6 \text{ rpm}$$

According to the passport of the machine, we take n = 63 rpm.

Actual cutting speed:

$$V = \frac{\pi \cdot D \cdot n}{1000} = \frac{3.14 \cdot 25 \cdot 72{,}6}{1000} = 5{,}7 \text{ m/min}$$

Checking the selected mode for axial force and power is not performed.

5.3.3 Determination of the main (technological) time

The size of the cut-in and overrun of the tools l_1 during work on the passage for the drill is equal to 6 mm; for countersink 6 mm and for reaming 20 mm.

With the hole length l = 125 mm, the basic (technological) time of each transition is equal to:

$$T_{01} = \frac{l + l_1}{S \cdot n} = \frac{125 + 6}{0{,}4 \cdot 250} = 1{,}31$$

$$T_{02} = \frac{l + l_1}{S \cdot n} = \frac{125 + 6}{0{,}56 \cdot 355} = 0{,}66$$

$$T_{03} = \frac{l + l_1}{S \cdot n} = \frac{125 + 20}{1{,}6 \cdot 63} = 1{,}44$$

$$T_0 = T_{01} + T_{02} + T_{03} = 1{,}31 + 0{,}66 + 1{,}44 = 3{,}41 \text{ min}$$

The initial data for performing the work are given in Table. 5.11.

Table 5.1 – Sizes of holes after boring when processing holes of 9 quality in solid material

Diameter of the hole being processed, mm	Diameter, mm				
	Drills		Hole after boring	counter sink	Reamers for hole quality 9 (H9)
	1st	2nd			
3	2,9	-	-	-	3
4	3,9	-	-	-	4
5	4,8	-	-	-	5
6	5,8	-	-	-	6
8	7,8	-	-	-	8
10	9,8	-	-	-	10
12	11	-	-	11,85	12
13	12	-	-	12,85	13

Continuation of table 5.1

14	13	-	-	13,85	14
15	14	-	-	14,85	15
16	15	-	-	15,85	16
18	17	-	-	17,85	18
20	18	-	19,8	79,8	20
22	20	-	21,8	21,8	22
24	22	-	23,8	23,8	24
25	23	-	24,8	24,8	25
26	24	-	25,8	25,8	26
28	26	-	27,8	27,8	28
30	18	28	28,8	29,8	30
32	20	30	31,7	31,75	32
35	20	33	34,7	34,75	35
38	25	36	37,7	37,75	38
40	25	38	39,7	39,75	40
42	25	40	41,7	41,75	42
45	25	43	44,7	44,75	45
48	25	46	47,7	47,75	48
50	25	48	47,7	49,75	50

Table 5.2 – Feeds mm/rev when drilling steel, cast iron, copper and aluminum alloys with high-speed steel drills

Drill diameter, mm	Steel				Gray and malleable	
	HB < 160	HB 160 – 240	HB 240 – 300	HB > 300	HB < 170	HB > 170
2-4	0,09-0,13	0,08-0,10	0,06-0,07	0,04-0,06	0,12-0,18	0,09-0,12
4-6	0,13-0,19	0,10-0,15	0,07-0,11	0,06-0,09	0,18-0,27	0,12-0,18
6-8	0,19-0,26	0,15-0,20	0,11-0,14	0,09-0,12	0,27-0,36	0,18-0,24
8-10	0,26-0,32	0,20-0,25	0,14-0,17	0,12-0,15	0,36-0,45	0,24-0,31
10-12	0,32-0,36	0,25-0,28	0,17-0,20	0,15-0,17	0,45-0,55	0,31-0,35
12-16	0,36-0,43	0,28-0,33	0,20-0,23	0,17-0,20	0,55-0,66	0,35-0,41
16-20	0,43-0,49	0,33-0,38	0,23-0,27	0,20-0,23	0,66-0,76	0,41-0,47
20-25	0,49-0,58	0,38-0,43	0,27-0,32	0,23-0,26	0,76-0,89	0,47-0,54
25-30	0,58-0,62	0,43-0,48	0,32-0,35	0,26-0,29	0,89-0,96	0,54-0,60
30-40	0,62-0,78	0,48-0,58	0,35-0,42	0,29-0,35	0,96-1,19	0,60-0,71
40-50	0,78-0,89	0,58-0,66	0,42-0,48	0,35-0,40	1,19-1,36	0,71-0,81

Table 5.3 – The value of the C_V coefficient and degree indicators in the formula for the cutting speed when drilling

The material being processed	Material of the cutting part of the tool	Feed rate mm/rev	Coefficient and degree indicators			
			C_V	q	y	m
Structural carbon steel	P6M5	≤ 0,2 > 0,2	7,0 9,8	0,40	0,70 0,50	0,20
Gray cast iron		≤ 0,3 > 0,3	14,7 17,1	0,25	0,55 0,40	0,125

Table 5.4 – Average values of the stability period of drills, countersinks and reamers

Tool	The material being processed	Material of the cutting part	Resistance *T*, min., at the diameter of the tool, mm							
			< 5	6-10	11-20	21-30	31-40	41-50	51-60	61-80
drill bit	Structural, carbon and alloy steel	High-speed steel	15	25	45	50	70	90	110	-
		Solid alloy	8	15	20	25	35	45	-	-
	Corrosion-resistant steel	High-speed steel	6	8	15	25	-	-	-	-
drill bit	Gray and ductile iron, copper and aluminum alloys	High-speed steel	20	35	60	75	105	140	170	-
		Solid alloy	15	25	45	50	70	90	-	-
Countersinks	Structural, carbon and alloy steel, gray and ductile iron	High-speed steel and hard alloy	-	-	30	40	50	60	80	100
Розгортки	Structural, carbon and alloy steel	High-speed steel	-	25	40	80	80	120	120	120
		Solid alloy	-	20	30	50	70	90	110	140
	Gray and malleable cast iron	High-speed steel	-	-	60	120	120	180	180	180
		Solid alloy	-	-	45	75	105	135	165	210

Table 5.5 – The value of the K_r coefficient and the degree indicator n_v for the calculation of the K_{MV} coefficient

The material being processed	coefficient K_r	degree indicator n_v
Carbon steel $\sigma_в$ < 550	1,0	-0,9
Carbon steel $\sigma_в$ > 550	1,0	0,9
Gray cast iron	–	1,3

Table 5.6 – Correction factor K_{U_V} that takes into account the influence of the tool material on the cutting speed

Material	The value of the coefficient K_{U_V} depends on the tool material						
Structural steel	Т5К12В	Т5К10	Т14К8	Т15К6	Т15К6	Т30К4	ВК8
	0,35	0,65	0,8	1,00	1,15	1,4	0,4
Corrosion-resistant and heat-resistant steels	ВК8	Т5К10	Т15К6	Р18	-	-	-
	1,0	1,4	1,9	0,3	-	-	-
Hardened steel	35…50 HRC				51…62 HRC		
	Т15К6	Т30К4	ВК6	ВК8	ВК4	ВК6	ВК8
	1,0	1,25	0,85	0,83	1,0	0,92	0,74
Gray and malleable cast iron	ВК8	ВК6	ВК4	ВК3	ВК3	-	-
	0,83	1,0	1,1	1,15	1,25	-	-
Steel, cast iron, copper and aluminum alloys	Р6М5	ВК4	ВК6	9ХС	ХВГ	У12А	-
	1,0	2,5	2,7	0,6	0,6	0,5	-

Table 5.7 – Correction factor K_{l_V}

Parameter	Drilling					Drilling, countersinking, reaming
The depth of the hole being machined	3D	4D	5D	6D	8D	–
coefficient K_{l_V}	1,0	0,85	0,75	0,7	0,6	1,0

Table 5.8 – Values of coefficients and degree indicators in the formulas of torque and axial force during drilling, undrilling and reaming

The material being processed	Operation	Material of the cutting part of the tool	Coefficient and power exponents in formulas							
			A turning point				Axial force			
			$C_м$	*q*	*x*	*y*	C_p	*q*	*x*	*y*
Structural carbon steel $\sigma_в$ = 750 MPa	Drilling	High-speed steel	0,0345	2	-	0,8	68	1	-	0,7
	Drilling and countersinking		0,09	1	0,9	0,8	67	-	1,2	0,65
Heat-resistant steel 12X18H9T, HB 141	Drilling		0,041	2	-	0,7	143	1,0	-	0,7
	drilling and countersinking		0,106	1,0	0,9	0,8	140	-	1,2	0,65
Gray cast iron, HB 190	Drilling	Solid alloy	0,012	2,2	-	0,8	42	1,2	-	0,75
	Drilling and countersinking		0,196	0,85	0,8	0,7	46	-	1,0	0,4
	Drilling	High-speed steel	0,021	2	-	0,8	42,7	1,0	-	0,8
	Drilling and countersinking		0,085	-	0,75	0,8	23,5	-	1,2	0,4

Table 5.9 – Feed when processing holes with countersinks made of high-speed steel and hard alloy

The material being processed	Countersink diameter D, mm								
	By 15	By 20	By 25	By 30	By 35	By 40	By 50	By 60	By 80
Steel	0,5-0,6	0,6-0,7	0,7-0,9	0,8-1,0	0,9-1,1	0,9-1,2	1,0-1,31	1,1-1,3	1,2-1,5
Cast iron HB<200	0,7-0,9	0,9-1,1	1,0-1,2	1,1-1,3	1,2-1,5	1,4-1,7	1,6-2,0	1,8-2,2	2,0-2,4
Cast iron HB>200	0,5-0,6	0,6-0,7	0,7-0,8	0,8-0,9	0,9-1,1	1,0-1,2	1,2-1,4	1,3-1,5	1,4-1,5

Table 5.10 – The value of the C_V factor and degree indicators in the cutting speed formula for reaming, countersinking and reaming

The material being processed	Type of processing	Material of the cutting part of the tool	Coefficient and degree indicators				
			C_V	Q	x	y	m
Structural carbon steel	Drilling	P6M5 BK8	16,2 10,8	0,4 0,6	0,2	0,5 0,3	0,2 0,25
	Countersinking	P6M5 T15K6	16,3 18,0	0,3 0,6	0,2	0,5 0,3	0,3 0,25
	Reaming	P6M5 T15K6	10,5 100,6	0,3 0,3	0,2 0	0,65 0,65	0,4
Gray cast iron	Drilling	P6M5 BK8	23,4 56,9	0,25 0,5	0,1 0,15	0,4 0,45	0,125 0,4
	Countersinking	P6M5 BK8	18,8 105,0	0,2 0,4	0,1 0,15	0,4 0,45	0,125 0,4
	Reaming	P6M5 BK8	15,6 109,0	0,2 0,2	0,1 0	0,5 0,5	0,3 0,45

Table 5.11 – Output data for work

Variant	Hole size l, mm	Hole diameter D, mm	Workpiece material
1	80	30H9	Gray cast iron СЧ30, HB 200
2	55	28H9	Steel 38XA, $\sigma_в$ = 680 MPa
3	45	45H9	Gray cast iron СЧ15, HB 170
4	100	44H9	Steel 40XH, $\sigma_в$ = 700 MPa
5	95	22H9	Steel 40X, $\sigma_в$ = 750 MPa
6	85	38H9	Gray cast iron СЧ20, HB 180
7	40	20H9	Steel 20X, $\sigma_в$ = 580 MPa
8	45	23H9	Gray cast iron СЧ30, HB 220
9	50	18H9	Steel 12XH2, $\sigma_в$ = 800 MPa
10	90	35H9	Gray cast iron СЧ120, HB210

5.4 Control questions

5.4.1 What parameters of mechanical processing are called cutting mode?

5.4.2 Define cutting depth, feed rate and cutting speed?

5.4.3 What are the initial data when determining the cutting mode?

LABORATORY WORK №6
DETERMINATION OF RELIABILITY OF TECHNOLOGICAL SYSTEMS ACCORDING TO ACCURACY PARAMETERS

Duration of scheduled study is 4 hours

6.1 The purpose of the work

Determining the possibility of using the developed technological process for the manufacture of products with the required quality parameters.

6.2 General notes

A technological system can be imagined as a set of 7 components. Machining accuracy depends on all components of the technological system – machine, tool, workpiece, fixture, environment and operator.

Calculation methods for assessing the accuracy of technological systems are based:

– on the use of mathematical models for measuring product quality parameters or technological process parameters, taking into account the nature of failures and data on the properties of technological systems of this class.

– on the use of data on patterns of changes over time in factors that affect one or several parameters of product quality at the same time.

6.3 The steps of work execution

6.3.1 Using the initial data given in Table. 6.2 determine the value of the total error (scattering field) of the controlled parameter:

$$\omega = K \cdot \sqrt{\lambda_1 \cdot \Delta_1^2 + \lambda_2 \cdot \Delta_2^2 + ... + \lambda_n \cdot \Delta_n^2}$$

where Δ_1, Δ_2, Δ_n, – limit values of elementary errors;

K – risk factor;

λ_1, λ_2, λ_n – coefficients that take into account the law of distribution of elementary errors when they are equally likely to exceed both limits of the tolerance field. For the normal distribution law λ_1, λ_2, λ_n = 0,111.

6.3.2 Based on the found value of ω and the given tolerance on the controlled parameter T, calculate the accuracy coefficient K_m according to the expression:

$$K_m = \frac{\omega}{T}$$

where ω – total elementary processing error;

T – tolerance on the controlled parameter.

Table 6.1 – Values of coefficient *K*

P, %	32,00	10,00	4,50	1,00	0,27	0,10	0,01
K	1,00	1,65	2,00	2,57	3,00	3,29	3,89

6.3.3 It is necessary to analyze the results obtained and draw a conclusion about the accuracy of the operation based on the value of the accuracy coefficient.

6.3.4 Using the values of $x(t)$ and x_0, calculate the average deviation of the controlled parameter relative to the middle of the tolerance field using the expression:

$$\overline{\Delta}(t) = \left| \bar{x}(t) - x_0 \right|$$

where $x(t)$ – average value of the controlled size;

x_0 – the value of the controlled size, which corresponds to the middle of the tolerance field (with a symmetrical tolerance field, it coincides with the nominal values).

Table 6.2 – Output data for calculating the accuracy factor

Output data, μm	Variant									
	1	2	3	4	5	6	7	8	9	10
Geometric errors of the machine	40	30	35	45	50	45	35	40	50	55
Technological positioning error	60	0	50	45	65	65	0	55	50	70
Fixation	30	20	35	15	40	35	25	40	20	45
Device manufacturing error	30	20	15	25	10	35	25	20	30	15
Tool manufacturing error	5	0	10	0	15	10	5	15	5	20
Error setting the cutter to size	50	40	20	15	30	60	50	30	25	40
Error due to dimensional wear of the tool	15	0	5	20	10	20	10	10	25	20
Measurement error	100	90	60	40	50	105	95	65	45	55
Error caused by elastic deformations under the action of cutting forces	40	30	25	35	20	45	35	30	40	25
Tolerance on the controlled parameter	330	200	150	250	50	340	210	160	260	60
Acceptable risk	1,00	0,27	0,10	1,00	0,27	1,00	0,27	0,10	1,00	0,27

6.3.5 Using the values $\overline{\Delta}(t)$ and T, calculate the coefficient of displacement of the instantaneous parameter:

$$K_C = \frac{\overline{\Delta}(t)}{T}$$

where $\overline{\Delta}(t)$ – the average value of the deviation of the controlled parameter relative to the middle of the tolerance field at the moment of time *t*:

6.3.6 Using the values of ω(*t*) and *T*, determine the instantaneous scattering coefficient $K_p(t)$:

$$K_p(t) = \frac{\omega(t)}{T}$$

where ω(*t*) – the scattering field of the controlled parameter at time *t*.

Accuracy margin factor:

$$K_з(t) = 0{,}5 - K_C(t) - 0{,}5K_p(t)$$

Analyze the obtained result and draw a conclusion about the accuracy of the operation. The obtained value of the margin of accuracy must be greater than 0. A negative value of the margin of accuracy indicates the absence of a margin of accuracy for the monitored parameter.

Table 6.3 – Output data for calculating the value of the margin of accuracy

Variant	Output data, mm			
	Controlled size	Tolerance value *T*	Average value of controlled size *x*(*t*)	Dispersion field ω(*T*)
1	40±0,8	0,16	40,05	0,12
2	$50^{+0,039}$	0,39	50,3	0,1
3	$75_{-0,46}$	0,46	74,7	0,1
4	$100^{+0,22}$	0,22	100,1	0,08
5	$150^{+0,4}$	0,4	150,3	0,06
6	30±0,12	0,24	30,05	0,15
7	$60^{+0,040}$	0,40	60,3	0,3
8	$100^{+0,46}$	0,46	100,2	0,1
9	80±0,22	0,44	80,05	0,16
10	$150^{+0,2}$	0,2	150,2	0,08

6.4 Control questions

6.4.1 What elementary errors make up the total error of the controlled parameter?
6.4.2 How is the accuracy factor determined?
6.4.3 Describe the calculation methods for determining the reliability of technological systems?

LABORATORY WORK №7
DETERMINATION OF THE MAIN PARAMETERS OF THE ASSEMBLY CONVEYOR

Duration of scheduled study is 4 hours

7.1 The purpose of the work

Study of the basic principles of designing assembly processes and determining the main parameters of the assembly line.

7.2 General notes

Assembly is the final stage of the manufacturing process, which largely depends on the quality of the products and their release on time. Nowadays, the labor intensity of assembly work in mechanical engineering in general and in electrical apparatus construction in particular is 25-30% of the total labor intensity of manufacturing products [1]. When designing technological processes of assembly, the initial data are assembly drawings of the product, specifications of parts that are included in the assembly, technical requirements for acceptance of the product and assembly, the size of the production task and the terms of its execution, and the terms of execution of assembly works [4].

The degree of detailing of technological process design depends on the scale of production of products. With a large scale of production of products, the technological process is developed in detail with the design of operational technology. In the general case, the design of the technological assembly process is based on the calculation of the assembly clock and the selection of organizational forms of the assembly process, the assembly of technological operations, the determination of the composition of control operations, the development of the technological planning of the sections of the assembly shop [4].

Various means of mechanization and automation are used when assembling products and their assembly units to facilitate work and increase productivity]. Conveyors are used for mobile assembly [1].

7.3 The steps of work execution

Annual production volume of products by the assembly area $Д_{рік}$ = 10000 pcs.; labor intensity of assembly of one product $T_{скл}$ = 20 min; the length of the product $l_{вир}$ = 0,5 m; the mode of operation of the assembly shop is two-shift; assembly of the product and two control operations are performed on the conveyor; distance between products $l_{пр}$ = 1 m.

It is necessary to determine the assembly cycle, the number of assembly places on the conveyor, the length of the conveyor and the speed of its movement. The initial data for the individual calculation are given in the Table 7.1.

The production cycle is determined by the following formula:

$$Тв = 60Ф_р / Д_{рік}$$

where $Ф_р$ – the valid annual fund of assembly conveyor working time, taking into account the specified variability (under the condition of two-shift work and taking into account the time for equipment repair $Ф_р$ = 4008 hours);

$Д_{рік}$ – annual production volume of products.

$$Тв = 60 \cdot 4008/10000 = 2,4 \text{ min}$$

The total number of assembly places is determined by the formula:

$$M_{ск} = T_{скл.} /(Тв \cdot P_{сер})$$

where $T_{скл}$ – labor intensity of the assembly process, min;

$P_{сер}$ = 1,2 ... 1,8 – average work density (defined by the number of employees at one workplace).

$$M_{ск} = 20/(2{,}4 \cdot 1{,}2) = 6{,}9$$

For further calculations, we accept $M_{ск}$ = 7.

Table 7.1 – Output data for the execution of the work

Variant	Annual output volume $Д_{рік}$	Labor intensity of assembly $Т_{скл}$, min	Number of work shifts	The number of control points $M_к$	Product length $l_{вир}$, m	Distance between products $l_{пр}$, m
1	200	10,8	2	3	0,6	1
2	400	8,9	3	4	0,8	1
3	50	42,7	1	1	1,3	0,8
4	175	95	2	3	0,3	1
5	75	48,5	2	2	1,1	7
6	220	12,8	2	2	0,7	1
7	420	10,9	3	3	0,9	1
8	70	44,7	1	1	1,4	0,8
9	195	97	2	4	0,4	1
10	95	50,5	2	3	1,2	7

The total number of assembly places, taking into account control $M_к$ and reserve $M_{рез}$:

$$M_{ск.заг.} = M_{ск} + M_к + M_{рез} = 7 + 2 + 3 = 12$$

The working length of the flow assembly line is determined from the expression:

$$l_{конв} = l \cdot M_{ск.заг.} = 12 \cdot (0{,}5 + 1) = 18\,\text{m}$$

The speed of movement of the conveyor under the condition of continuous movement is equal to:

$$\upsilon_{конв} = (l_{вир} + l_{пр}) / T_в = 1{,}5/2{,}4 = 0{,}625\,\text{м/хв}$$

7.4 Control questions

7.4.1 Name the initial data when designing the technological process of assembly?

7.4.2 Describe the devices for automation and mechanization of the assembly technological process?

7.4.3 What is the technological scheme of product assembly?

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