

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
Національний університет «Запорізька політехніка»

РЕЦЕНЗІЯ
на дипломний проект (роботу)

Технологічні методи напруження
(вказати тему дипломного проекту (роботи))
екст валів ГТД
Студент (ка) Сурдуков М.

Спеціальність 131 Прикладна механіка
(код, найменування спеціальності)

Обсяг проекту повний.

Кількість аркушів креслень 10,25

Кількість сторінок пояснювальної записки 124

а) короткий зміст проекту (роботи) та прийнятих рішень

В роботі спроектовано механологічний процес виготовлення валу, обрано обладнання, інструмент, складено управлюючу програму для обробки на верстаті з ЧПУ

б) висновок про відповідність проекту (роботи) завданню

виконаний проект відповідає завданню

в) характеристика виконання кожного розділу дипломного проекту (роботи), рівень відповідності останнім досягненням науки та техніки і передовим методам роботи

робота виконана з використанням програмного забезпечення розрахунків на міцність деталей на складання програм на верстаті з ЧПУ

г) негативні особливості виконання проекту (роботи) ЧПУ

д) позитивні особливості робота виконана англійською мовою

е) оцінка графічного оформлення та пояснювальної записки до проекту (роботи)

у роботі дотримані всі вимоги до

оформлення пояснювальної записки, на графічне застосування, але є зауваження щодо нумерації в листі та в тексті які не співпадають.

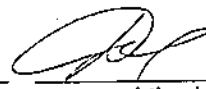
є) відгук про проект (роботу) загалом робота виконана

ж) інші зауваження технологічних карт невірне позначення на ескізах пристосування, обраний інструмент не відповідає оброблюваній поверхні

з) оцінка проекту (роботи) В цілому робота заслуговує оцінки «добре»

Рецензію склав

Зол.кар.Глеб Дереза
(посада, місце роботи, прізвище, ім'я, по батькові)


(підпис)

«05» 12 2019 р.

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National University "Zaporizhzhya Polytechnic"

REVIEW
of the diploma project (work)

Technological methods to improve the
quality of gas turbine engine shafts

Student Suzdukov Mykyta

Specialty 131 Applied mechanics

Project scope full

Number of drawings 1025

Number of explanatory note sheets 1025

a) short content of project (work) and decisions taken 1. Method of obtaining of workpiece with economic justification was chosen. 2. Calculation of allowance and operating sizes. 3. Designing of the workpiece profile. 4. Design and calculation of working and control architecture. 5. Reduction automation. 6. Detail strength calculation. 7. Collecting occupational health data.

b) conclusion about the conformity of the project to the task
The work is completely up to the task

c) completion characteristic of each section of the diploma project (work), level of compliance with the latest achievements of science and technology, advanced methods of work

The work corresponds to the latest achievements of science and technology at a sufficient level

d) negative features of project (work) implementation

no negative features were found

e) positive features

e) evaluation of graphic design and explanatory note of the project (work) The explanatory note and drawings are in accordance with current standards

f) feedback on the project (work) in general

In general the master's thesis of the student of M-118M group of Mykyta Surdukov meets the requirements of the high school

g) other remarks

There are a lot of personal pronouns in master's work that do not meet the requirements of academic English; some prepositions are misused; the word order in some sentences is violated

i) evaluation of the project (work)

In general the master's thesis of the student of the M-118M group of Mykyta Surdukov deserves a grade of "good"

The review was made by head of engineering technology department Serhii Dyadya



« 05 » 12 2019 y.

[12:31:22] **Ra** Найдено 1% совпадений по адресу:

https://www.who.int/occupational_health/publications/en/oehairbornedust3.pdf

[12:31:42] **Ra** Найдено 1% совпадений по адресу: <https://www.coursehero.com/file/pd01c5/To-reduce-the-number-of-translation-stalls-and-to-eliminate-page-eviction-time/>

[12:32:13] **Ra** Найдено 1% совпадений по адресу: https://en.wikipedia.org/wiki/List_of_engineering_branches

[12:32:29] Возникла ошибка при загрузке поисковой страницы №427 [3] (200026 миллисек.): Yandex (Время ожидания операции истекло)

[12:32:40] **Yan** Найдено 1% совпадений по адресу:

<http://ec.europa.eu/DocsRoom/documents/3286/attachments/1/translations/en/renditions/pdf>

[12:32:44] **Ba** Найдено 1% совпадений по адресу: https://en.wikipedia.org/wiki/Mechanical_Engineering

[12:32:49] Возникла ошибка при загрузке поисковой страницы №437 [3] (200026 миллисек.): Yandex (Время ожидания операции истекло)

[12:32:56] Возникла ошибка при загрузке поисковой страницы №432 [3] (200042 миллисек.): Yandex (Время ожидания операции истекло)

[12:34:48] Возникла ошибка при загрузке поисковой страницы №442 [3] (200026 миллисек.): Yandex (Время ожидания операции истекло)

[12:40:10] Возникла ошибка при загрузке поисковой страницы №472 [3] (200074 миллисек.): Yandex (Время ожидания операции истекло)

[12:40:20] Возникла ошибка при загрузке поисковой страницы №477 [3] (200058 миллисек.): Yandex (Время ожидания операции истекло)

[12:40:49] Возникла ошибка при загрузке поисковой страницы №482 [3] (200027 миллисек.): Yandex (Время ожидания операции истекло)

[12:41:51] Возникла ошибка при загрузке поисковой страницы №487 [3] (200043 миллисек.): Yandex (Время ожидания операции истекло)

[12:42:15] Возникла ошибка при загрузке поисковой страницы №492 [3] (200058 миллисек.): Yandex (Время ожидания операции истекло)

[12:42:43] Возникла ошибка при загрузке поисковой страницы №497 [3] (200043 миллисек.): Yandex (Время ожидания операции истекло)

[12:42:52] Возникла ошибка при загрузке поисковой страницы №502 [3] (200027 миллисек.): Yandex (Время ожидания операции истекло)

[12:43:00] Возникла ошибка при загрузке поисковой страницы №507 [3] (200043 миллисек.): Yandex (Время ожидания операции истекло)

[12:43:00] Тип проверки: *Стандартная*

[12:43:00] Уникальность текста 97%

03.12.2019 

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
Національний університет «Запорізька політехніка»

Engineering

(повне найменування інституту, факультету)

Engineering Technology

(повне найменування кафедри)

Пояснювальна записка
до дипломного проекту (роботи)
second (masters)
(ступінь вищої освіти)

на тему Technological methods to improve the quality of gas turbine engine shafts

Виконав: студент 2 курсу, групи M-118M

Спеціальності 131 Applied mechanics
(код і найменування спеціальності)

Освітня програма (спеціалізація)

Engineering Technology

Surdukov M.

(прізвище та ініціали)

Керівник Pukhalska G., doc.

(прізвище та ініціали)

Рецензент Dyadya S., doc.

(прізвище та ініціали)

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
 Національний університет «Запорізька політехніка»
 (повне найменування вищого навчального закладу)

Інститут, факультет Engineering
 Кафедра Engineering Technology
 Ступінь вищої освіти (освітній ступінь) (master) second
 Спеціальність 131 Applied mechanics
 Освітня програма (спеціалізація) Engineering Technology

ЗАТВЕРДЖУЮ

Завідувач кафедри doc., Dyadya S.

“ 05 ” 12 2019 року

ЗАВДАННЯ
 НА ДИПЛОМНИЙ ПРОЕКТ (РОБОТУ) СТУДЕНТУ

Surdukov Mykyta
 (прізвище, ім'я, по батькові)

1. Тема проекту (роботи) Technological methods to improve the quality of gas turbine engine shafts.

керівник проекту (роботи) Pukhalska G., doc.

(прізвище, ім'я, по батькові, науковий ступінь, вчене звання)

затверджені наказом вищого навчального закладу від “26” 11 2019 року № 416

2. Строк подання студентом проекту (роботи) є

3. Вихідні дані до проекту (роботи) drawing of detail, annual release program

4. Зміст розрахунково-пояснювальної записки (перелік питань, які потрібно розробити) selection of workpiece production method, calculation of allowances and operating sizes, design of workpiece route, design of operations in Siemens NX, design of work and control equipment, production automation, calculation of workpiece in Siemens NX, labor protection.

5. Перелік графічного матеріалу (з точним зазначенням обов'язкових креслень)

Drawing of the workpiece, the workpiece, the control and the work fixture, the automated fixture, the route of the workpiece, the RTC of turning, milling and drilling operations, three sheets of special task.

6. Консультанти розділів проекту (роботи)

Розділ	Прізвище, ініціали та посада консультанта	Підпис, дата	
		завдання видав	приймав виконане завдання
Normal control	Kozlova O.	<i>[Signature]</i> 3.12.19	<i>[Signature]</i> 3.12.19
Labor protection	Shmyrko V.	<i>[Signature]</i> 4.10.19	<i>[Signature]</i> 19.11.19
project Manager	Pukhalska G.	<i>[Signature]</i> 10.09.19	<i>[Signature]</i> 23.11.19

7. Дата видачі завдання 10.09.19

КАЛЕНДАРНИЙ ПЛАН

№ з/п	Назва етапів дипломного проєкту (роботи)	Строк виконання етапів проєкту (роботи)	Примітка
1	Choosing a method of obtaining workpiece with economic justification		
2	Calculation of allowances and operating sizes	20.02.19	
3	Designing the workpiece route	15.03.19	
4	Design and calculation of working and control adaptation	23.04.19	
5	Production automation	30.05.19	
6	Strength detail calculation	15.06.19	
7	Collecting data from a task force	28.06.19	
8	Collecting Occupational Health Data	24.07.19	
		19.10.19	

Студент

Керівник проєкту (роботи)

[Signature]
(підпис)

[Signature]
(прізвище та ініціали)

SUMMARY

EN: 117 page, 8 tables, 35 pictures, 16 sources, 4 applications.

Object of study – Shaft.

The objective of the work – development of a technological process of shaft production, analysis of the most effective means of control of products of machine-building equipment.

The technological process of workpiece processes is designed. Working and inspection equipment are designed. The efficiency of usage of the device with pneumatic actuator is calculated and compared with universal one.

An automated beating control device was designed to reduce the size control time.

Disbalance of parts and assembly units appears due to inaccuracies of the manufacture, incorrect assembly, uneven surface wear. The irregularity is very harmful, as vibrations occur, sharply increase load on the parts and machine as a whole, which in conclusion leads to acceleration bearing assemblies and destruction of many details. For balancing of parts carry out balancing.

SHAFT, TECHNOLOGICAL PROCESS, CONTROL, BALANCING,
AUTOMATION, ADAPTATION

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LIST OF SYMBOLS, SYMBOLS, UNITS, ABBREVIATIONS, AND TERMS

HFM - horizontal forging machine;

CHSP - crank hot-stamping press;

STR – surface treatment route;

RMP - the route of manufacturing part;

WSP – wet-spinning equipment;

SDS – self-driving system;

PC – personal computer.

INTRODUCTION

Technological process – a part of production process, set of technological operations, which is being made in a balanced and consistent manner through time and space over homogeneous or similar objects, and has a result in aggregate state to have been changed, location or industrial purpose of a workpiece to have been completed. There are main and secondary technological processes.

Technological process consists of sequentially performed technological operations over this object.

There are stages of the technological process description according to the design process and technological preparation steps can be distinguished, such as:

- Collection, processing and studying of raw data.
- Identification of the main technological solutions.
- Preparation of feasibility study.
- Technical process documentation.

Designing – one of the hardest, the most responsible and creative stages of the machine-building products creating.

1 TECHNOLOGICAL PART

1.1 Description of construction and official detail's designation

The detail which is being used - the shaft, which usually makes of alloy 13C11N2W2MF-W (EI 961-W) for GOST 1133-71.

The alloy is being used to make critical loaded parts operating at temperatures to +600°C, disks of compressor, shoulder-blades and other loaded details, small rods of hot-rolled stripes and is applied for details making of forged constructions, in aircraft building, whole-roll rings of the different industrial setting, shaped founding for aviation industry, details for aircraft building. This steel applies to corrosion resistant and heat-resistant martensitic class.

maximum operating temperature is recommended for a long time (up to 10000 hours) +600 °C.

Workpiece - stamping 1 control group, which is made according to GOST 190013-81.

List 1.1 - Chemical composition in % of 13C11N2W2MF-W

C	Si	Mn	Ni	S	P	Cr	Mo	W	V
0,1 - 0,16	up to 0,6	up to 0,6	1,5 - 1,8	up to 0,03	up to 0,03	10,5 - 12	0,35 - 0,5	1,6 - 2	0,18 - 0,3

List 1.2 - Mechanical properties at T=20 °C of 13C11N2W2MF-W

Assortment	Size	Wat	σ_g	σ_T	d ₅	δ	KCU	Heattreatment
-	mm	-	M.P.	M.P.	%	%	kJ / m ²	-
Rod, GOST 5949-75			880- 1080	735- 930	13- 15	55	880	Hardening and tempering
Workpiece			950	850	10	50	600	Harderind, lubricant, release 580 - 670°C,

Shaft-drive consists of the fan shaft, turbine shaft, front and rear support and it's serves to transmit torque and axial force from the low pressure turbine to the ventilator. The shaft of ventilator mounts on two supports. Front support is the radially-persistent ball-shaped bearing with a cut internal holder. Front support - damper with a resilient ring.

There is a flange in the first side of the ventilator with 16 wheels and ventilator mounting bolts.

The torque from the turbine shaft to the shaft of the fan is transmitted by involute spline connection. The resulting axial force between the fan and turbine perceived persistent radial bearing and the shaft is transmitted from the turbine to the fan shaft through a package of two rings levied nut. The shaft of the turbine in the back of a seat with slots to connect the turbine low pressure rotor.

The rear ventilator support is a roller bearing used on the ventilator shaft.

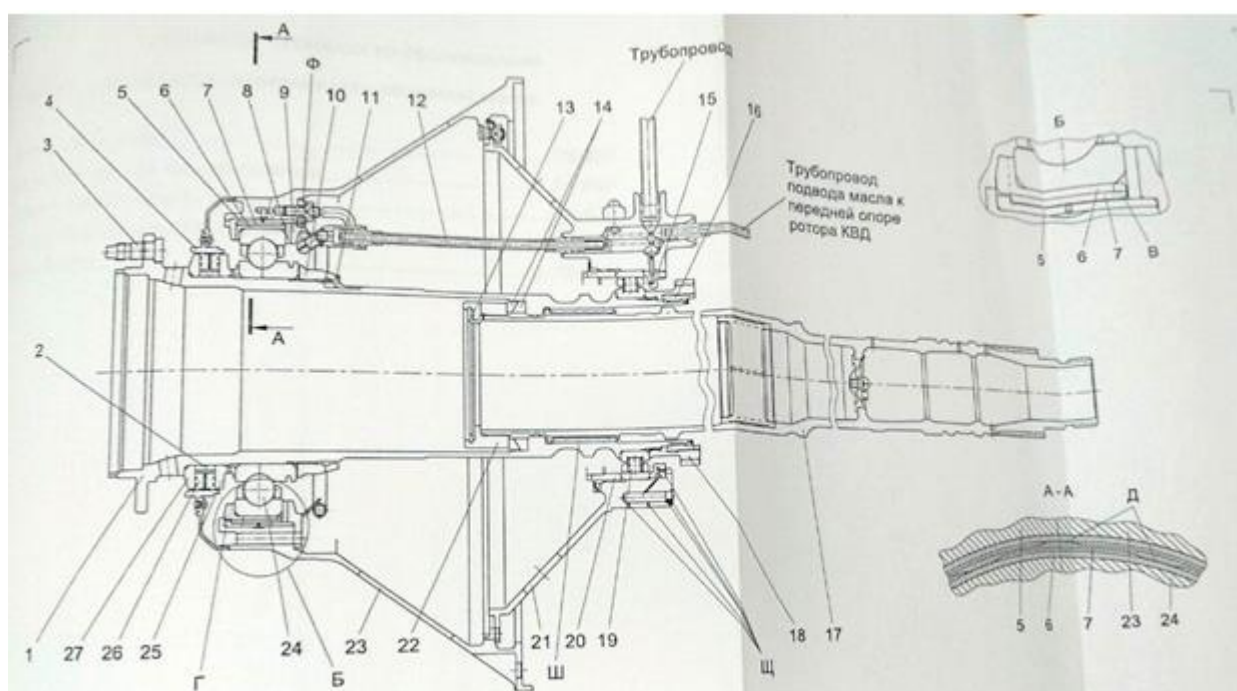


Figure 1.1 - Shaft structure:

1 - fan shaft; 2 - the spacer ring; 3 - a bolt; 4 - sleeve; 5 - sleeve; 6 - ring; 7 - elastic ring; 8 - an adjusting ring; 9 - nozzle ring; 10 - a nut; 11 - a clamp; 12 - pipeline; 13 - a clamp; 14 - ring; 15 - nozzle ring; 16 - a nut; 17 - turbine shaft; 18 - a gear-inductor; 19 - roller bearing; 20 - a nut; 21 - rear support housing; 22 - a nut; 23 - front support housing; 24 - the bearing; 25 - ring; 26 - a sealing ring; 27 - ring

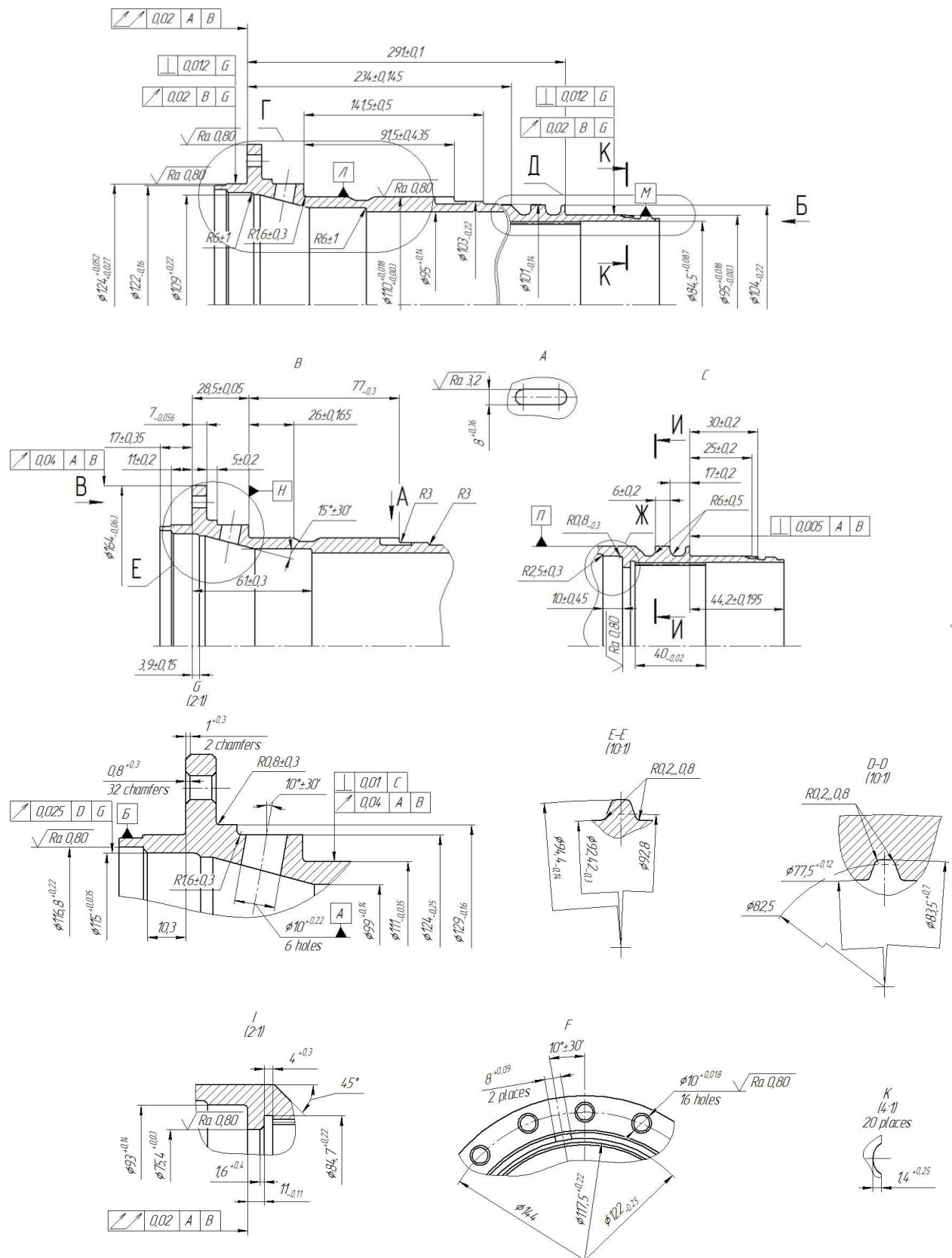


Figure 1.2 - Drawing details

1.2 Choosing the type of production and forms of work organization

The type of production refers the totality of organizational, technical and economic features, that is, a complex characteristic of the organization and technical level of the enterprise, due to the degree of its specialization, complexity and stability of the product nomenclature, the size and frequency of production, as well as the scale of production. At the production's choice influence: the choice of type of production is influenced by: nomenclature of manufactured products, volume of output, degree of sustainability of the commodity nomenclature of the enterprise, nature of job loading. Depending on the level of concentration and specialization, there are three types of production: single, serial and mass production.

The type of production at the enterprise is determined by the type of production of the leading craft and the type of production of the workshop is the characteristic of the site where the most responsible operations are performed and the major part of the production assets which is concentrated. The attribution of the enterprise to one or another type of production is conditional, since the enterprise and even in separate crafts might be different types of production.

There is also applies the meaning of type of productivity, which is different from the type. Depending on mass production parts and production programs choose the serial type of production.

Mass production - type of organization of production which is characterized by the simultaneous manufacture of the company with wide range of similar products which release is repeated for a long time and extensive specialization jobs.

The form of organized production consists in the fact that it combines in itself and in the space of the manufactured product, while observing this integration, basically functioning different connections.

We choose a parallel-sequential form of work organization.

The form of organization of production with the parallel and consecutive transfer of objects of work is intermediate between sequential and parallel forms and partially eliminates their inherent disadvantages. Products from operation to operation are transferred by transport parties. This ensures the continuity of the use of equipment and manpower, possibly partially parallel passage of a batch of parts on the operations of the technological process.

Define the amount party manufactured products

$$n = \frac{a \cdot N}{A}$$

where $a = 12$ – amount of launching parts into production;

$$n = \frac{a \cdot N}{A} = \frac{12 \cdot 7000}{250} = 336 \text{ pieces}$$

1.3 Choosing the type and method of the workpiece obtaining which includes economic justification

The choice of workpiece affect son the complexity and the technological process itself. The method of obtaining the workpiece is established on the basis of the study of the drafting of the finished part and specifications for its manufacture. The most important facts, which influence at choice of the workpiece have such factors like material, form, size and weight of the finished part, production program.

Scale of production (or production program) affects the choice and the method of the workpiece obtaining.

At a single or small-scale production a workpiece can be got of easy forging, casting in sandy forms (hand forming after a wooden model), because another ways of receipt of workpiece (punching is in the envisaged stamps, machine forming after a metallic model) not rational through a high cost of rigging (stamps, metallic models).

At a mass production, especially when mechanic tool is conducted on the adjusted equipment (automats, semi-automatic devices, aggregate machine-tools), the most important role exactness of sizes of workpiece, due to stability of assumptions on tooling allow provide high firmness of instruments.

In mass production, there is a necessity to give preferences such advanced methods of billet production like molding, die-casting, stamping in closed bezel-free dies, stamping on a horizontal forging machine and etc.

I propose to compare two types of workpiece stamping: in the crank hot press (CHSP) and the horizontal forging machine (HFM).

Output data:

Material – alloy 13C11N2W2MF-W

Annual release program $N = 7000$ pc.

Type of production – serial

The coefficient of the using of material is determined as an attitude of mass of detail toward mass of workpiece after a formula 1.2:

$$\eta = \frac{q}{Q} \quad (1.2)$$

where q - the mass of the detail, kg;

Q – weight of the workpiece, kg.

The cost of the 1 workpiece is obtained by stamping:

$$B = \frac{B_E}{1000} \cdot Q \cdot K_T \cdot K_M \cdot K_B \cdot K_3 \cdot K_{II} - (Q - q) \cdot \frac{B_{omx}}{1000}$$

where B_E – base cost of 1 t. of a workpiece, UAH

$K_T, K_M, K_B, K_3, K_{II}$ – coefficients, which take accuracy class into account, material, difficulty group, workpiece mass, release program.

Annual economy on making of workpiece :

$$E_{u32} = (B_2 - B_1) \cdot N$$

where B_1, B_2 - the cost of 1 workpiece, UAH;

N - an annual release program.

Annual economy of material :

$$M = \frac{q \cdot (\eta_1 - \eta_2)}{\eta_1 \cdot \eta_2} \cdot N$$

where q – mass of detail;

η_1, η_2 – coefficients of using material for the first and second way of getting workpiece.

To simplify configuration of a workpiece it is necessary to appoint exterior aspects of openings $\varnothing 10,2$ mm and $\varnothing 10$ mm; all grooves, bevels, indents and samples.

The side allowance is chosen for [2, p. 12, table. 1.3] and chronicle in table 1.2.

Determine stamp's mass in the program Compass 3D on CHSP (fig. 1.3). A stamp's sketch is on the CHSP on fig. 1.4.

Determine stamp's mass in the program Compass 3D on HFM (fig. 1.5). A stamp's sketch is on the rice 1.6.

Determine mass of detail in the program Siemens NX (fig. 1.7).

Table 1.2 – Sizes of a workpiece on CHSP

Nominal size, mm	Calculation of size, mm	Actual size, mm
Ø124	$124+2\cdot2,7=129,4$	Ø129
Ø164	$164+2\cdot2,7=169,4$	Ø169
Ø129	$129+2\cdot2,7=134,4$	Ø134
Ø110	$110+2\cdot2,4=114,8$	Ø115
Ø104	$104+2\cdot2,4=108,8$	Ø109
Ø95	$95+2\cdot2,4=99,8$	Ø100
Ø115	$115-2\cdot2,4=110,2$	Ø110
Ø95	$95-2\cdot2,4=90,2$	Ø90
Ø85	$85-2\cdot2,4=80,2$	Ø80
352	$352+2\cdot2,9=357,8$	358
291	$291+2\cdot2,9=296,8$	297
91,5	$91,5+2,4-2,4=91,5$	92
22	$22+2,3-2,3=22$	22
17	$17+2,3-2,3=17$	17
7	$7+2\cdot2,3=11,6$	12
251	$251+2,7-2,7=251$	251
20	$20+2,3-2,3=20$	20

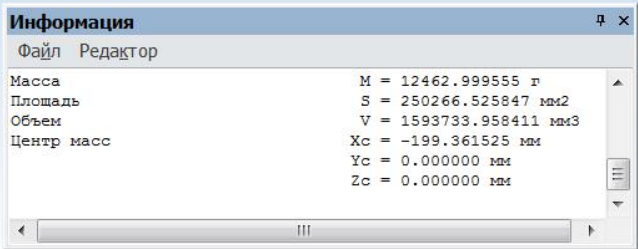


Figure 1.3 – Determination of stamp’s mass on CHSP in Compass 3D

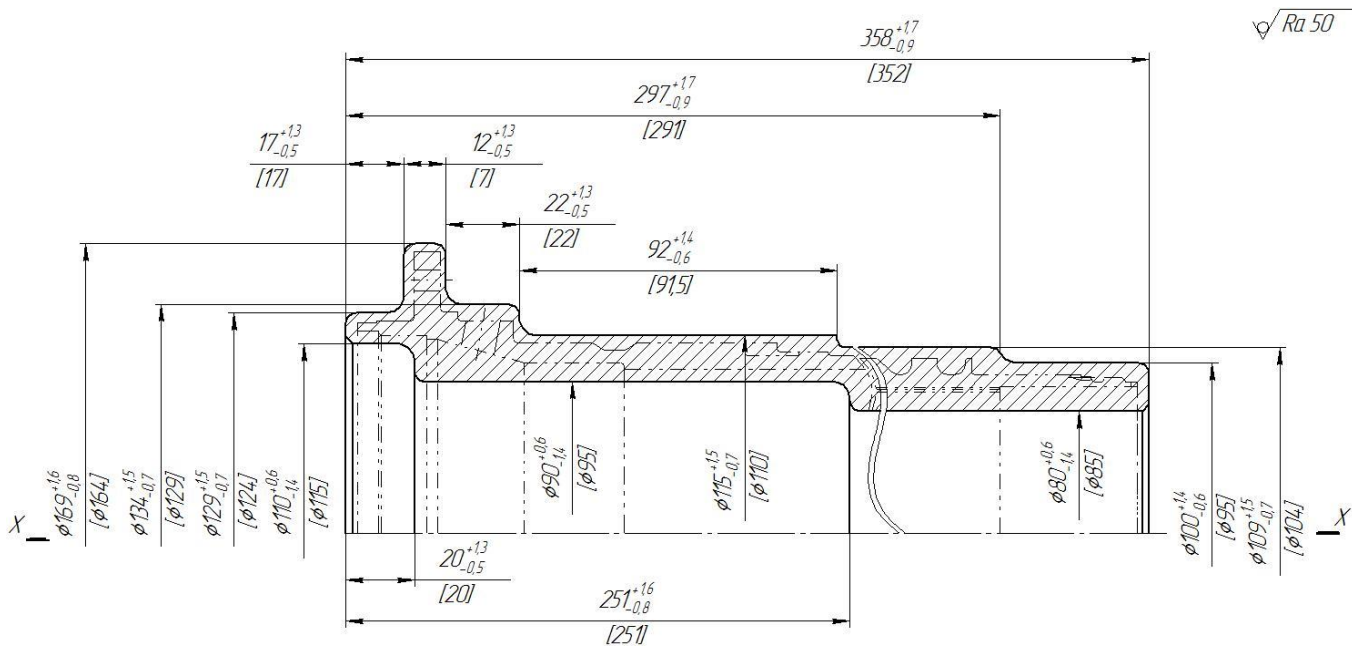


Figure 1.4 - Thumb nail stamping on CHSP

Table 1.3 – Sizes of a workpiece on HFM

Nominal size, mm	Calculation, mm	Actual size, mm
Ø124	$124+2\cdot3,6=131,2$	Ø131
Ø164	$164+2\cdot23,6=171,2$	Ø171
Ø129	$129+2\cdot3,6=136,2$	Ø136
Ø110	$110+2\cdot3,2=116,4$	Ø116
Ø104	$104+2\cdot3,2=110,4$	Ø110
Ø95	$95+2\cdot3,2=101,4$	Ø101
Ø115	$115-2\cdot3,2=108,6$	Ø109
Ø95	$95-2\cdot3,2=88,6$	Ø89
Ø85	$85-2\cdot3,2=78,6$	Ø79
352	$352+2\cdot4,0=360$	360
291	$291+2\cdot4,0=299$	299
91,5	$91,5+3,2-3,2=91,5$	92
22	$22+3,0-3,0=22$	22
17	$17+3,0-3,0=17$	17
7	$7+2\cdot3,0=13$	13
251	$251+3,6-3,6=251$	251
20	$20+3,0-3,0=20$	20

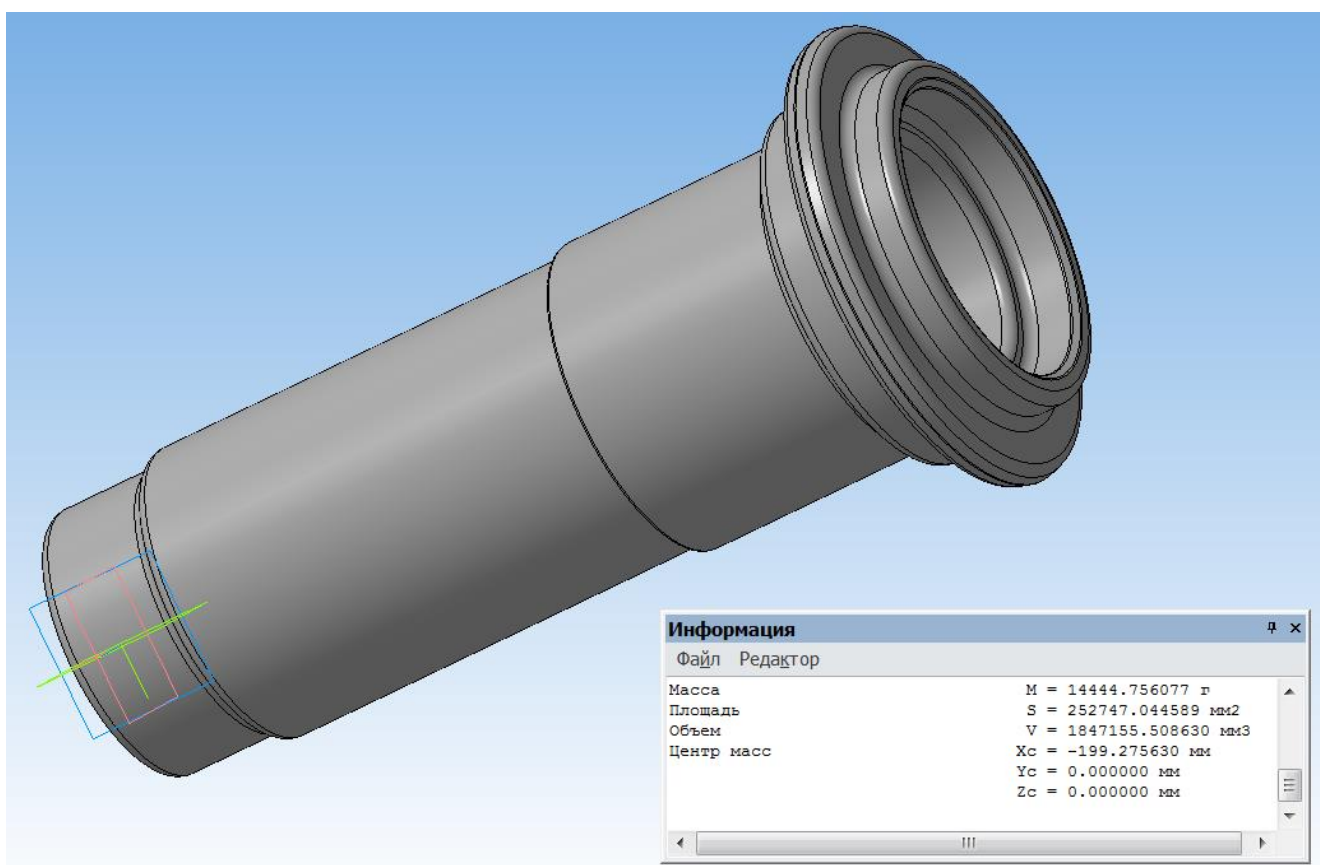


Figure 1.5 - Determination of stamping mass on HFM in Compass 3D

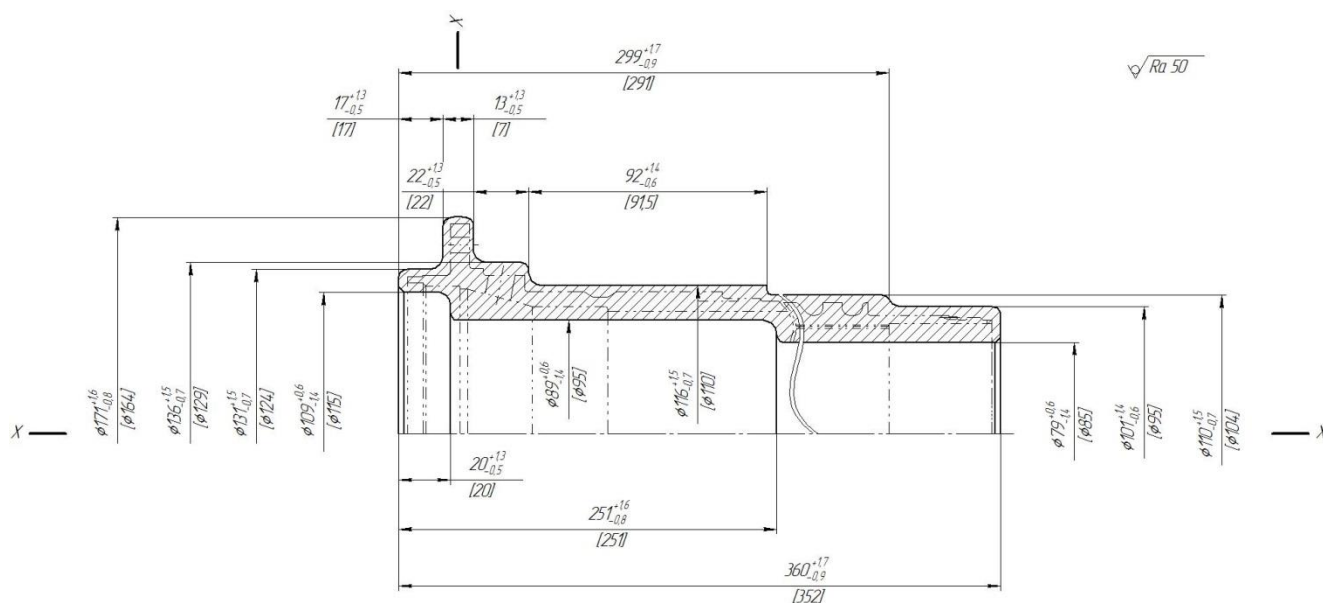


Figure 1.6 - Sketch of stamping on HFM

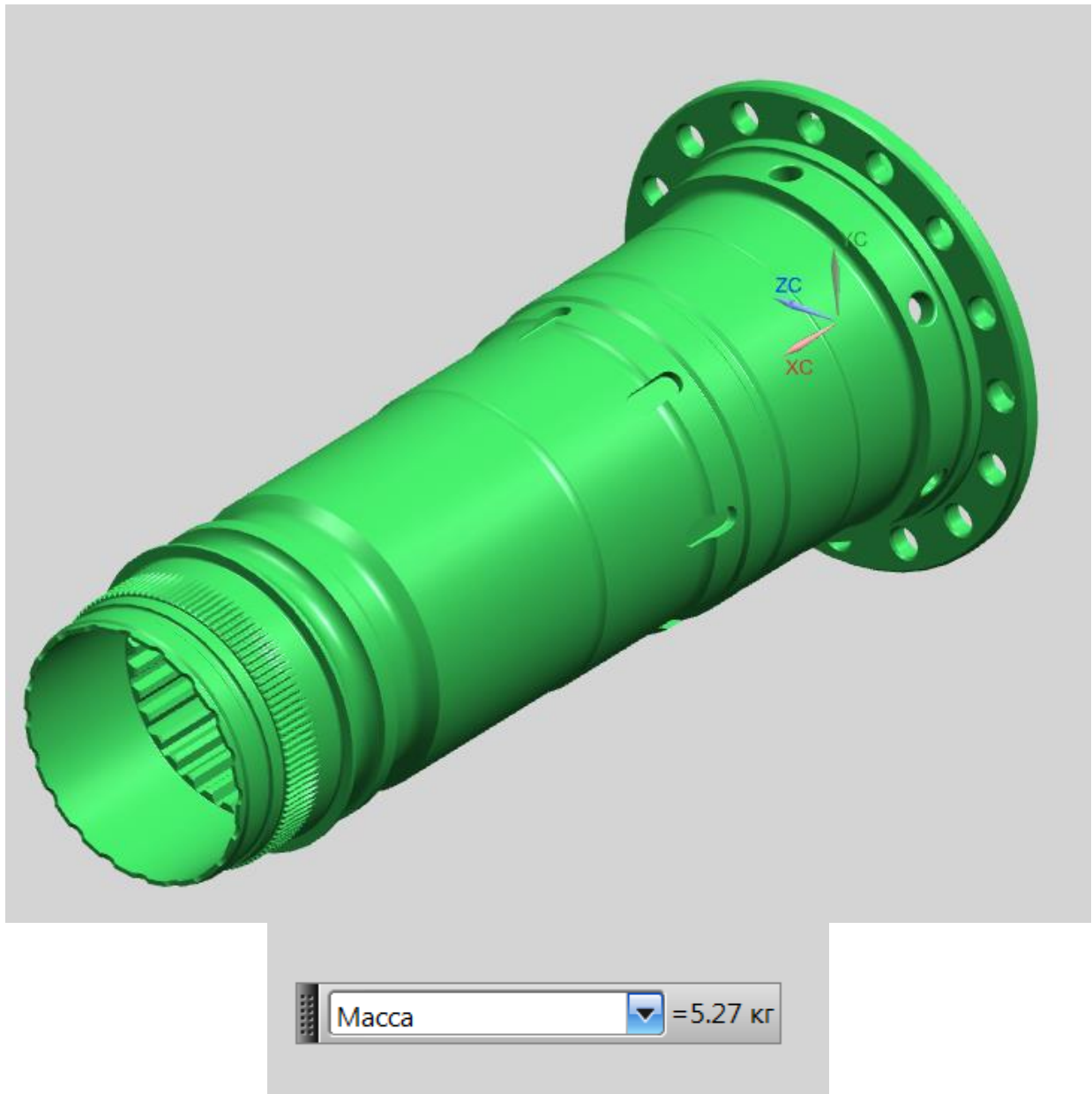


Figure 1.7 – Calculation of weight details

A coefficient is used after a formula 1.2:

$$\eta_{\text{HFM}} = \frac{5,27}{14,44} = 0,36$$

$$\eta_{\text{CHSP}} = \frac{5,27}{12,46} = 0,42$$

$$\eta_{\text{HFM}} < \eta_{\text{CHSP}}$$

The total cost of workpieces by formula 1.3:

$$B_{\text{HFM}} = \frac{3150}{1000} \cdot 14,44 \cdot 0,9 \cdot 1,8 \cdot 0,89 \cdot 0,8 \cdot 1 - (14,44 - 5,27) \cdot \frac{140}{1000} = 51,19 \text{ UAH};$$

$$B_{\text{CHSP}} = \frac{3500}{1000} \cdot 12,46 \cdot 0,9 \cdot 1,8 \cdot 0,89 \cdot 0,8 \cdot 1 - (12,46 - 5,27) \cdot \frac{140}{1000} = 49,3 \text{ UAH};$$

$$B_{\text{HFM}} > B_{\text{CHSP}}$$

Annual economy on making of workpiece :

$$E = (51,19 - 49,3) \cdot 7000 = 13230 \text{ UAN}$$

Annual economy of material :

$$M = \frac{5,27 \cdot (0,42 - 0,36)}{0,42 \cdot 0,36} \cdot 7000 = 14638,9 \text{ kg}$$

As $B_{\text{HFM}} > B_{\text{CHSP}}$ and $\eta_{\text{HFM}} < \eta_{\text{CHSP}}$ it's better to make this detail by CHSP, due to this method is cheaper and more productive.

Table 1.4 – Workpiece parameters

Indicator	Designation	Unit of measure	HFM	CHSP
Mass	Q	Kg	14,44	12,46
The base price of 1 t. of workpiece	$B_{\bar{o}}$	UAH	3150	3500
The value of 1 t. of a wool	B_{omx}	UAH	140	140
The value of 1 workpiece	B	UAH	51,19	49,3
URM (utilization rate of material)	η	-	0,36	0,42

1.4 Technological route design of workpiece processing.

1.4.1 The structural analysis of the technological efficiency of the detail.

Technological construction is a combination of the property, which provides the lowest cost of labor in these conditions of production and operation, instrumentalities, materials and time for technological preparation of production, production and repair of the product.

Work way to ensure technological effectiveness of the design might be channeled on the increase of productivity, reducing the time, material costs on the designing technical process, technical preparation of production maintenance and repair of the product with ensuring its required quality (GOST 14.201 - 73).

The product (including detail) is considered technological, if in the conditions of a particular enterprise the design provides the least technological cost price. The technological effectiveness of the design steps from, for example:

1. rational choice of a workpiece, material and kinds of thermal;
2. determination of the optimal accuracy of dimensions, shape and relative positioning of surfaces, roughness parameters;
3. correct sizes formulation, etc.

Commonly are used the general guidelines for the manufacturability of structural parts, such as:

4. the construction of detail should be collected of the standard and unified constructive elements;
5. details should be designed of the standard and unified workpieces;
6. sizes and component surfaces should have the trade-off reliability and roughness;
7. workpiece should be obtained by rational way with the current volume and kind of production;
8. interface between component surfaces, which have other rough edges and accurate, shall be appropriate the equipment methods and data-processing hardware;

9. the design part should be provide an opportunity of using standart technical processes of production;

The adaptability of details analyze on two levels - qualitative and quantitative.

On the qualitative level, the detail is evaluated according the following criteria: sight of the specific, configuration, rigidity of the structure, the availability of exact side and an opportunity for processing of a special instrument on the multi-purpose equipment.

The dimensions of the detail and using allows to use rational methods for getting a workpiece such as: rolling, punching, molding.

To ensure necessary roughness is possible with using standard tool.

Double-spindle is conducted by common cutting methods.

There is no necessity for using specific equipment, non-standard, combined tools, original fixtures.

A given level of precision on the blueprint doesn't appear to present major difficulties in processing. The most accurate sizes processed on a lathe and belt sander. Using chandlers with wet-spinning equipment (WSE) allows to get some component surfaces very precise in only one setting.

In the construction of detail there are many simple surfaces, which can be used as a clean databases.

For some indicators the detail "shaft" – technological.

The quantitative description of the manufacturability detail is available using a different measures using a unified structural components, precision of the dimensions, surface roughness.

An utilization rate of the workpiece:

$$K_{UF} = \frac{5,27}{12,46} = 0,42 < 0,8$$

On this indicator the detail is technological.

The coefficient of unification of structural elements of the detail:

$$K_{y.e.} = \frac{Q_{y.e.}}{Q_e} \geq 0,6$$

where $Q_{y.e.}$ – the total number of constructive elements;

Q_e – the amount of unification elements

$$K_{y.e.} = \frac{20}{22} = 0,9 \geq 0,6$$

On this ratio the detail is technological.

The rate of a surface accuracy:

$$K_{AC} = 1 - \frac{1}{A_{AV}} > 0,8 \quad (1.8)$$

$$A_{AV} = \frac{k_1 n_1 + k_2 n_2 + \dots + k_n n_n}{n_{Com}}$$

where n – the sizes amount, which have the relevant quality;

K – the quality of accuracy;

A_{AV} – an average quality of accuracy;

$$A_{AV} = \frac{15 \cdot 5 + 14 \cdot 5 + 13 \cdot 10 + 12 \cdot 8 + 9 \cdot 6 + 7 \cdot 3 + 5 \cdot 1}{38} = 11,87$$

$$K_{AC} = 1 - \frac{1}{11,87} = 0,91 > 0,8$$

On this ratio the detail is technological.

The rate of a surface roughness:

$$K_{SH} = \frac{1}{B_{AV}} < 0,32$$

where B_{AV} – an average value of parameters roughness (on the blueprint);

$$B_{AV} = \frac{k_1 n_1 + k_2 n_2 + \dots + k_n n_n}{n_{gen}}$$

where k – roughness parameter;

n – the amount of surfaces, which has considered roughness

$$B_{AV} = \frac{0,8 \cdot 9 + 1,6 \cdot 30 + 3,2 \cdot 8}{47} = 1,72$$

$$K_R = \frac{1}{3,1} = 0,52 > 0,32$$

On this ratio the detail isn't technological.

With using quantifiable characteristics we can deduce that the detail isn't technological.

1.4.2 A route of the surface treating design

The transition from workpiece to detail need to be manufactured by some stages. The amount of stages, sequence, shall be determined with designing the surface treatment route (DSTR).

DSTR – the sequence of technological transformations treating the surface of workpiece, which is needed for achieve universal targets for the quality of surface.

DSTR is a technological basis of a technical process of machining, as in this part are laid physico-mechanical, thermochemically processes of a surface.

For determining the number of mechanical conversions for getting sufficient accuracy and quality of the surface are counting:

- generally clarified:

$$\varepsilon_{0i} = \frac{Ti_{workpiece}}{Ti_{detail}}$$

where $Ti_{workpiece}$ – tolerance on the i – parameter of a workpiece;

Ti_{detail} – tolerance on the i – parameter of the detail by blueprint;

- the amount of forward by limitations indicator:

$$k_{Ti} = 2lg\varepsilon_{T0i}$$

- partial refinement at each j -th transition

$$\varepsilon_{ij} = \frac{Ti_{(j-1)}}{Ti_j}$$

where $Ti_{(j-1)}$ and Ti_j – technological tolerances, which were provided in last $(j - 1)$ and current j -th shifts.

The way of surface treatment is considered accepted if condition is fulfilled:

$$\varepsilon_{i0} \leq \prod_{i=1}^k \varepsilon_{ij}$$

The route design of outer cylindrical surface $\varnothing 95^{+0,018}_{+0,003}$ mm.

Outgoing data:

Workpiece:

$Td_3 = 2000$ mkm;

$Ra_3 = 50$ mkm;

The quality - IT 15;

The detail:

$Td_D = 0,015$ mm = 15 mkm;

$Ra_D = 0,8$ mkm

The quality – k5

Define general refinements by formula (1.12):

$$\varepsilon_{oTd} = \frac{Td_{workpiece}}{Td_{detail}} = \frac{2000}{15} = 133$$

$$\varepsilon_{oRa} = \frac{Ra_{workpiece}}{Ra_{detail}} = \frac{50}{0,8} = 62,5$$

Define the amount of forward by limitations indicators on the formula (1.13):

$$k_{dimension} = 2lg\varepsilon_{oTd} = 4,2$$

We accept the amount of conversions $K=4$.

The differences between qualifications:

$$\Delta = IT_{workpiece} - IT_{Detail} = 15 - 5 = 10 = 4 + 3 + 2 + 1$$

Putting up a sequence of PTK:

$$IT15 \rightarrow h11 \rightarrow h8 \rightarrow h6 \rightarrow T/O \rightarrow k5$$

$$Ra 50 \rightarrow Ra 6,3 \rightarrow Ra 3,2 \rightarrow Ra 1,6 \rightarrow T/O \rightarrow Ra 0,8$$

We define the refinement by formula (1.14):

1) Rough turning

$$\varepsilon_{Td1} = \frac{Td_{workpiece}}{Td_1} = \frac{2100}{220} = 9,1,$$

$$\varepsilon_{Ra1} = \frac{Ra_{workpiece}}{Ra_1} = \frac{50}{6,3} = 7,94.$$

2) Cleaning turning

$$\varepsilon_{Td2} = \frac{Td_1}{Td_2} = \frac{220}{54} = 4,1,$$

$$\varepsilon_{Ra2} = \frac{Ra_1}{Ra_2} = \frac{6,3}{3,2} = 1,97.$$

3) Fine turning

$$\varepsilon_{Td4} = \frac{Td_2}{Td_4} = \frac{54}{22} = 2,5$$

$$\varepsilon_{Ra4} = \frac{Ra_2}{Ra_4} = \frac{3,2}{1,6} = 2.$$

4) Thermal treatment

5) Sandling

$$\varepsilon_{Td5} = \frac{Td_2}{Td_5} = \frac{22}{15} = 1,5$$

$$\varepsilon_{Ra5} = \frac{Ra_2}{Ra_5} = \frac{1,6}{0,8} = 2.$$

Overall clarifications to verify the itinerary thus chosen by formula (1.15):

$$\varepsilon_{Td0} = \prod_{i=1}^k \varepsilon_{iTd} = \varepsilon_{1Td} \cdot \varepsilon_{2Td} \cdot \varepsilon_{3Td} \cdot \varepsilon_{5Td} = 9,1 \cdot 4,1 \cdot 2,5 \cdot 1,5 = 136,9$$

$$\varepsilon_{Ra0} = \prod_{i=1}^k \varepsilon_{iRa} = \varepsilon_{1Ra} \cdot \varepsilon_{2Ra} \cdot \varepsilon_{3Ra} \cdot \varepsilon_{5Ra} = 7,94 \cdot 1,94 \cdot 2 \cdot 2 = 62,6$$

$$\varepsilon_{oTd} \leq \Pi \varepsilon_{iTd}$$

$$133 \leq 136,9 - \text{correct}$$

$$\varepsilon_{oRa} \leq \Pi \varepsilon_{iRa}$$

$$65,5 \leq 62,6 - \text{correct}$$

As the check was true the processing route of the selected detail consider acceptable.

Designing the processing route of the inner cylindrical surface $\varnothing 115^{+0,035}$ mm.

We define the information about detail and workpiece:

Workpiece

$Td_3 = 2000$ mkm;

$Ra_3 = 50$ mkm;

The quality - IT 15;

Detail:

$Td_d = 0,035$ mm = 35 mkm;

$Ra_d = 0,8$ mkm

The quality – H7

Define overall clarifications by formula (1.12):

$$\varepsilon_{oTd} = \frac{Td_{\text{workpiece}}}{Td_{\text{detail}}} = \frac{2000}{35} = 57,1$$

$$\varepsilon_{oRa} = \frac{Ra_{\text{workpiece}}}{Ra_{\text{detail}}} = \frac{50}{0,8} = 62,5$$

Define the amount of forward by limitations indicator by formula (1.13):

$$K_{calc.} = 2lg\varepsilon_{Ra} = 3,2$$

We accept the number of forward $K=3$

The difference between qualifications:

$$\Delta = IT_{\text{workpiece}} - IT_{\text{detail}} = 15 - 7 = 8 = 4 + 2 + 2$$

Compose the sequence MA:

$$IT15 \rightarrow H11 \rightarrow H9 \rightarrow T/O \rightarrow H7$$

$$Ra\ 50 \rightarrow Ra\ 3,2 \rightarrow Ra\ 1,6 \rightarrow T/O \rightarrow Ra\ 0,8$$

Define the refinement by formula (1.14):

1) Rough:

$$\varepsilon_{Td1} = \frac{Td_{\text{workpiece}}}{Td_1} = \frac{2000}{220} = 9,1,$$

$$\varepsilon_{Ra1} = \frac{Ra_{\text{workpiece}}}{Ra_1} = 3,2 = 15,6.$$

2) Cleaning

$$\varepsilon_{Td2} = \frac{Td_1}{Td_2} = \frac{220}{87} = 2,6,$$

$$\varepsilon_{Ra2} = \frac{Ra_1}{Ra_2} = \frac{3,2}{1,6} = 2.$$

3) Heat treatment

4) Thin recess

$$\varepsilon_{Td4} = \frac{Td_2}{Td_4} = \frac{87}{35} = 2,5$$

$$\varepsilon_{Ra4} = \frac{Ra_2}{Ra_4} = \frac{1,6}{0,8} = 2$$

General consensus for verification the selected route by formula (1.15):

$$\varepsilon_{Td0} = \prod_{i=1}^k \varepsilon_{iTd} = \varepsilon_{1Td} \cdot \varepsilon_{2Td} \cdot \varepsilon_{4Td} = 9,1 \cdot 2,6 \cdot 2,5 = 59,2$$

$$\varepsilon_{Ra0} = \prod_{i=1}^k \varepsilon_{iRa} = \varepsilon_{1Ra} \cdot \varepsilon_{2Ra} \cdot \varepsilon_{4Ra} = 15,6 \cdot 2 \cdot 2 = 62,5$$

$$\varepsilon_{oTd} \leq \prod \varepsilon_{iTd}$$

$$57,1 \leq 59,2 - \text{correct}$$

$$\varepsilon_{oRa} \leq \prod \varepsilon_{iRa}$$

$$62,5 \leq 62,5 - \text{correct}$$

As everything came together, we consider the route of processing the specified acceptable surface. Data is entered in the table 1.5.

Table 1.5 –The surface treatment plan

	Indicator	Clarification	Number of forward	Variations occur MAQ	i	Method of processing		Td, mkm	Relative positions	Ra,	ε_{iTd}	ε relative pos.	ε_{iRa}
Outside cylindrical surface. $\varnothing 95^{+0,018}_{+0,003}$	Td Ra	133 62,5	4	15-5= =10=4+3 +2+1	1	Established	IT15	2000	1,8	50	-	-	-
					2	Rough turning	h11	220	0,6	6,3	9,1	3	7,94
					3	Clean turning	h8	54	0,06	3,2	4,1	10	1,97
					4	Thin turning	h6	22	0,03	1,6	2,5	2	2
					5	Heat treatment	-	-	-	-	-	-	-
					6	Sanding	k5	15	0,02	0,8	1,5	1,5	2
					Refinement						136,9	90	62,6
Internal cylindrical surface $\varnothing 115^{+0,035}_{+0,035}$	Td Ra	57,1 62,5	3	15-7= =8=4+2+ +2	1	Established	IT15	2000	1,8	50	-	-	-
					2	Rough turning	H11	220	0,6	3,2	9,1	3	15,6
					3	Clean turning	H9	87	0,06	1,6	2,6	10	2
					4	Heat treatment	-	-	-	-	-	-	-
					5	Thin turning	H7	35	0,03	0,8	2,5	2	2
					Refinement						59,2	60	62,5

Table 1.6 – Summary table STR

№	Dimensions, mm	Surface view	Workpiece			Detail			ε_{oTd}	ε_{oRa}	k	Δ
			Qual.	Td, mkm	Ra, mkm	Qual.	Td, mkm	Ra, mkm				
1	$\varnothing 164_{-0,063}$	outer cylindrical	IT15	2400	50	h8	63	0,8	38,1	62,5	3	7
2	$\varnothing 124^{+0,052}_{+0,027}$	outer cylindrical	IT15	2200	50	n6	25	0,8	88	62,5	4	9
3	$\varnothing 110^{+0,018}_{+0,003}$	outer cylindrical	IT15	2200	50	k5	15	0,8	146,7	62,5	4	10
4	$\varnothing 95^{+0,14}$	internal cylindrical	IT15	2000	50	H10	140	1,6	14,3	31,25	2	5
5	$\varnothing 103_{-0,22}$	outer cylindrical	-	-	-	h11	220	1,6	-	-	2	-
6	$\varnothing 101_{-0,14}$	outer cylindrical	-	-	-	h10	140	1,6	-	-	2	-
7	$\varnothing 85^{+0,087}$	internal cylindrical	IT15	2000	50	H9	87	1,6	23	31,25	2	6
8	$\varnothing 95^{+0,018}_{+0,003}$	outer cylindrical	IT15	2000	50	k5	15	0,8	133	62,5	4	10
9	$352_{-0,14}$	abuts	IT15	2600	50	h9	140	1,6	18,6	31,25	2	6
10	$291 \pm 0,1$	abuts	IT15	2600	50	js10	200	1,6	13	31,25	2	5
11	$248 \pm 0,36$	abuts	-	-	-	js 12	720	1,6	-	-	2	-
12	$234 \pm 0,145$	abuts	-	-	-	js 10	290	1,6	-	-	2	-
13	$141,5 \pm 0,5$	abuts	-	-	-	js14	1000	1,6	-	-	1	-
14	$91,5 \pm 0,4$	abuts	-	-	-	js13	800	1,6	-	-	1	-
15	$22_{-0,052}$	abuts	IT15	1800	50	h9	52	1,6	34,6	31,25	2	6
16	$7 \pm 0,02$	abuts	IT15	1800	50	js9	40	1,6	45	31,25	2	6
17	$17 \pm 0,02$	abuts	IT15	1800	50	js9	40	1,6	45	31,25	2	6
18	$20 \pm 0,02$	abuts	IT15	1800	50	js8	40	1,6	45	31,25	2	7
19	$251 \pm 0,04$	abuts	IT15	2200	50	js8	80	0,8	27,5	62,5	3	7
20	$\varnothing 109^{+0,22}$	internal cylindrical	-	-	-	H11	220	1,6	-	-	2	-
21	$12 \pm 0,2$	abuts	-	-	-	js14	400	1,6	-	-	1	-
22	$\varnothing 10^{+0,018}$	internal cylindrical	-	-	-	H7	18	0,8	-	-	3	-
23	$\varnothing 117,5^{+0,22}$	internal cylindrical	-	-	-	H11	220	1,6	-	-	2	-
24	$8^{+0,09}$	abuts	-	-	-	H11	90	3,2	-	-	1	-
25	$\varnothing 10^{+0,22}$	internal cylindrical	-	-	-	H12	220	1,6	-	-	2	-
26	$\varnothing 115^{+0,035}$	internal cylindrical	IT15	2200	50	H7	35	0,8	62,9	62,5	3	8
27	$\varnothing 129_{-0,16}$	outer cylindrical	IT15	2200	50	h10	160	1,6	13,8	31,25	2	5
28	$\varnothing 124_{-0,25}$	outer cylindrical	-	-	-	h11	250	1,6	-	-	1	-
29	$\varnothing 111_{-0,035}$	outer cylindrical	-	-	-	h7	35	1,6	-	-	3	-
30	$4^{+0,3}$	abuts	-	-	-	H14	300	3,2	-	-	1	-

1.4.3 Detail manufacturing route

The result of this stage – an appointment of a general plan of processing parts, building technology road-mapping and the last range of equipment. In further, in case of change type of manufacturing part, programs of producing manufacturing parts and other, this route might be modified. As the starting material, factory route technological processes are used.

During installation the continuity of process, firstly treat the surface, which are taken as technological bases. Then cultivate other surfaces in a sequence, reserve degree of their accuracy.

If the detail is submitted of heat treatment, it means that technological process of producing of detail divide on two parts: before heat treatment and after.

To resolve any possible distortions often have to anticipate editing details or processing of individual surfaces after heat treatment.

The continuity of data depends on appointed development base.

After mechanical treatment appoint a control operation. The sequence of operations also may change, if the detail is machined according typical processes.

The developing of the content of operations means the sequence of moving in operation.

The developing of the technological operation begins of detecting elementary surfaces, processing of which may be carried out of a certain instrument with division of operation into switchovers.

In processes of developing shifts, should consider, that simultaneously processing of some surfaces provides consistency of this surfaces with higher exactness.

The operation might consider one or more facilities and also one and more shifts.

At first address and define the amount and sequence of installations, then – transitions.

For each installation is used individual sketch with reference symbol of a workpiece.

1.5 The truck of over measure and technological sizes.

The cylindrical outer surface $\varnothing 95^{+0,018}_{+0,003}$ mm.

Choosing minimum over measure by table method [2, p. 39, table. 4.3]:

Rough: $2z_2^{min} = 2 \cdot 4,3 = 8,6$ mm;

Cleaning: $2z_3^{min} = 2 \cdot 0,4 = 0,8$ mm;

Subtle $2z_4^{min} = 2 \cdot 0,23 = 0,46$ mm;

One-way grinding $2z_6^{min} = 2 \cdot 0,1 = 0,2$ mm;

Define nominal over measures:

$$2z_2^H = 2z_2^{min} + ei_1 = 8,6 + 0,6 = 9,2 \text{ mm};$$

$$2z_3^H = 2z_3^{min} + Td_2 = 0,8 + 0,22 = 1,02 \text{ mm};$$

$$2z_4^H = 2z_4^{min} + Td_3 = 0,46 + 0,054 = 0,514 \text{ mm};$$

$$2z_6^H = 2z_6^{min} + Td_4 = 0,2 + 0,022 = 0,222 \text{ mm};$$

Finding nominal diameters:

$$d_1^H = d_2^H + 2z_2^H = 96,756 + 9,2 = 105,956 \text{ mm};$$

$$d_2^H = d_3^H + 2z_3^H = 95,736 + 1,02 = 96,756 \text{ mm};$$

$$d_3^H = d_4^H + 2z_4^H = 95,222 + 0,514 = 95,736 \text{ mm};$$

$$d_4^H = d_6^H + 2z_6^H = 95 + 0,222 = 95,222 \text{ mm};$$

$$d_6^H = d_{det}^H = 95 \text{ mm}.$$

Finding maximal over measures:

$$2z_2^{max} = 2z_2^{min} + Td_1 + Td_2 = 8,6 + 2 + 0,22 = 10,82 \text{ mm};$$

$$2z_3^{max} = 2z_3^H + Td_3 = 1,02 + 0,054 = 1,074 \text{ mm};$$

$$2z_4^{max} = 2z_4^H + Td_4 = 0,514 + 0,022 = 0,536 \text{ mm};$$

$$2z_6^{max} = 2z_6^H + Td_6 = 0,222 + 0,015 = 0,237 \text{ mm};$$

Total nominal over measures:

$$2z_0^H = \sum 2z_i^H = 9,2 + 1,02 + 0,514 + 0,222 = 10,956 \text{ mm}.$$

Verification:

$$1. d_{gen.}^H - d_{det.}^H = 2z_0^H$$

$$105,956 - 95 = 10,956$$

$$10,956 = 10,956 - \text{true}.$$

$$2. 2z_2^{max} - 2z_2^{min} = Td_1 + Td_2$$

$$10,82 - 8,6 = 2 + 0,22$$

$$2,22 = 2,22 - \text{true}.$$

$$2z_3^{max} - 2z_3^{min} = Td_2 + Td_3;$$

$$1,074 - 0,8 = 0,22 + 0,054$$

$$0,274 = 0,274 - \text{true}.$$

$$2z_4^{max} - 2z_4^{min} = Td_3 + Td_4;$$

$$0,536 - 0,46 = 0,054 + 0,022$$

$$0,076 = 0,076 - \text{true}.$$

$$2z_6^{max} - 2z_6^{min} = Td_4 + Td_6;$$

$$0,237 - 0,2 = 0,022 + 0,015$$

$$0,037 = 0,037 - \text{true}.$$

Contributing the results in the table 1.7.

Cylindrical inner surface $\varnothing 115^{+0,035}_{-0,035}$ mm.

Determining the height of the inequalities R_z and the height of defective ball h [2, p. 19, table 3.7]: $R_z = 160$ mkm; $h = 300$ mkm.

For transitioning:

Rough turning $R_z = 40$ mkm; $h = 75$ mkm.

Clean turning. $R_z = 20$ mkm; $h = 20$ mkm.

Thin turning. $R_z = 10$ mkm; $h = 15$ mkm.

Table 1.7 – Calculation of measures for surface treatment $\varnothing 95^{+0,018}_{+0,003}$ mm

	Operations	es, mm	ei, mm	Td, mm	$2z_i^H$, mm	d_i^H , mm	Executive size d, mm	$2z_i^{max}$, mm	$2z_i^{min}$, mm
1	Workpiece	1,4	-0,6	2,0	-	105,956	$\varnothing 106^{+1,4}_{-0,6}$	-	-
2	Rough turning	-	-0,22	0,22	9,2	96,756	$\varnothing 96,76_{-0,22}$	10,82	8,6
3	Clean turning	-	-0,054	0,054	1,02	95,736	$\varnothing 95,74_{-0,054}$	1,074	0,8
4	Thin turning	-	-0,022	0,022	0,514	95,222	$\varnothing 95,22_{-0,022}$	0,536	0,46
5	Heat treatment	-	-	-	-	-	-	-	-
6	Last grinding	-	-0,035	0,035	0,222	95	$\varnothing 95^{+0,018}_{+0,003}$	0,237	0,2

Define the importance of spatial deviation ρ for the workpiece [2, p. 25, table. 3.9]:

$$\rho_{kop}^{table} = 1,2 \text{ mkm/mm}$$

$$\rho_{warping} = \rho_{warping}^{table} \cdot l = 1,2 \cdot 352 = 422,4 \text{ mkm}$$

$$\rho_{offset} = 0,8 \text{ mm} = 800 \text{ mkm}$$

$$\rho = \sqrt{\rho_{warping}^2 + \rho_{offset}^2} = \sqrt{422,4^2 + 800^2} = 904,7 \text{ mkm}$$

For crossing:

Refinement coefficients [4, p. 190, table. 29]:

$$K_{\text{rough.recess}} = 0,06 ; K_{\text{clean recess}} = 0,04 ; K_{\text{thin recess}} = 0,03$$

$$\rho_2 = 904,7 \cdot 0,06 = 54 \text{ mkm.}$$

$$\rho_3 = 54 \cdot 0,04 = 2 \text{ mkm.}$$

$$\rho_4 = \rho_{wp/t.} \cdot l = 0,5 \cdot 352 = 176 \text{ mkm.}$$

$$\rho_5 = 176 \cdot 0,03 = 5 \text{ mkm.}$$

where $\rho_{wp/t.} = 0,5 \text{ mkm/mm}$ [4, p.186, t.16] – warping of a workpiece after heat treatment;

Determining minimum over measures:

$$2z_2^{\text{min}} = 2(160 + 300 + \sqrt{904,7^2 + 200^2}) = 2,7 \text{ mm;}$$

$$2z_3^{\text{min}} = 2(40 + 75 + \sqrt{40^2 + 80^2}) = 0,4 \text{ mm;}$$

$$2z_5^{\text{min}} = 2(20 + 20 + \sqrt{176^2 + 50^2}) = 0,4 \text{ mm;}$$

Determining nominal over measures:

$$2z_2^{\text{H}} = 2z_2^{\text{min}} + es_1 = 2,7 + 1,4 = 4,1 \text{ mm;}$$

$$2z_3^{\text{H}} = 2z_3^{\text{min}} + Td_2 = 0,4 + 0,22 = 0,62 \text{ mm;}$$

$$2z_5^{\text{H}} = 2z_5^{\text{min}} + Td_3 = 0,4 + 0,087 = 0,487 \text{ mm;}$$

Determining nominal sizes:

$$d_1^{\text{H}} = d_2^{\text{H}} - 2z_2^{\text{H}} = 113,893 - 4,1 = 109,793 \text{ mm;}$$

$$d_2^{\text{H}} = d_3^{\text{H}} - 2z_3^{\text{H}} = 114,513 - 0,62 = 113,893 \text{ mm;}$$

$$d_3^{\text{H}} = d_5^{\text{H}} - 2z_5^{\text{H}} = 115 - 0,487 = 114,513 \text{ mm;}$$

$$d_5^H = d_{det}^H = 115 \text{ mm.}$$

Finding maximum over measures:

$$2z_2^{max} = 2z_2^{min} + Td_1 + Td_2 = 2,7 + 2 + 0,22 = 4,92 \text{ mm;}$$

$$2z_3^{max} = 2z_3^H + Td_3 = 0,62 + 0,087 = 0,707 \text{ mm;}$$

$$2z_5^{max} = 2z_5^H + Td_5 = 0,487 + 0,035 = 0,522 \text{ mm;}$$

Total nominal over measures:

$$2z_0^H = \sum 2z_i^H = 4,1 + 0,62 + 0,487 = 5,207 \text{ mm.}$$

Verification:

$$1. d_{det}^H - d_{workpiece}^H = 2z_0^H$$

$$115 - 109,793 = 5,207$$

$$5,207 = 5,207 - \text{true.}$$

$$2. 2z_2^{max} - 2z_2^{min} = Td_1 + Td_2$$

$$4,92 - 2,7 = 2 + 0,22$$

$$2,22 = 2,22 - \text{true.}$$

$$2z_3^{max} - 2z_3^{min} = Td_2 + Td_3;$$

$$0,707 - 0,4 = 0,22 + 0,087$$

$$0,307 = 0,307 - \text{true.}$$

$$2z_5^{max} - 2z_5^{min} = Td_3 + Td_5;$$

$$0,522 - 0,4 = 0,087 + 0,035$$

$$0,122 = 0,122 - \text{true.}$$

Results are making in a table 1.8

Table 1.8 – Over measures calculation for the surface treatment $\varnothing 115^{+0,035}$

	Operations	R_z , mkm	h, mkm	ρ , mkm	ε_i , mkm	Td, mm	$2z_i^H$, mm	d_i^H , mm	Exec. s-s d, mm	$2z_i^{max}$, mm	$2z_i^{min}$, mm
1	Established	160	300	904,7	-	2,0	-	109,793	$\varnothing 109,8^{+1,4}_{-0,6}$	-	-
2	Rough turning	40	75	40	200	0,22	4,1	113,893	$\varnothing 113,89^{+0,22}$	4,92	2,7
3	Clean turning	20	20	2	80	0,087	0,62	114,513	$\varnothing 114,51^{+0,08}$	7,07	0,4
4	Heat treatment	-	-	176	-	-	-	-	-	-	-
5	Grinding	10	15	2	50	0,035	0,487	115	$\varnothing 115^{+0,035}$	0,522	0,4

1.6 Calculation of cutting modes and technical rate of time

Stages of the appointment of cutting conditions.

1. Choose a cutting tool.

2. Appoint durability of the cutting tool T, min. Choose from the table of the directory[3], depending on kind, material and instrument geometry with workpiece parameters.

3. Appoint the cutting depth t, mm.

- for the turning, round grinding, recess, truncated, countersinking:

$$t = \frac{d_{i-1} - d_i}{2}$$

where d_{i-1} – dimentions of parts, which turned out on previous operation;

d_i – dimention, which gets by this operation, mm.

- for drilling

$$t = \frac{d_{dr.}}{2}$$

where $d_{dr.}$ – the diameter of a drill, mm

4. Appoint a submission.

1) Choose S_{table} , mm/turn with special tables;

2) Finding S_{truck} , mm/turn;

For turning:

$$S_{truck} = S_{table} \cdot K_{Sn} \cdot K_{Su} \cdot K_{Sf} \cdot K_{S3} \cdot K_{Sf} \cdot K_{5m} \quad (1.18)$$

where K_{Sn} –therate, which are taking consideration of blasting surface;

K_{Su} –therate, which are taking material of the instrument;

K_{Sf} –the rate, which are taking the form of surface;

K_{S3} –therate, which are taking the heat treating;

K_{Sj} –therate, which are taking rigidity of technology system;

K_{SM} –therate, which are taking the material of detail.

For drilling:

$$S_{truck} = S_{table} \cdot K_{Si} \cdot K_{Su} \cdot K_{Sd} \cdot K_{Sj} \cdot K_{SM}$$

where K_{Si} –the rate, which are taking the drilling depth;

K_{Sd} –the rate, which are taking the kind of machined hole.

For milling:

$$S_{truck} = S_{table} \cdot K_{Sc} \cdot K_{Su} \cdot K_{Sf} \cdot K_{SR}$$

where K_{Sc} –the rate, which are taking the code of milling scheme;

K_{SR} –the rate, which are taking the surface roughing.

For grinding:

$$S_{truck} = S_{table} \cdot K_m \cdot K_R \cdot K_D \cdot K_{Vk} \cdot K_t \cdot K_T \cdot K_h$$

where K_R –the rate, which are taking the radius of dumbbell;

K_D –the rate, which are taking the diameter of a circle;

K_{Vk} –the rate, which are taking the speed of a circle;

K_t –the rate, which are considering the stability of the circle;

K_T –the rate, which are considering the accuracy of processing;

K_h –the rate, which are considering the over measure for processing.

3) Determining S_o , mm/turn the machine passport.

5. Determining the speed of cutting.

1) Choosing V_{table} , m/min by special tables;

2) Finding $V_{calculation}$, m/min

For turning:

$$V_{calculation} = V_{table} \cdot K_{Vn} \cdot K_{Vu} \cdot K_{V\varphi} \cdot K_{V3} \cdot K_{V\mathcal{H}} \cdot K_{Vm} \cdot K_{Vo}$$

where K_{Vo} – the rate, which impact cutting fluids;

$K_{V\varphi}$ –the rate, which is considering the angle in plan.

For drilling:

$$V_{truck} = V_{table} \cdot K_{Vl} \cdot K_{Vu} \cdot K_{Vd} \cdot K_{VT} \cdot K_{Vm} \cdot K_{Vo}$$

For milling:

$$V_{truck} = V_{table} \cdot K_{Vn} \cdot K_{Vu} \cdot K_{V\varphi} \cdot K_{Vc} \cdot K_{V\phi} \cdot K_{Vm} \cdot K_{Vo} \cdot K_{VB} (1.24)$$

where K_{VB} –the rate, which is considering the ration of the actual width of milling to regulatory.

6. Define the speed n , rpm

1) Define $n_{calculation}$

$$n_{calculation} = \frac{1000 \cdot V_{calc.}}{\pi \cdot d}$$

3) On the machine passport taking the nearest smaller value $n_{worktable}$, rpm.

4) Define the ground speed by cutting V_f , m/min:

$$V_f = \frac{\pi \cdot d \cdot n_{worktable}}{1000}$$

Technological rating:

$$t_{in-r} = t_{in} + \frac{t_{soft.}}{n}$$

where t_{in} – afticial time, min;

$t_{soft.}$ – preparatoly-final time, min;

n – volume of the party, piece.

$$t_{piece} = t_{on} + t_{approx.}$$

$$t_{op} = t_o + t_e$$

$$t_{approx.} = t_{on} \cdot \alpha_{\Sigma}$$

where t_{ct} – cost time, min;

$t_{approx.}$ – the time for spending workplace service and relax, min;

α_{Σ} – the rate of surplus time;

t_o - main time, min;

t_e - extra time, min.

$$t_o = \sum t_{oj},$$

$$t_{oj.} = \sum t_{oi},$$

$$t_{oi} = \frac{l_{p.x.}}{S_o * n} * i$$

where $t_{oj.}$ – the main time of the i-th transition, min;

t_{oi} – the main time of processing of the i-th surface, min;

$l_{r.x.}$ - length of working stroke;

i – number of passes.

For sanding the full time by formula:

$$T_{mail} = \frac{L_{cut.} \cdot z \cdot k}{S_o \cdot S_p \cdot n_{det.}} \cdot i$$

$$t_{\epsilon} = k \cdot (t_{downl.} + t_{value} + t_{ref} + t_{sp} + t_{sw} + t_{contr.})$$

where k – the rate, which considers seriality;

$t_{down}, t_{mean.}$ – time for installation and removal of the workpiece, min.

$t_{control.}$ – time, required to operate the machine, min.

t_{sp}, t_{sv} - quickly tooling up and down in the beginning position, min;

$t_{control.}$ – time for measurement and control of basic parameters of the part, min;

$$t_{ex.} = t_{turn\ on.} + t_{turn\ down} + t_{turn.} + t_{first\ part} + t_{ogr.}$$

where $t_{turn\ on}$ и $t_{turn\ off}$ - time for activation and deactivation of workbench, min;

$t_{turn.}$ – time for turning revolving head to the next position, min;

$t_{first\ part}$ – time to switch spindle speed, min;

t_{fence} - time on a fence from a shaving, min.

Operation 020 Turning with CNC

The operation is doing on the lathe with CNC DUS-560ti.

Device: three-cam cartridge.

Instrument: incisor 25x30, $\varphi = 30^\circ$, T5K10, R=1 mm;

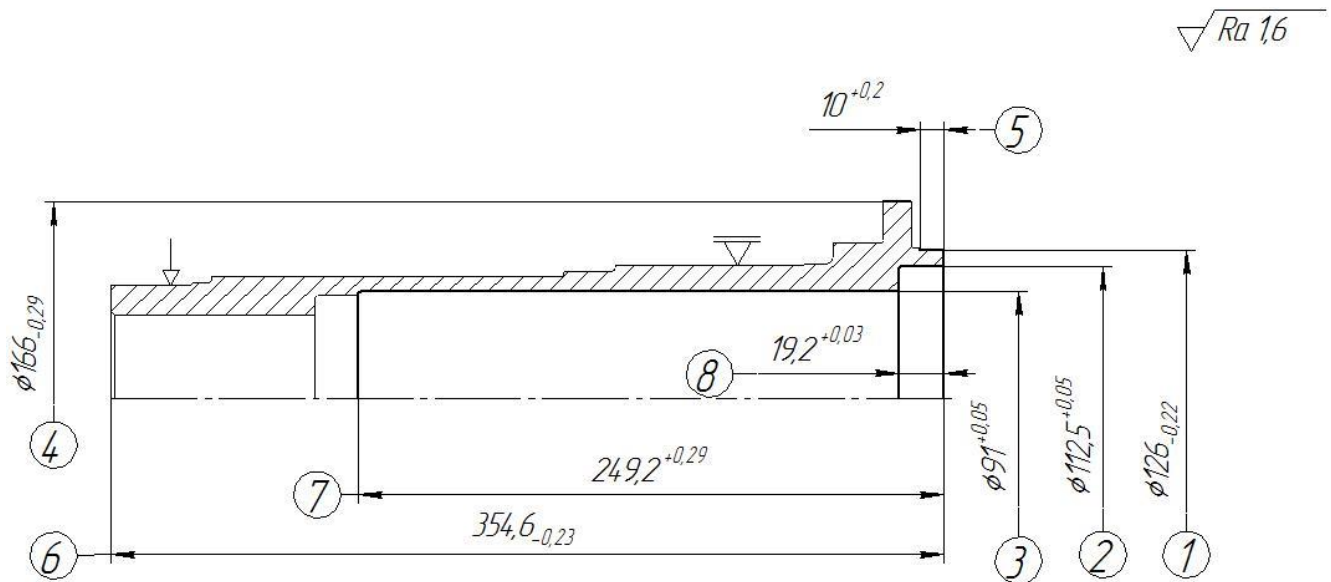


Figure 1.8 – Operating sketch of a turning operation

Cutting modes:

Durability of the tool T = 60 min;

Cutting depth:

$$t_1 = \frac{112,5 - 110}{2} = 1,25 \text{ mm}$$

$$t_2 = \frac{128 - 126}{2} = 1 \text{ mm}$$

$$t_3 = \frac{166 - 166}{2} = 1 \text{ mm}$$

$$t_4 = 251 - 249,2 = 1,8 \text{ mm}$$

Transition 1: Sharpen the surface 4.

Choosing the filing for [3, p.237, t.26]: $S_{table} = 0,57 \text{ mm/rev}$.

By formula (1.18) choosing $S_{solut.}$:

$$S_{solut.} = 0,57 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 = 0,57 \text{ mm/rev.}$$

where $K_{Sn} = 1$ – for the surface without any cork;

$K_{Su} = 1$ –for the instrument of the solid alloy;

$K_{Sf} = 1$;

$K_{Sz} = 1$;

$K_{Sj} = 1$ –for the machined diameter more than 40 mm to 150 mm;

$K_{Sm} = 1$ –for 9 group of materials;

Accepting $S_o = 0,55 \text{ mm/rev.}$

Table speeding we are choosing by [3,p.246, t.40]: $V_{table} = 39 \text{ m/min.}$

Defining $V_{calc.}$ by formula (1.22):

$$V_{calc.} = 39 \cdot 1 \cdot 1,4 \cdot 1 \cdot 1 \cdot 0,9 \cdot 1 \cdot 1,2 = 59 \text{ m/min.}$$

where $K_{Vn} = 1$ - for the surface without any cork;

$K_{Vu} = 1,4$ –for the instrument of the solid alloy;

$K_{Vz} = 1$;

$K_{Vj} = 1$ –for machining diameter lower than 150 mm;

$K_{Vm} = 0,9$ –for 9 group of materials;

$K_{Vo} = 1$ –processing with LCL;

$K_{V\varphi} = 1,2$ –the coefficient, which is considering the angle in a plan of 30° .

By formula (1.25) define $n_{calc.}$

$$n = \frac{1000 \cdot 59}{3,14 \cdot 168} = 111,8 \frac{\text{rev}}{\text{min.}}$$

Choosing speed the engine $n = 100 \frac{\text{rev}}{\text{min.}}$

Determining the factual speed of cutting V_f by formula (1.26)

$$V = \frac{3,14 \cdot 168 \cdot 100}{1000} = 52,8 \frac{\text{m}}{\text{min}}.$$

Transition 1: Sharpen the surface 1,5.

Choose the feed on [3, p.237, t.26]: $S_{table} = 0,57 \text{ mm/rev.}$

By formula(1.18) choosing $S_{calc.}$:

$$S_{calc.} = 0,57 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0,9 = 0,51 \text{ mm/rev.}$$

where $K_{Sn} = 1$ – for the surface without any cork;

$K_{Su} = 1$ –for the instrument of the hard alloy;

$K_{Sf} = 1$;

$K_{Sz} = 1$;

$K_{S_{\mathcal{H}}C} = 0,9$ –for the machined diameter more than 70 mm to 150 mm;

$K_{Sm} = 1$ –for 9 group of material.

Accepting $S_o = 0,5 \text{ mm/rev.}$

Table speeding we are choosing by [3,p.246, t.40]: $V_{table} = 39 \text{ m/min.}$

Defining $V_{calc.}$ by formula (1.22):

$$V_{calc.} = 39 \cdot 1 \cdot 1,4 \cdot 1 \cdot 0,8 \cdot 0,9 \cdot 1 \cdot 1,2 = 47,2 \text{ m/min.}$$

where $K_{Vn} = 1$ – for the surface without any cork;

$K_{Vu} = 1,4$ –for the instrument of the hard alloy;

$K_{V_3} = 1$;

$K_{Vj} = 0,8$ – for the machined diameter more than 70 mm to 150 mm;

$K_{Sm} = 1$ –for 9 group of material.

$K_{Vo} = 1$ –processing with LCL;

$K_{V\varphi} = 1,2$ –the coefficient, which is considering the angle in a plan of 30° .

By formula(1.25) choosing $n_{calc.}$:

$$n = \frac{1000 \cdot 47,2}{3,14 \cdot 128} = 117,5 \frac{\text{rev}}{\text{min.}}$$

Choosing speed the engine $n = 100 \frac{\text{rev}}{\text{min.}}$

Determining the factual speed of cutting V_f by formula (1.26)

$$V = \frac{3,14 \cdot 128 \cdot 100}{1000} = 40 \frac{\text{m}}{\text{min.}}$$

Transition 3: Sharpen the surface 2,3,6,7,8.

Choosing the feed by [3, p.237, t.26]: $S_{table} = 0,57 \text{ mm/rev.}$

By formula(1.18) choosing $S_{calc.}$:

$$S_{calc.} = 0,57 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0,9 = 0,51 \text{ mm/rev.}$$

where $K_{Vn} = 1$ – for the surface without any cork;

$K_{Su} = 1$ –for the instrument of the hard alloy;

$K_{Sf} = 1$;

$K_{Sz} = 1$;

$K_{S\mathcal{H}} = 0,9$ –for the machined diameter more than 70 mm to 150 mm;

$K_{Sm} = 1$ –for 9 group of material.

Accepting $S_o = 0,5 \text{ mm/rev.}$

Table speeding we are choosing by [3,p.246, t.40]: $V_{table} = 39 \text{ m/min.}$

Defining $V_{calc.}$ by formula (1.22):

$$V_{calc.} = 39 \cdot 1 \cdot 1,4 \cdot 1 \cdot 0,8 \cdot 0,9 \cdot 1 \cdot 1,2 = 47,2 \text{ m/min.}$$

where $K_{Vn} = 1$ – for the surface without any cork;

$K_{Vu} = 1,4$ –for the instrument of the hard alloy;

$K_{V3} = 1$;

$K_{Vj} = 0,8$ – for the machined diameter more than 70 mm to 150 mm;

$K_{Sm} = 0,9$ –for 9 group of material.

$K_{Vo} = 1$ –processing with LCL;

$K_{V\varphi} = 1,2$ –the coefficient, which is considering the angle in a plan of 30° .

By formula(1.25) choosing n_{calc} :

$$n = \frac{1000 \cdot 47,2}{3,14 \cdot 128} = 117,5 \frac{\text{rev}}{\text{min}}$$

Choosing speed the engine $n = 100 \frac{\text{rev}}{\text{min}}$.

Determining the factual speed of cutting V_f by formula (1.26)

$$V = \frac{3,14 \cdot 128 \cdot 100}{1000} = 40 \frac{\text{m}}{\text{min}}$$

Main time:

Transition 1:

Main time by formula (1.34):

$$L_1 = 12 + 3 + 3 = 18 \text{ mm}$$

$$T_{main\ 1} = \frac{18}{0,55 \cdot 100} = 0,33 \text{ min.}$$

Transition 2:

$$L_2 = 10 + 0 + 3 = 13 \text{ mm}$$

$$T_{main\ 2} = \frac{13}{0,5 \cdot 100} = 0,26 \text{ min.}$$

Transition 3:

$$\begin{aligned} L_3 &= 19,2 + 3 + 0 = 22,2 \text{ mm} \\ L_4 &= \frac{112,5 - 91}{2} + 3 + 0 = 13,75 \text{ mm} \\ L_5 &= 249,2 - 19,2 + 3 + 3 = 236 \text{ mm} \\ T_{main\ 3} &= \frac{22,2 + 13,75 + 236}{0,5 \cdot 100} = 5,44 \text{ min.} \end{aligned}$$

Main time of operation by formula (1.32):

$$T_o = T_{main\ 1} + T_{main\ 2} + T_{main\ 3} = 0,33 + 0,26 + 5,44 = 6,03 \text{ min}$$

Auxiliary time by formula (1.36):

$$T_{inst.} = 0,67 \times_B [5, \text{kart } 51, \text{ p. } 138];$$

$$T_{man.} = 0,08 + 0,05 + 0,15 + 0,03 = 0,31 \text{ min.} [5, \text{kart } 60-61, \text{ p. } 150];$$

$$T_{contr.} = 0,12 + 0,06 = 0,18 \text{ min.} [5, \text{kart } 64, \text{ p. } 160];$$

$$T_{add.} = 0,67 + 0,31 + 0,18 = 1,16 \text{ min.}$$

Operation time by formula (1.30):

$$T_{op} = 2,83 + 1,16 = 3,99 \text{ min.}$$

Service time for the workplace and relax by formula (1.31):

$$T_{ex.time} = (0,03 + 0,04 + 0,04) \cdot 3,99 = 0,44 \text{ min.}$$

Artificial calculation time by formula (1.28):

$$T_{ar.-c.} = 3,99 + 0,44 + \frac{19}{336} = 4,49 \text{ min.}$$

Operation 125 Boring with a CNC.

Operation is making on the drilling machine with a CNC WKV-100.

Instrument: drill $\varnothing$ 10 mm GOST2034-80, material P6M5; countersink $\varnothing$ 20 mm GOST 1677-75, material P6M5;

Cutting regimes:

Durability of the tool: T=60 min.;

Cutting depth:

$$t_1 = \frac{10}{2} = 5 \text{ mm}$$

$$t_2 = 0,8 \text{ mm}$$

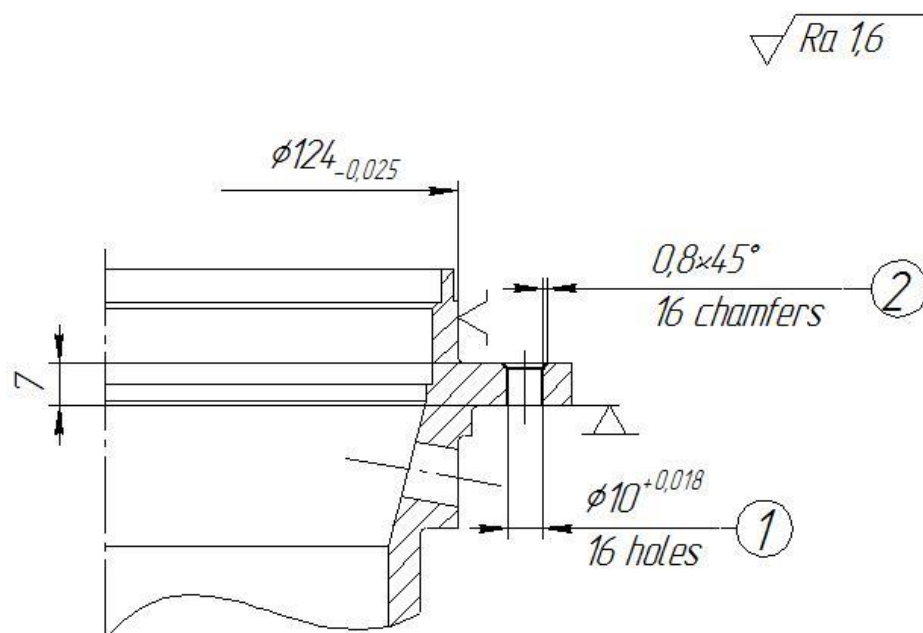


Figure 1.9 – Operating sketch of drilling operation

Transition 1: Drill 16 holes $\varnothing$ 10 mm.

At first we are choosing filling on [3, c.267, т.64]: $S_{ma\bar{o}l} = 0,18$ mm/rev.

By formula (1.16) choosing $S_{calc.}$:

$$S_{calc.} = 0,18 \cdot 1 \cdot 1 \cdot 1 \cdot 0,75 = 0,135 \text{ mm/rev}$$

where $K_{Sl} = 1$ –for drilling depth $< 3D$;

$K_{Su} = 1$ –for the instrument of the high-speed steel;

$K_{Sd} = 1$ – for through hole;

$K_{Sm} = 0,75$ –for 9 group of materials.

Accepting $S_o = 0,13 \text{ mm/rev}$.

Table speed we are choosing by [3,p.271, t.68]: $V_{table} = 15 \text{ m/min}$

Defining V_{rated} by formula (1.0):

$$V_{rated} = 15 \cdot 1 \cdot 0,86 \cdot 1 \cdot 1 \cdot 1 \cdot 1 = 12,9 \text{ m/min}$$

where $K_{Vn} = 1$ –for the surface without any cork;

$K_{Vu} = 0,86$ –for the instrument of P6M5;

$K_{Vd} = 1$ – for through hole;

$K_{VT} = 1$;

$K_{Sl} = 1$ – for the drilling depth $< 3D$;

$K_{Vo} = 1$ –processing of CF.

By formula (1.22) finding n_{pozp} :

$$n = \frac{1000 \cdot 12,9}{3,14 \cdot 10} = 410,8 \frac{\text{rev}}{\text{min}}$$

Finding speeds the engine $n = 400 \frac{\text{rev}}{\text{min}}$.

Defining factual speed cutting V_f by formula (1.23)

$$V = \frac{3,14 \cdot 10 \cdot 400}{1000} = 12,5 \frac{\text{m}}{\text{min}}$$

Transition 2: Countersink 16 facets 0,8x45° mm.

Choosing supply by [3, p.277, t.73]: $S_{table} = 1,65$ mm/rev.

By formula (1.16) choosing $S_{calc.}$:

$$S_{calc.} = 1,65 \cdot 1 \cdot 0,36 = 0,59 \text{ mm/rev.}$$

where $K_{sd} = 1$ – for through role;

$K_{Sm} = 0,36$ –for 9 group materials.

Accepting $S_o = 0,5$ mm/rev.

Table speed we are choosing by [3,p.280, t.79]: $V_{table} = 25$ m/min.

Choosing $V_{calc.}$ by formula (1.20):

$$V_{calculation} = 25 \cdot 1 \cdot 0,86 \cdot 1 \cdot 1 \cdot 1 \cdot 1 = 21,5 \text{ m/min.}$$

where $K_{Vn} = 1$

$K_{Vu} = 0,86$ –for instrument of P6M5;

$K_{Vd} = 1$ – for through hole;

$K_{VT} = 1$;

$K_{Vo} = 1$ –processing of CF.

By formula (1.22) choosing n_{sizes} :

$$n = \frac{1000 \cdot 21,5}{3,14 \cdot 10} = 684,7 \frac{\text{rev}}{\text{min}}$$

Choosing speed the engine $n = 650 \frac{\text{rev}}{\text{min}}$.

Defining factual speed cutting V_f by formula (1.23)

$$V = \frac{3,14 \cdot 10 \cdot 650}{1000} = 20,4 \frac{m}{min}.$$

Main time:

Transition 1:

Main time by formula (1.31):

$$L_1 = 5 + 5 + 7 = 17 \text{ mm}$$

$$T_{main\ 1} = \frac{17}{0,13 \cdot 400} \cdot 16 = 5,2 \text{ min.}$$

Transition 2:

$$L_2 = 5 + 0 + 0,8 = 5,8 \text{ mm}$$

$$T_{main\ 2} = \frac{5,8}{0,5 \cdot 650} \cdot 16 = 0,3 \text{ min.}$$

Main time of operation by formula (1.29):

$$T_o = T_{main\ 1} + T_{main\ 2} = 5,2 + 0,3 = 5,5 \text{ min.}$$

Overtime by formula (1.33):

$$T_{inst.} = 0,53 \text{ min [5, kart 81, p.158];}$$

$$T_{man.} = 0,08 + 0,05 + 0,1 + 0,05 = 0,28 \text{ min [5, kart 85-66, p.170];}$$

$$T_{contr.} = 0,12 + 0,06 = 0,18 \text{ min [5, kart 88, p.172];}$$

$$T_{extra} = 0,53 + 0,28 + 0,18 = 0,99 \text{ min.}$$

Operational time by formula (1.27):

$$T_{op} = 5,5 + 0,99 = 6,49 \text{ min.}$$

Time for serving the workplace and relaxing by formula (1.28):

$$T_{app.} = (0,03 + 0,04 + 0,04) \cdot 6,49 = 0,71 \text{ min}$$

Artificial time calculation by formula (1.25):

$$T_{art.-t.} = 6,49 + 0,71 + \frac{29}{336} = 7,25 \text{ min.}$$

Operation 075 milling with CNC.

Operation is doing on the shaper with CNC MA-655A8.

Instrument: mill Ø 4 mm GOST 29092-91, material P9M4K8;

Cutting modes:

Drilling of the tool T=60 min;

Cutting depth: $t_1 = 4 \text{ mm}$;

Choosing pitching at the tooth [3, p.305, t.113]: $S_{Ztable} = 0,2 \text{ mm/tooth}$.

By formula (1.20) we are choosing $S_{calc.}$:

$$S_{Zcalc.} = 0,2 \cdot 0,66 \cdot 1 \cdot 0,5 = 0,066 \text{ mm/rev.}$$

where $K_{Vf} = 0,66$ –for grooving;

$K_{Vu} = 1$ –for instrument of high-speed steel;

$K_{SR} = 0,5$.

$$S_o = S_{Zpozp} \cdot Z = 0,066 \cdot 2 = 0,132 \text{ mm/rev}$$

where $Z=2$ – amount of teeth cutters.

Adopting $S_o = 0,13 \text{ mm/rev}$.

Table speed we are choosing by [3,p.320, t.130]: $V_{table} = 51 \text{ m/min}$.

Defining $V_{\text{calculation}}$ by formula (1.24):

$$V_{\text{calculation}} = 51 \cdot 0,57 \cdot 1,12 \cdot 1 \cdot 1 \cdot 1 = 32,6 \text{ m/min.}$$

where $K_{Vs} = 1$ – surface without crust;

$K_{V\phi} = 0,57$ –for grooving;

$K_{Vu} = 1,12$ –for instrument of P9M4K8;

$K_{VB} = 1$;

$K_{Vo} = 1$ –processing of CF.

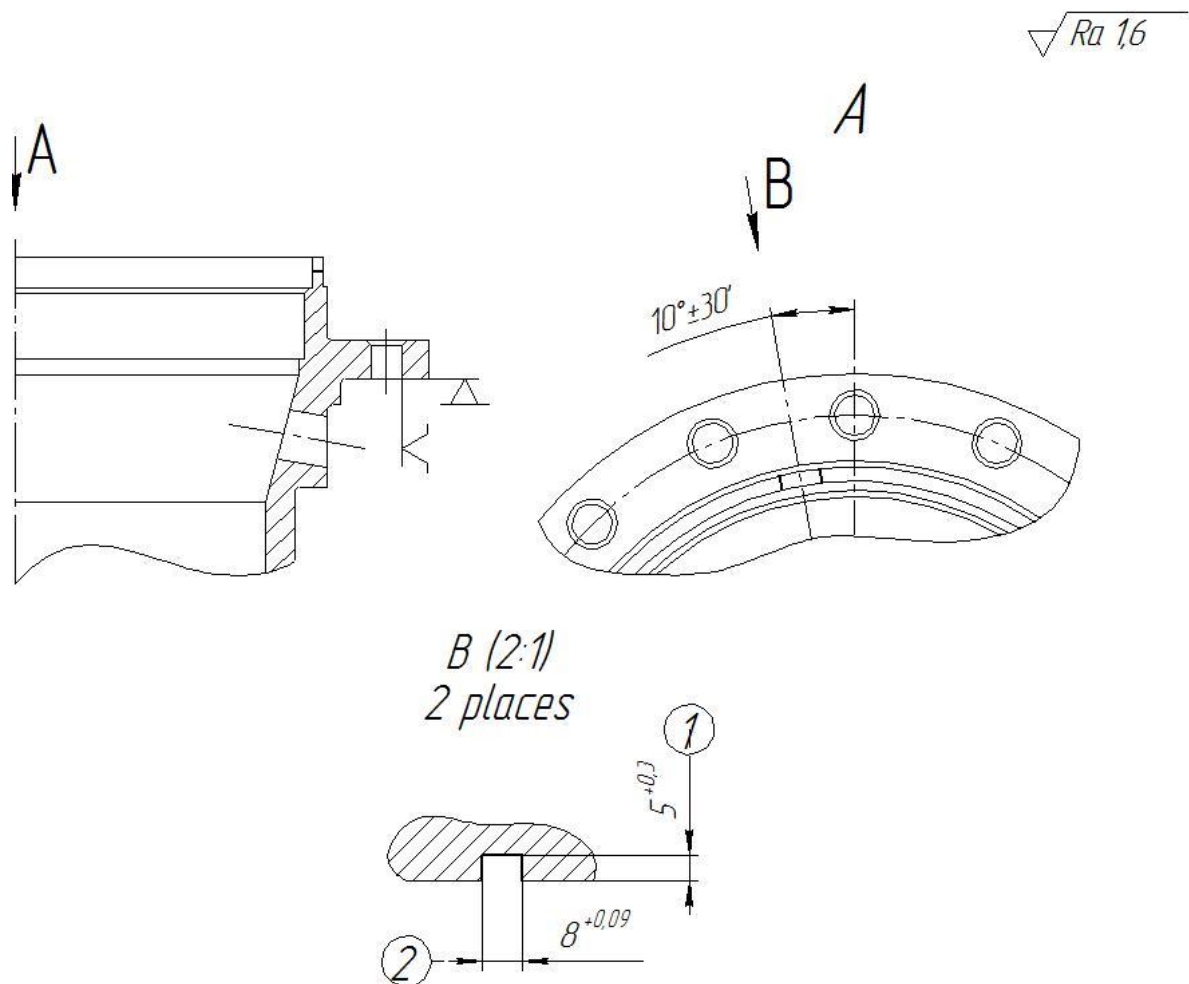


Figure 1.10 – Operating sketch of a milling operation

By formula (1.24) choosing $n_{\text{calc.}}$:

$$n = \frac{1000 \cdot 32,6}{3,14 \cdot 124} = 83,7 \frac{\text{rev}}{\text{min}}$$

Choosing the engine speed by formula $n = 80 \frac{\text{rev}}{\text{min}}$.

Choosing factual speed of cutting V_f by formula (1.26)

$$V = \frac{3,14 \cdot 124 \cdot 80}{1000} = 31,1 \frac{\text{m}}{\text{min}}$$

Main time:

Main time by formula (1.34):

$$L_1 = 5 + 5 + 18 = 28 \text{ mm}$$

$$T_{main.} = \frac{28}{0,13 \cdot 80} \cdot 2 = 5,38 \text{ min.}$$

Auxiliary time by formula (1.36):

$$T_{inst.} = 0,53 \text{ min [5, kart 81, стр.158];}$$

$$T_{man.} = 0,08 + 0,05 + 0,1 + 0,05 = 0,28 \text{ min [5, kart 85-66, p.170];}$$

$$T_{contr.} = 0,12 + 0,06 = 0,18 \text{ min[5, kart 88, p.172];}$$

$$T_{extra} = 0,53 + 0,28 + 0,18 = 0,99 \text{ min.}$$

Operating time by formula (1.30):

$$T_{op} = 5,38 + 0,99 = 6,37 \text{ min.}$$

Time for maintenance of the workplace and rest by formula (1.31):

$$T_{nearly} = (0,03 + 0,04 + 0,04) \cdot 6,37 = 0,7 \text{ min.}$$

Artificial calculation time by formula (1.28):

$$T_{art.-c.} = 6,37 + 0,7 + \frac{29}{336} = 7,12 \text{ min.}$$

Operation 120 Grinding

It is performed on a grinding machine 3K229A.

Grinding disc 5-200x30x63 24A 40CM1K GOST 2424-82, 35 m/s.

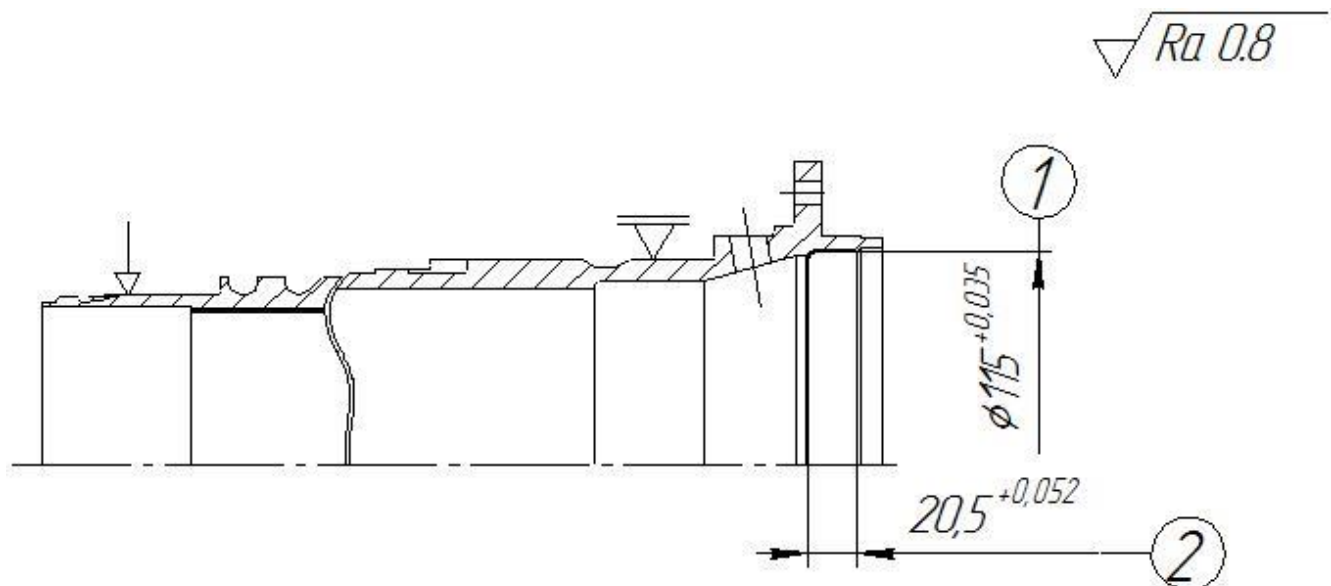


Figure 1.11 – Operating sketch of grinding operation

Selection radial feed by [3, p.351, table. 169]: $S_{table} = 0,014 \text{ mm/rev.}$

By formula (1.21) choosing $S_{calc.}$:

$$S_{calc.} = 0,014 \cdot 0,6 \cdot 1 \cdot 1 \cdot 1,4 \cdot 0,75 \cdot 0,76 = 0,007 \text{ mm/rev}$$

where $K_M = 0,6$;

$$K_D = 1;$$

$$K_{Vk} = 1;$$

$$K_t = 1,4;$$

$$K_T = 0,75;$$

$$K_h = 0,76.$$

Accepting $S_o = 0,007$ mm/rev.

Table workpiece speed rotation we are choosing by [3, p.343, table.161]:

$$V_{\text{det.}} = 50 \text{ m/min.}$$

Speed engine:

$$n_{\text{circle}} = \frac{1000 \cdot V_{\text{circle}} \cdot 60}{\pi \cdot D_{\text{circle}}} = \frac{1000 \cdot 35 \cdot 60}{3,14 \cdot 115} = 3200 \frac{\text{rev}}{\text{min}}$$

$$n_{\text{det.}} = \frac{1000 \cdot V_{\text{det.}}}{\pi \cdot D_{\text{det.}}} = \frac{1000 \cdot 50}{3,14 \cdot 115} = 138,5 \frac{\text{rev}}{\text{min}}$$

Choosing the speed engine $n_{\text{circle}} = 3200 \frac{\text{rev}}{\text{min}}, n_{\text{det.}} = 130 \frac{\text{rev}}{\text{min}}$.

Factual speed:

$$V_{\text{circle}} = \frac{\pi \cdot D \cdot n}{1000 \cdot 60} = \frac{3,14 \cdot 115 \cdot 630}{1000 \cdot 60} = 37,9 \frac{\text{m}}{\text{s}}.$$

$$V_{\text{detail}} = \frac{\pi \cdot D \cdot n}{1000} = \frac{3,14 \cdot 115 \cdot 130}{1000} = 46,9 \frac{\text{m}}{\text{min}}.$$

Main time by formula (1.35):

$$L = \frac{115 - 109}{2} + 5 + 5 + 20,5 = 33,5 \text{ mm.}$$

$$T_{\text{main.}} = \frac{33,5 \cdot 0,3 \cdot 1,7}{0,2 \cdot 0,007 \cdot 130} = 23,8 \text{ min.}$$

Auxiliary time by formula (1.36):

$$T_{\text{inst.}} = 0,43 \text{ min. [5, kart 91, p.188];}$$

$$T_{\text{man.}} = 0,08 + 0,05 + 0,2 + 0,03 = 0,36 \text{ min. [5, kart 94, p.190];}$$

$$T_{contr.} = 0,15 + 0,06 = 0,21 \text{ min. [5, kart 98, p.194];}$$

$$T_{extra} = 0,43 + 0,36 + 0,21 = 1 \text{ min.}$$

Operating time by formula (1.30):

$$T_{op} = 23,8 + 1 = 24,8 \text{ min.}$$

Time for maintenance of the workplace and rest by formula (1.31):

$$T_{nearly} = (0,03 + 0,04 + 0,04) \cdot 24,8 = 2,7 \text{ min.}$$

Artificial calculation time by formula (1.28):

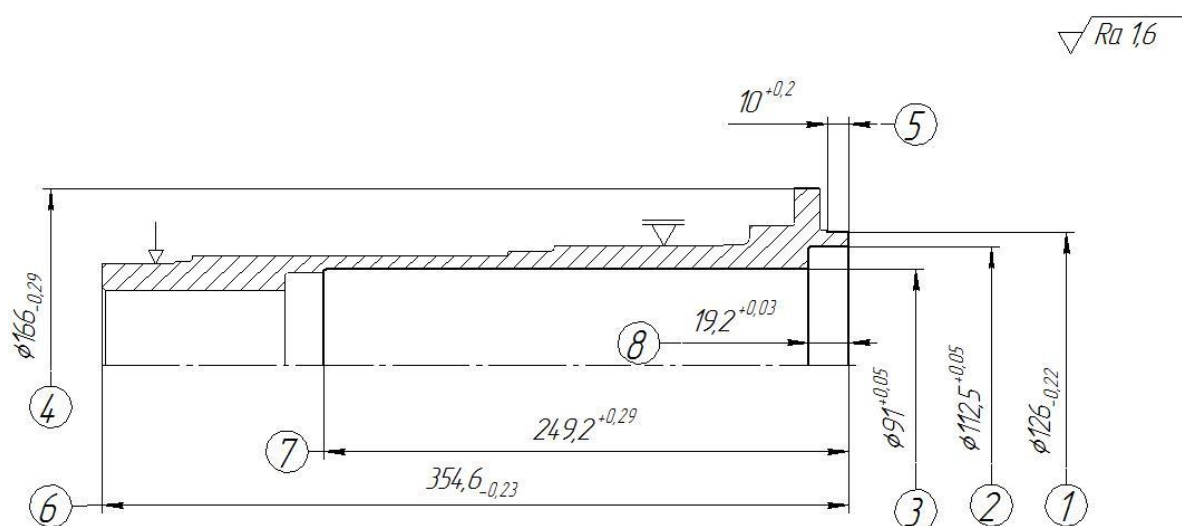
$$T_{art-c.} = 24,8 + 2,7 + \frac{6}{336} = 27,55 \text{ min.}$$

1.7 Developing technological operations on the high-performance machines of CNC.

1.7.1 Developing turning operation

Operation 020 Turning with CNC.

Operation is doing on the turning machine with CNC DUS-560ti.



Picture 1.12 – Operating sketch of turning operation

Transition 1: Sharpening the surface, withstanding the size 4.

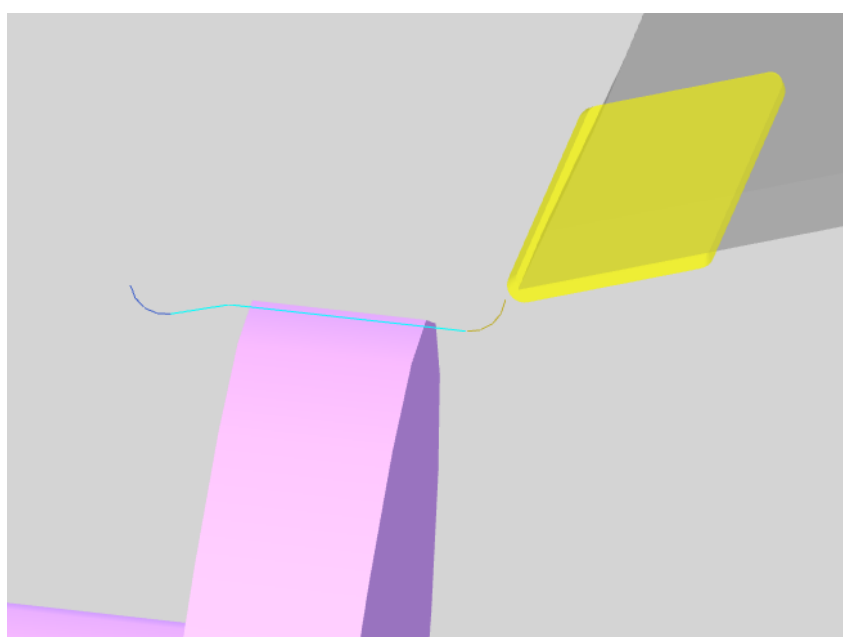


Figure 1.13 – Trajectory of the turning operation (transition 1)

Transition 2: Sharpening the surface, with standing the size 1,5.

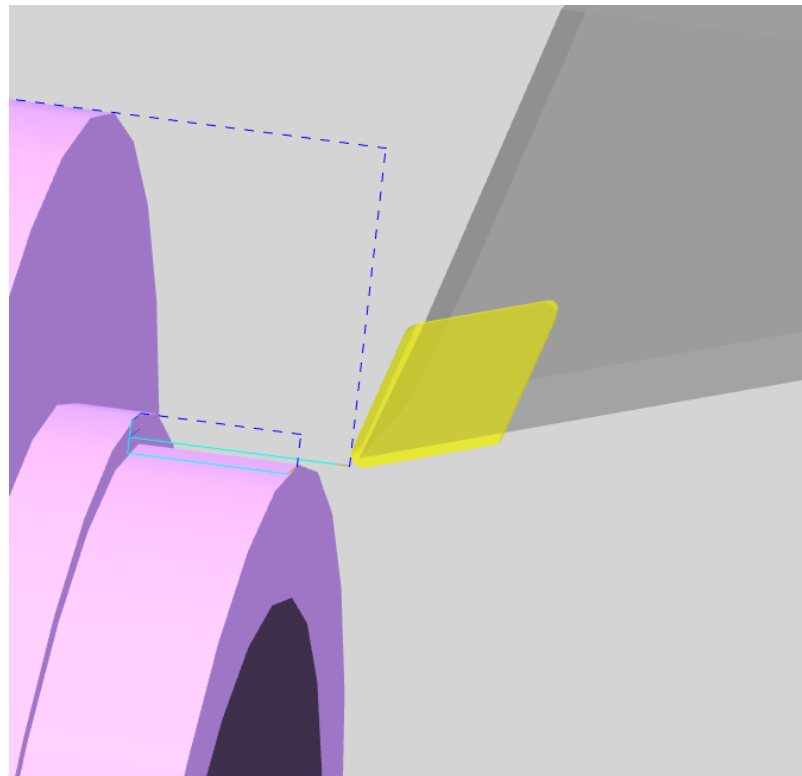


Figure 1.14 – Trajectory of the turning operation (transition 2)
 Transition 3: Sharpening the surface, withstanding the sizes 2,3,6,7,8.

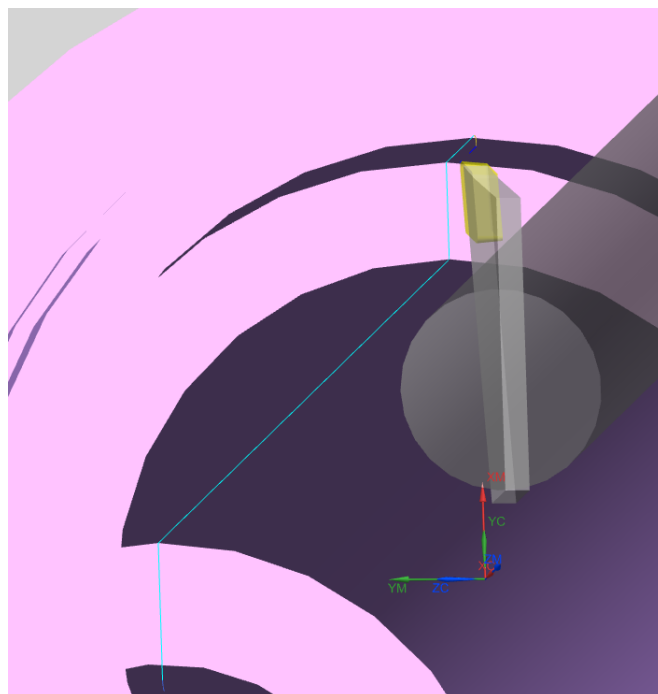


Figure 1.15 – Trajectory of the turning operation (transition 3)

```

N0010 G02 G90 X3.2677 Y0.0 U0.0 V0.0 I0.0 J0.0
N0020 G01
N0030 X3.2391
N0040 G02 X3.283 I-.0607
N0050 G00 X3.3071
N0060 X2.5197
N0070 G01
N0080 X2.5591
N0090 X2.5813
N0100 G00
N0110 X2.5026
N0120 G01 X2.4803
N0130 X2.5197
N0140 X2.542
N0150 G00 X2.091
N0160 G03 X2.154 I0.0
N0170 G01
N0180 X1.6816
N0190 X1.0123
N0200 G03 X.9493
N0210 M02
N0220 G00 G90 X3.3071 Y0.0 U0.0 V0.0
N0230 X2.5197
N0240 G01
N0250 X2.5591
N0260 X2.5813
N0270 G00
N0280 X2.5026
N0290 G01 X2.4803
N0300 X2.5197
N0310 X2.542
N0320 M02
N0330 G00 G90 X2.091 Y0.0 U0.0 V0.0
N0340 G03 X2.154 I0.0 J0.0
N0350 G01
N0360 X1.6816
N0370 X1.0123
N0380 G03 X.9493
N0390 M02

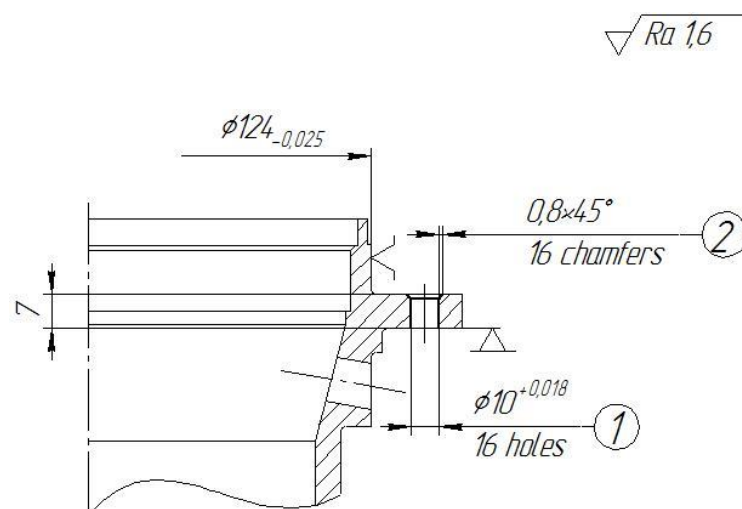
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Figure 1.16 – Governing program of turning operation

1.7.2 Developing of the drilling operation

Operation 125 Drilling with CNC.

Operation is making on the drilling machine with CNC WKV-100.



Picture 1.17 – Operating sketch of the turning operation

Transition 1: drill 16 holes $\varnothing 10$ mm.

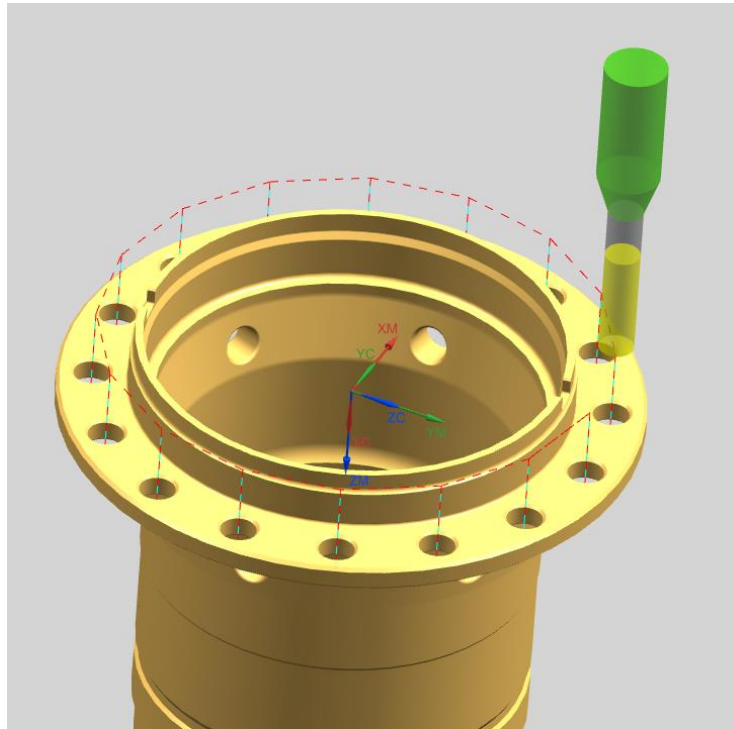


Figure 1.18 - Trajectory of the drilling operation (transition 1)

Transition 2: countersink 16 facets $0,8 \times 45^\circ$ mm.

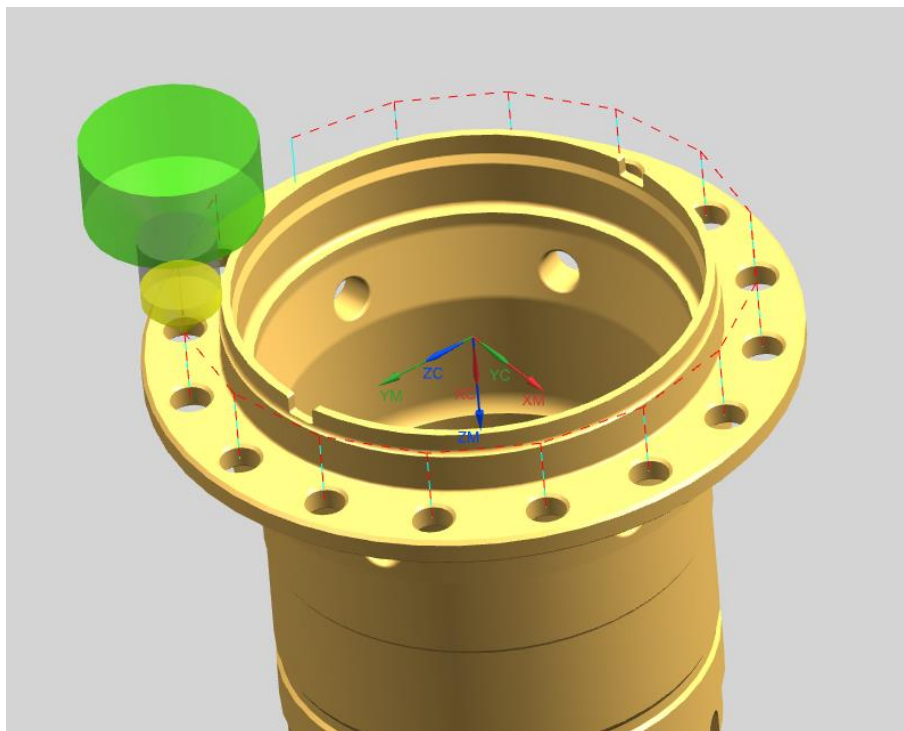


Figure 1.19 - Trajectory of the drilling operation (transition 2)

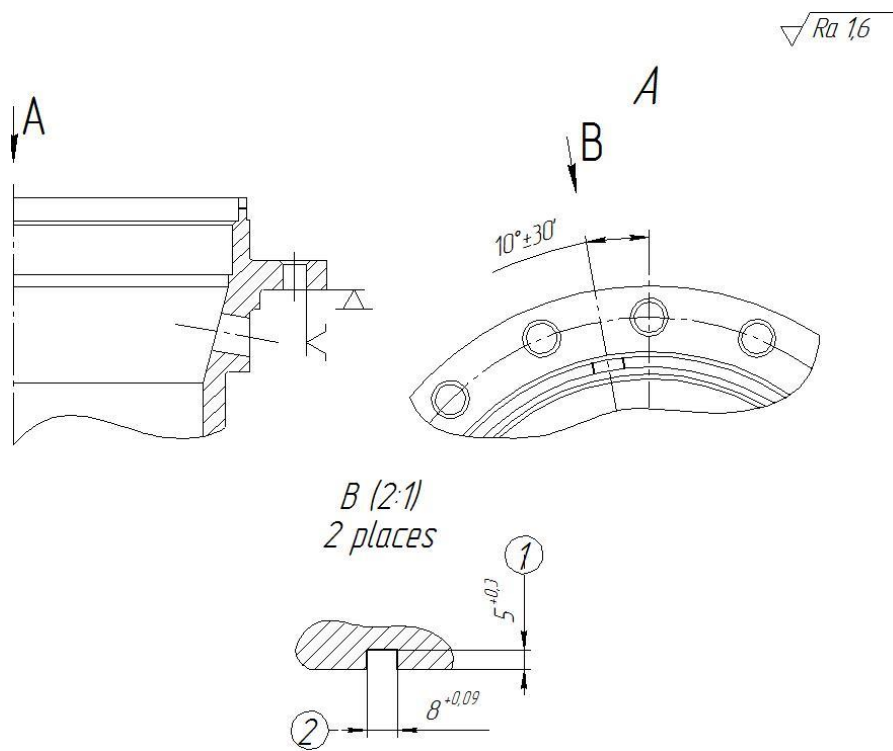


Figure 1.21 – Operating sketch of a milling operation

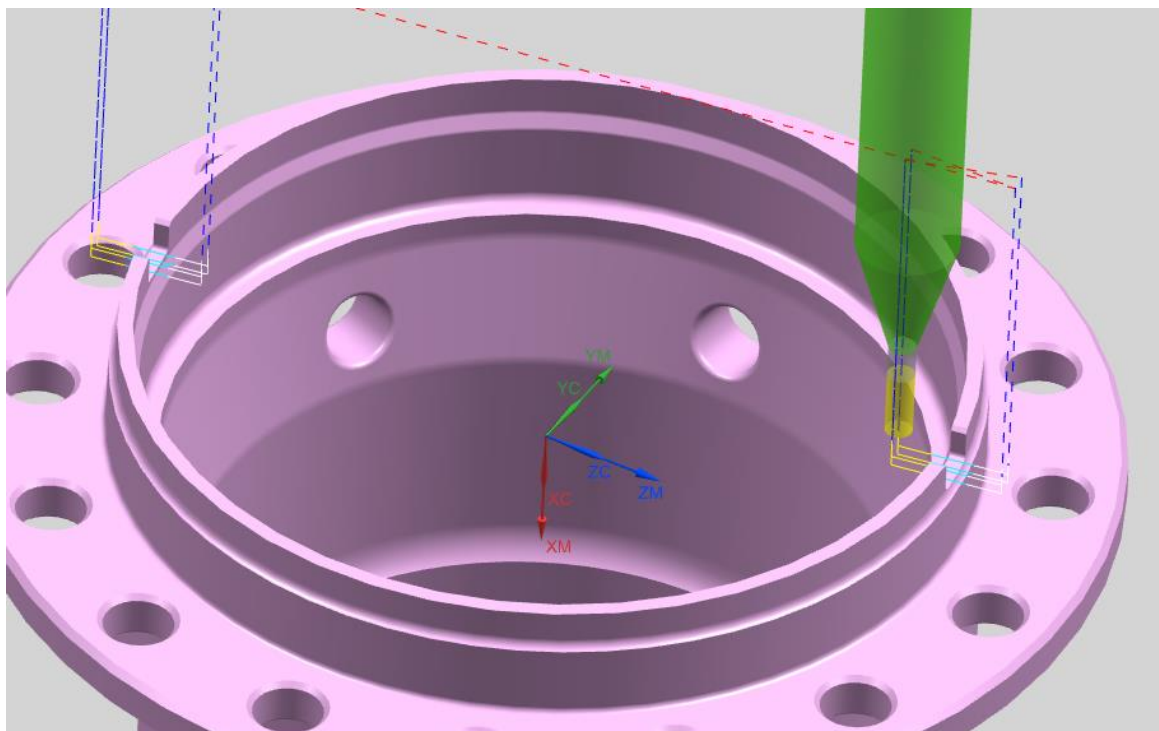


Figure 1.22 – The trajectory of the milling operation

```

TOOL PATH/FLOOR_WALL,TOOL,MILL
TLDDATA/MILL,4.0000,0.0000,15.0000,0.0000,0.0000
MSYS/0.0000,0.0000,0.0000,1.0000000,0.0000000,0.0000000,0.0000000,1.0000000,0.0000000
$$ centerline data
PAINT/PATH
PAINT/SPEED,10
PAINT/COLOR,186
RAPID
GOTO/-67.0000,10.2587,50.7235,-1.0000000,0.0000000,0.0000000
PAINT/COLOR,211
RAPID
GOTO/-16.5000,10.2587,50.7235
PAINT/COLOR,42
FEDRAT/MMPM,250.0000
GOTO/-13.5000,10.2587,50.7235
GOTO/-13.5000,11.1271,55.6485
PAINT/COLOR,31
GOTO/-13.5000,12.2256,61.8785
PAINT/COLOR,37
GOTO/-13.5000,13.1234,66.9703
GOTO/-16.5000,13.1234,66.9703
PAINT/COLOR,211
RAPID
GOTO/-67.0000,13.1234,66.9703
PAINT/COLOR,186
RAPID
GOTO/-67.0000,7.7055,51.1737
PAINT/COLOR,211

```

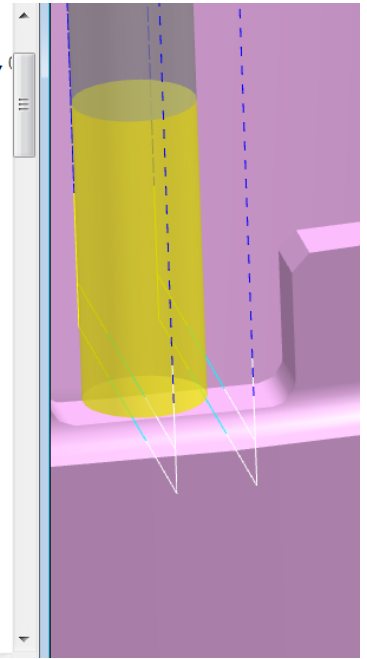


Figure 1.23 – Managing program of the milling operation

2 THE DESIGN PART

2.1 Work fixture Designing.

2.1.1 Description of the construction and working principle.

Working device for CNC milling operation.

Workpiece is installed on three components. Fastening of a part is carried out with the help of the device with horizontal clamping strap, with pneumatic actuator double acting.

2.1.2 Accuracy calculation

Installation error – the part of processing error, which is consisted of an error of basing and fixing.

Base error - projection on the direction of the executable size, of the difference of the limiting distances between measuring base and set to size by cutting tool or focus, which occurs as a result of mismatch of the measuring and adjustment base.

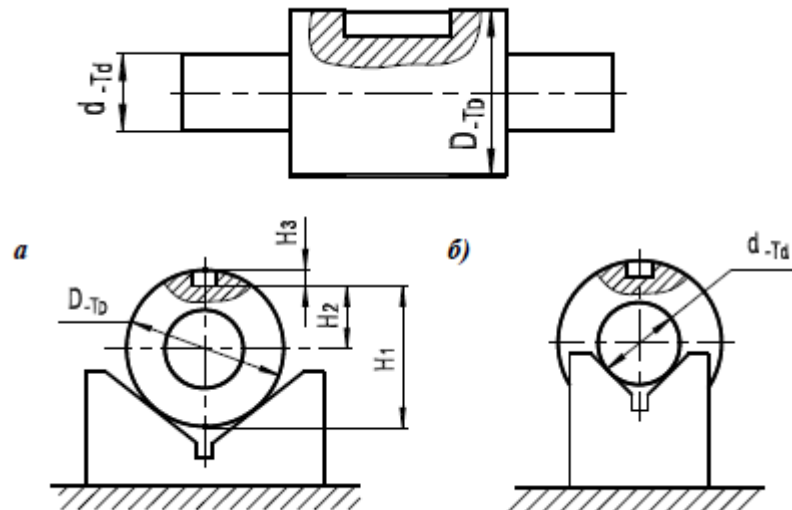
Fixation error - projection on the direction of the executable size, of deviation of the measured base, with setting cutting tool to the size, which arises under the action of the anchoring forces applied.

$$\varepsilon_{down.} = \varepsilon_b + \varepsilon_z$$

where ε_b – base error;

ε_z – fixation error.

At the base of the workpiece you need to get rid of its six degrees of freedom.



Picture 2.1 – Diagram of an apparatus when milling the grooves of the keyway

Source data:

$k_2 = 0,58$ –for the prism angle 120° ;

$T_d = 0,22$ mm- tolerance on $\varnothing 107$;

$T_D = 0,14$ mm – tolerance on $\varnothing 110,8$;

Errors which are based on typical sizes will be determined by following terms:

$$\varepsilon_{6H1} = \varepsilon_{6H3} = k_2 \cdot T_d + \frac{T_D}{2} = 0,58 \cdot 0,22 + \frac{0,14}{2} = 0,198 \text{ mm}$$

$$\varepsilon_{6H2} = k_2 \cdot T_d = 0,58 \cdot 0,22 = 0,128 \text{ mm}$$

Fixation error $\varepsilon_z = 0$, because the direction of processing size and fixing forces will be mutually perpendicular.

The voltage:

$$\varepsilon_{volt.} = \varepsilon_b + \varepsilon_z = 0,198 + 0 = 0,198 \text{ mm.}$$

2.1.3 Calculation for accuracy

To reduce the time for settings of the instrument on the executive size on the milling tool can be applied installation. Setting is underway with using a probe, which allows exact feel the moment of output of the tool in size, while not bump mill into customizable surface institution.

Possible options of processing dimensions and setting scheme of the instrument of the imaginary point "0" which is showed on the fig. 2.2.

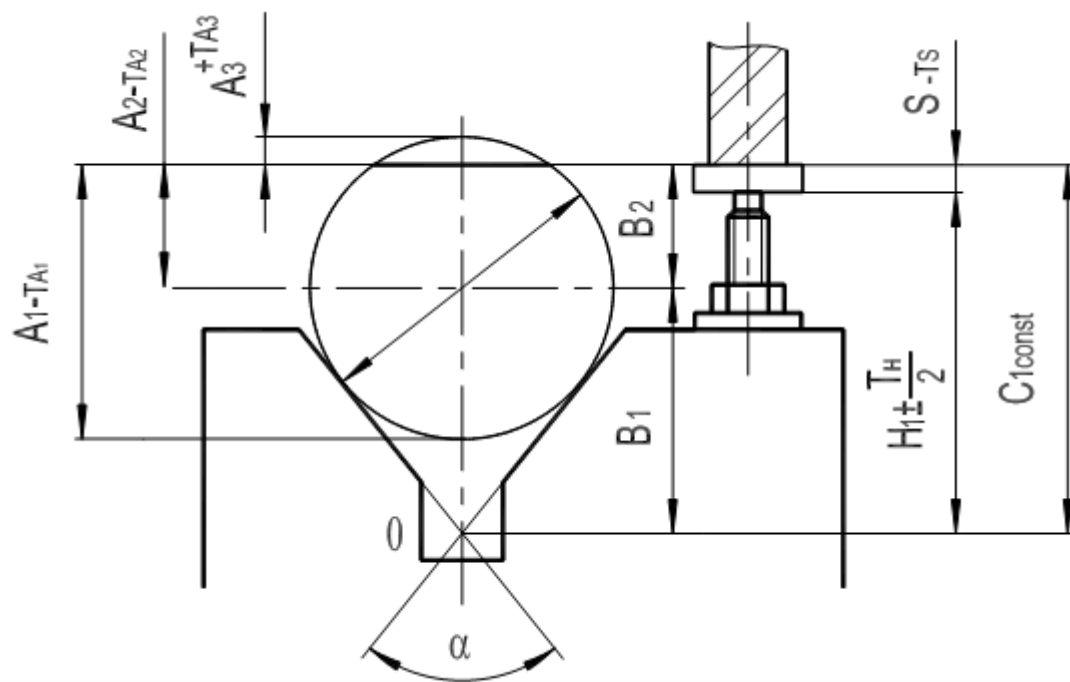


Figure 2.2. – Diagram of an apparatus blanks on the prism

This approach imposes certain difficulties, because this point is absent and estimated in the real prism. To avoid those difficulties estimated size of institution should be supplemented by the size from a zero point to a prism basics.

The sequence of calculation:

1. Choosing the average size of the treatment $A_{aver.}$:

$$A_{aver.} = A_{min} - \frac{T_A}{2}$$

2. Choosing the average diameter of the treatment $D_{\text{aver.}}$:

$$D_{\text{aver.}} = D_{\text{min}} + \frac{T_D}{2}$$

3. The average radius $R_{\text{aver.}}$:

$$R_{\text{aver.}} = \frac{D_{\text{aver.}}}{2}$$

4. The average size $B_{1\text{aver.}}$:

$$B_{1\text{aver.}} = \frac{R_{\text{aver.}}}{\sin \frac{\alpha}{2}}$$

5. The average size $B_{2\text{aver.}}$:

$$B_{2\text{aver.}} = R_{\text{aver.}} - A_{3\text{aver.}}$$

6. The average size of probe $S_{\text{aver.}}$:

$$S_{\text{aver.}} = S_{\text{min}} + \frac{T_S}{2}$$

7. Choosing the average size of institution height:

$$H_{\text{aver.}} = B_{1\text{aver.}} + B_{2\text{aver.}} - S_{\text{aver.}}$$

The resulting size from the conditional (custom) base. But, for the manufacture the installation there is a necessarily to get attached to the real

surface. The most comfortable for this is a plate surface on which is installed prism and institutions. The distance from the setting base to the plate is size a (fig. 2.3).

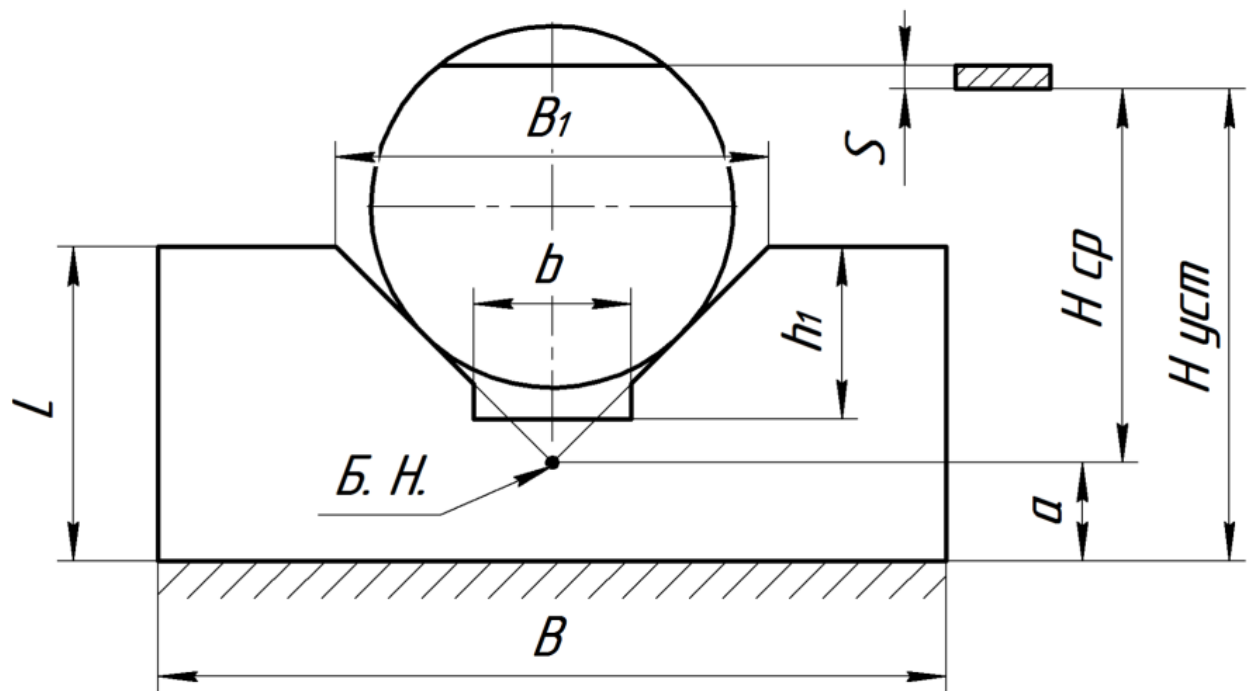


Figure 2.3 – Binding of the setting base to the setting plate

8. Determine the height of the institution:

$$H = H_{\text{aver.}} + a$$

9. The institution of the size tolerance will determine the degree of accuracy of the device:

$$T_n \leq T_{A3} - (0,21k_1\varepsilon_6 + \varepsilon_3 + k_2\omega)$$

where $T_{\text{process.}}$ - full processing size tolerance field;

$k_1 = 0,8 \dots 0,85$ – the coefficient, which consists reducing of basing errors, as a result that the fixture changes infrequently, but the actual base dimensions of a workpiece are seldom equal the limit.

ε_b - the error of the base of the workpiece in the device;

ε_f - the error of fixing the workpiece in the device;

$k_2 = 0,6...0,65$ - the coefficient, which consists the susceptible of processing errors from the overall, which was caused by matters, which don't depend on the construction of the adaptation.

ω – the average economic accuracy of processing.

10. Checking the condition of accuracy:

$$\frac{T_N}{2} < \frac{1}{3} T_{AZ}$$

Determine $T_N = \pm \frac{T_N}{2}$ and bringing to normalized.

11. Designating the executive size of the institution:

$$[H] = H_{-\frac{T_{inst.}}{2}}$$

Source data:

Size of processing for chanterelles $A_{-T_A} = 3,2_{-0,15}$ mm;

The distance from the setting base a to the plate = 45 mm;

The thickness of the probe $S = 3_{-0,004}$ mm.

The average size of cultivation by formula 2.2:

$$A_{av.} = 3,05 - \frac{0,15}{2} = 2,975 \text{ mm}$$

Determine the average diameter of cultivation $D_{av.}$ by formula 2.3:

$$D_{av.} = 106,78 + \frac{0,22}{2} = 106,89 \text{ mm}$$

The average radius $R_{av.}$:

$$R_{av.} = \frac{106,89}{2} = 53,445 \text{ mm}$$

The average size $B_{1av.}$:

$$B_{1av.} = \frac{53,445}{\sin \frac{120}{2}} = 61,67 \text{ mm}$$

The average size $B_{2av.}$:

$$B_{2av.} = 53,445 - 2,975 = 50,47 \text{ mm}$$

The average size of probe $S_{av.}$:

$$S_{av.} = 2,996 + \frac{0,004}{2} = 2,998 \text{ mm}$$

Determine the average height institution by the formula 2.8:

$$H_{av.} = 61,67 + 50,47 - 2,998 = 109,142 \text{ mm}$$

Determine the height of the institution by formula 2.9:

$$H = 109,142 + 45 = 154,142 \text{ mm}$$

$$\begin{aligned} T_H &= T_A - (k_1 \varepsilon_6 + \varepsilon_3 + k_2 \omega) = 0,22 - (0,21 \cdot 0,82 \cdot 0,198 + 0 + 0,6 \cdot 0,1) \\ &= 0,125 \end{aligned}$$

Checking the condition of accuracy:

$$\frac{0,125}{2} < \frac{1}{3} \cdot 0,22$$

$$0,0625 < 0,073$$

Condition is met.

$$T_N = \pm \frac{T_N}{2} = \frac{0,125}{2} = 0,0625 \approx 0,05$$

Designate the executive size of the institution:

$$[H] = 154,142_{-0,08} = 154,1_{-0,05} \text{ mm.}$$

2.1.4 Calculation of necessary measures of workpiece mounting and drive selection.

Safety factors fixing choosing by formula:

$$k = k_0 \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 \quad (2.13)$$

where k_0 – is a guaranteed propellant uncertainly margin:

$$k_0 = k'_0 \cdot k''_0 \cdot k'''_0 \quad (2.14)$$

where $k'_0 = 1,1 - 1,3$ – the coefficient, which is taking into account the imperfection of formulas for calculation of the cutting modes.

$k''_0 = 1,1 - 1,3$ – the coefficient, which is taking into account the imperfection of the calculation scheme.

$k_0''' = 1,2 - 1,3$ – the coefficient, which is relevant to higher reliability, takes into account sudden factors (solid inclusions in the material of treating, premature cutting of the cutting edge, etc.).

$k_1 = 1 - 1,2$ – takes into account changes (fluctuation) cutting forces during processing across uneven allowance for workpiece and takes into account only for draft conversions.

k_2 – accounted for in all processing cases and depends on the kind of processing, through-put and irregular wear of a shearing tool.

k_3 – takes into account the conditions of intermittent processing. $k_3 = 1,0$ – in assuming of a smooth cutting (milling);

k_4 – characterizes the clamping device in terms of constancy of clamping forces. $k_4 = 1,0$ - for all mechanized actuators (pneumatic, mechanical, hydraulic); $k_4 = 1,3$ – for manual clamps.

k_5 – characterizes manual clamps in terms of the readability of looseness. With convenient location of the handle and the angles of its rotation within 90° $k_5 = 1,0$.

k_6 – is taken into account only in torques, who want to turn the workpiece and depends on the type of the support surface of the device. $k_6 = 1$ - for point supports (support pins, prisms); $k_6 = 1,5$ – for solid supports (supporting ring).

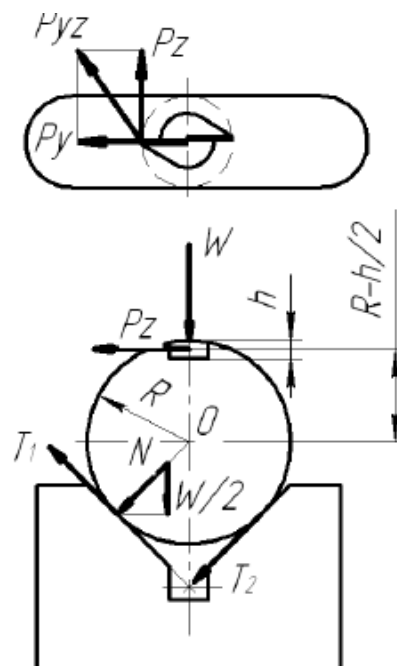


Figure 2.4 - Scheme of forces during milling

Equilibrium equation is made:

$$\sum M_{act.} = \sum M_{pr.} \quad (2.15)$$

where $\sum M_{act.}$ – sum of active forces and moments, who want to move or rotate the workpiece relative to the corresponding axes of the coordinates of the device;

$\sum M_{pr.}$ – sum of forces and moments, which counteract the shear and rotation of the workpiece.

Calculation formula for clamping force:

$$\begin{aligned} \sum M_{act.} &= M_{thr.} \\ \sum M_{pr.} &= M_{tr.} \end{aligned}$$

Then

$$\begin{aligned} k \cdot M_{thr.} &= M_{tr.} \\ k \cdot M_{thr.} - M_{tr.} &= 0 \\ M_{thr.} &= P_z \cdot \left(R - \frac{h}{2}\right) \\ M_{tr.} &= 2 \cdot T \cdot R \end{aligned}$$

Then the equation of the sum will have the form:

$$k \cdot P_z \cdot \left(R - \frac{h}{2}\right) - 2 \cdot T \cdot R = 0$$

where

$$T = f \cdot N$$

$$N = \frac{W}{\sin\left(\frac{\alpha}{2}\right)}$$

Following the formula 2.16:

$$k \cdot P_z \cdot \left(R - \frac{h}{2}\right) - 2 \cdot f \cdot \frac{W}{\sin\left(\frac{\alpha}{2}\right)} \cdot R = 0$$

From here

$$W = \frac{k \cdot P_z \cdot \left(R - \frac{h}{2}\right) \cdot \sin\left(\frac{\alpha}{2}\right)}{f \cdot R}$$

where k – the coefficient of mounting factor;

f – friction coefficient.

The tangential force in milling is determined by the equation:

$$P_z = \frac{10 \cdot C_p \cdot t^x \cdot s^y \cdot B^n \cdot z}{D^q \cdot n^w} \cdot K_{MP}$$

where t – depth of milling;

s - filing the tooth on the cutter;

z – the number of milling teeth;

B – milling width;

D – diameter of the mill;

n – speed the engine;

The force on the rod of the pneumatic cylinder is equal to:

$$Q = W + 3 \cdot W \cdot \frac{l}{H} \cdot f$$

Required diameter of the pneumatic cylinder:

$$D = \sqrt{\frac{4 \cdot Q}{\pi \rho \eta}} + d^2$$

where D - diameter of the pneumatic cylinder;

ρ – pressure of compressed air;

η – efficiency, which is taking into account friction losses, $\eta = 0,85 \dots 0,9$;

d – diameter of the pneumatic cylinders tem.

The guaranteed safety factor by formula 2.14:

$$k_0 = k'_0 \cdot k''_0 \cdot k'''_0 = 1,3 \cdot 1,2 \cdot 1,2 = 1,872$$

The safety factor is determined by formula 2.13:

$$k = k_0 \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 = 1,872 \cdot 1 \cdot 1,15 \cdot 1 \cdot 1 \cdot 1 \cdot 1 = 2,15$$

Tangential forces when milling are determined by formula 2.19:

$$P_z = \frac{10 \cdot 101 \cdot 5^{0,88} \cdot 0,2^{0,75} \cdot 8^1 \cdot 2}{4^{0,87} \cdot 80^0} \cdot 1,15 = 3877,2 \text{ H}$$

where $C_p = 101$; $x = 0,88$; $y = 0,75$; $u = 1$; $q = 0,87$; $w = 0$

[7, table.41, p.291]

$$K_{MP} = \left[\frac{\sigma_b}{750} \right]^n = \left[\frac{900}{750} \right]^{0,75} = 1,15$$

where $n = 0,75$ [7, table. 9, p.264]

By formula 2.18 the clamping force is equal:

$$W = \frac{2,7 \cdot 3877,2 \cdot \left(55,4 - \frac{5}{2} \right) \cdot \sin \left(\frac{120}{2} \right)}{0,25 \cdot 55,4} = 34626,27 \text{ H}$$

where $f = 0,25$ – friction coefficient;

$k = 2,7$ – coefficient of mounting stock.

Substituting the values obtained by formula 2.20, we obtain:

$$Q = 34626,27 + 3 \cdot 34626,27 \cdot \frac{100}{400} \cdot 0,25 = 41118,7 \text{ H}$$

By formula 2.21 calculate the required diameter of pneumatic cylinders:

$$D = \sqrt{\frac{4 \cdot 41118,7}{3,14 \cdot 4 \cdot 0,85} + 32^2} = 128,2 \text{ mm}$$

The diameter of pneumatic cylinders we choose from the standard row by GOST 6540-68 $D = 125 \text{ mm}$.

2.2 Control devices

Control device for radial beats checking.

The controls are used to check workpieces, details and machine assemblies. Devices are used for checking parts at intermediate stages of processing (inter-

operative control) and for the final acceptance and it is determining the accuracy of the dimensions, relative position of surfaces, geometric form.

This appliance (fig. 2.5) is appointed for beating control. Detail is installed on two prisms, to determine the beat, the workpiece is rotated on one or two turns.

Monitoring of the margin of measuring head determine beating given surfaces relative to the base.

The permissible measurement error $[\varepsilon_w]$ for this device is to be determined by the specified controlled parameter - beating with a tolerance of 0.02 mm. On the basis of [19, table. 3.1, p.129] we accept $[\varepsilon_w] = 0.006$ mm. The actual measurement error for a given control device is to be determined, which must be less than or equal to the permissible error by the formula:

$$\varepsilon_w = \varepsilon_{iy} + \varepsilon_{in} + \varepsilon_{im} + \sqrt{\varepsilon_{nb}^2 + \varepsilon_s^2 + \varepsilon_{is}^2 + \varepsilon_{zp}^2 + \varepsilon_m^2 + \varepsilon_{other}^2}$$

where ε_{iy} - system error, which is the reason for the inaccuracy of the manufacture of the installed elements and the inaccuracy of their location on the body of the measuring device during its assembly;

ε_{in} - system error, which is the reason of inaccuracy of manufacturing of transmission elements of levers, pins, rods;

ε_{im} - system error, which is the reason of inaccuracy of manufacturing of installed elements and reference details;

ε_{nb} - is the error that causes the measurement and technological bases to be incompatible;

ε_s - the error that occurs as a result of fixing the measuring part due to its possible deformation;

ε_{is} - is an error that depends on the measuring force and appears as a result of the displacement of the measuring base from the starting position in the measurement process;

ε_{zp} - is the error resulting from the occurrence of gaps between the axes of the transmitting device levers, if any;

ε_m - measurement error;

ε_{other} - other errors caused by the action of random factors in the control process.

The components of the total measurement error that can be excluded from the calculation formula due to the features of the device design and the measurement scheme used are to be determined

The manufacturing error of the installed fittings does not affect the measurement process, so the component ε_{iy} is excluded.

The device is designed to control the beating of one surface relative to the other, there is a combination of measuring and design bases, so the component ε_{nb} can also be excluded.

Obviously, the control will not shift the measuring base of the workpiece from a predetermined position under the action of the measuring forces, as the workpiece is pressed against the mounting surfaces. Therefore, the component ε_{is} is excluded.

The design of the device does not use standards, thus, the error ε_{in} and ε_{im} are excluded. There are also no clamping elements, so ε_s - we exclude.

Finally, the following calculation formula is accepted:

$$\varepsilon_w = \sqrt{\varepsilon_{zp}^2 + \varepsilon_{si}^2 + \varepsilon_{other}^2}$$

The measuring device in this device is a clock indicator IC1 with a split price of 0.001 mm and a measurement range of 0-1 mm. [19, tab. 3.4, p. 142] the error of the measurement tool $\varepsilon_{si} = 0,004$ mm.

$$z_{zp} = 0.004 \dots 0.006 - [19, \text{tab. 3.6, p. 159}]$$

Other errors are defined as part of the tolerance of the controlled parameter:

$$\varepsilon_{in} = 0,03 \cdot 0,02 = 0,0006 \text{ mm}$$

$$\varepsilon_w = \sqrt{0,004^2 + 0,004^2 + 0,0006^2} = 0,0057 \text{ mm}$$

The condition of suitability of this device is checked by comparing the value of the actual measurement error with the largest allowable value.

$$\begin{aligned}\varepsilon_w &\leq [\varepsilon_w] \\ 0,0057 &\leq 0,006\end{aligned}$$

The condition is fulfilled. Therefore, this instrumentation fully satisfies the precision requirements of the measuring equipment and can be used to perform a control operation

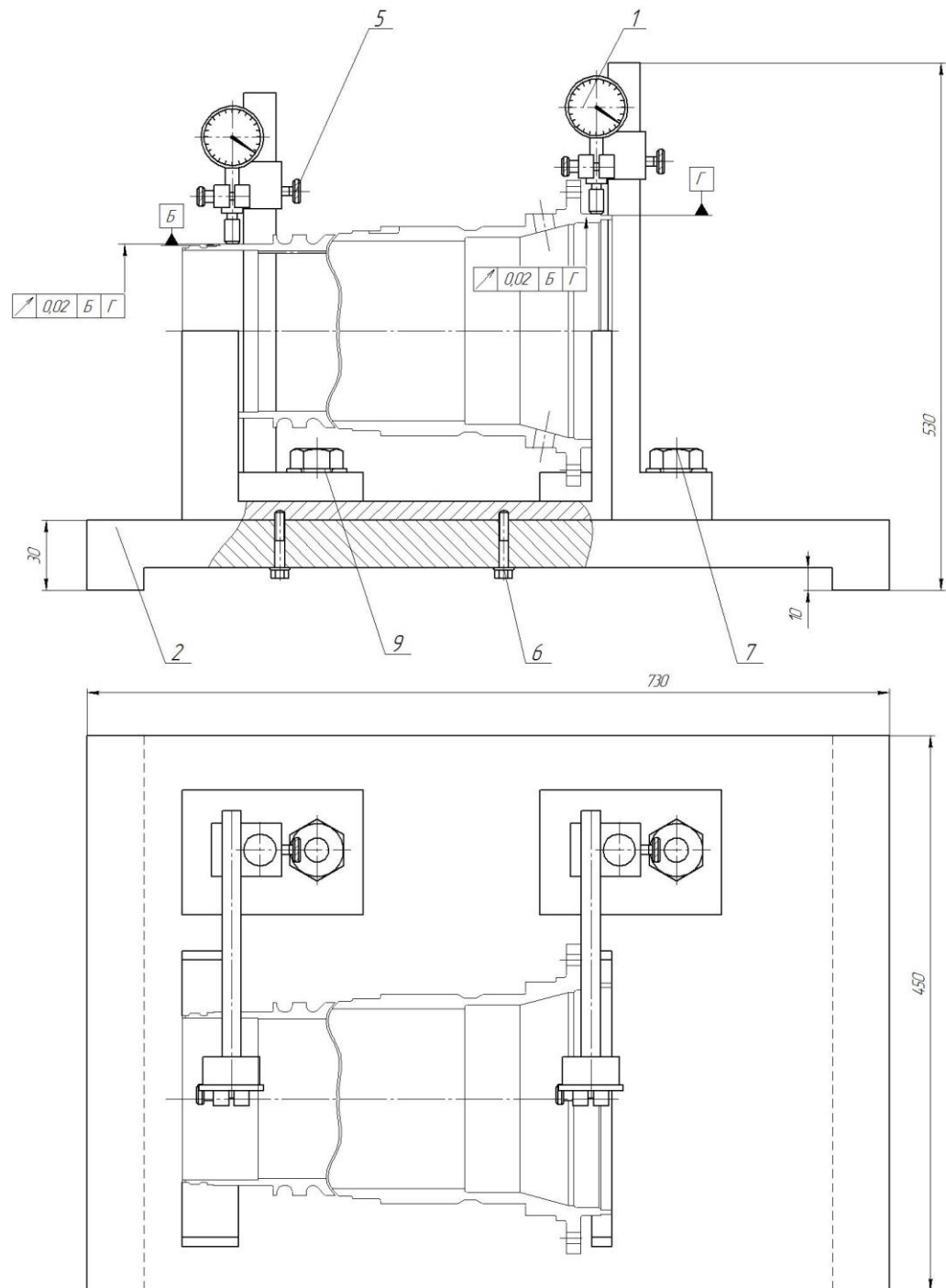


Figure 2.5 – Control device of radial run out while

3 THE AUTOMATION OF PRODUCTION

The automation of the productivity process are being achieved by the way of using automatic machine systems, which are a combination of heterogeneous equipment and other technical devices, are located in the technological sequence and united by means of transportation, control and control to perform partial manufacturing processes. A particularly important role at the same time plays an automation complex of production, when without human intervention, but under the control of automatic machines are doing all production processes - from the receipt of raw materials to the output of the finished product [8].

Automation of the production – a process, during which every part or some of them are transmitted to machines and are carried out without their personal involvement, expect function of debuging, supervision and control.

Increasing the efficiency are carried out in the following directions [8]:

- improving methodologies of technical-economy analyses of the options for automating a particular entity, informed choice of the most efficient choice and specific automation tools;
- provision of conditions for intensive use of automation means, improvement of their maintenance;
- improving the technical and economic characteristics of the equipment, which are produced and used for office automation.

Manufacturing automation and production management allows to save financial, physical and human resources for businesses, who uses robotic technology in their production and in auxiliary functions.

In order to automate loading of blanks need to automate her three elements:

- to capture the workpiece and transport it to the processing area;
- installation of the workpiece;
- fixing the workpiece;

For automation of unloading of workpieces it is necessary to automate:

- detachment of the workpiece;

- removal from the constituent elements;
- transportation of the workpiece;

Purpose and type of download types.

Depending on the design of using loading and unloading devices are divided into:

- structural units of the machine itself;
- independent self-sustained nodes;
- accommodation;

Devices for loading and unloading workpieces dividing on:

- cutters;
- unloaders;
- downloaders and more.

Cutters are served for separating blanks from the total: one or more pieces at a time. And the composition of the cutters are divided into pins, cams, anchors and drums [9].

The pin cutters work by moving the pins around the axis.

The cams have a pair of cams that are displaced relative to each other so that one of them when rotating releases the workpiece and the other holds others.

In anchors, the movement control of the workpiece is performed by rocking the anchor plug [9].

Drum cutters have discs with places under the workpiece. They rotate continuously or intermittently, the disc grips one workpiece and holds others.

Loaders are designed for loading and transporting workpieces to the work position of the machine. They are divided into shingles, butterflies, augers, drums and revolvers.

Slide feeders are the most common. In the starting position, the feeder receptacle is opposite the tray opening and the workpiece falls into it. When moving the gate from the right to the left, the workpiece is transferred to the device where it is clamped. When the gate returns to the starting position, the bar is folded, rotates around the axis and passes under the workpiece.

The butterfly loader differs from the shibernic in that it performs rotating movements at a certain angle.

The drum loader is shaped like a disk with a horizontal axis of rotation and slots into which the workpiece sinks. In the revolver loader the vertical axis of rotation [10].

Screw loaders are used for loading workpieces such as tapered rollers.

Simple pushers and ejectors can be used as loaders.

Automatic devices for piece-by-piece power are able to feed workpieces unrelated to the work area. They are divided into two types: store and hopper appliances [10].

Store supplies automatically feed pre-loaded pieces into the store manually. These devices are also called semi-automatic. They are used for:

1. For details of complex shape;
2. For parts with high interconnectivity due to the difficulty of their separation;
3. For parts that can be damaged (fragile, high-precision) when backfilled;
4. When automating the loading of work machines that perform a long processing cycle.

The drive or store serves to place in it a set number of oriented workpieces and transport them to feeder and then to work area of the machine. The number of workpieces downloaded should ensure uninterrupted operation over a period of time. Usually this time is 10... 30 min.

The blanks can be placed in a stack in one row, one layer or several rows, in one stack, in several stacks, and in a row, in several stacks and rows.

The simplest way is placement in a single row, because it simplifies the selection of workpieces, their transportation and loading. However, the size of the boot device increases.

Control automation

Control automation - is one of the most complex issues of complex automation of technological processes. It is carried out in two fundamentally

different directions: by automation of postoperative (passive) control and technological (active) control.

Another direction - aimed at intensifying control – is the most progressive and perspective ways, because the quality of the product is ensured by the technological process itself. [8]

In the case of passive control, the control devices fix the size of the parts or sort them by size, without affecting the course of the technological process.

With active control, the control devices influence the course of the technological process, that is, they actively interfere with the technological process. These systems refer to closed-loop automation systems, that is, feedback systems [8].

The size of the workpiece is controlled by the converter. Depending on the actual size, the converter signals to the control system, where it is compared to a given signal.

The magnitude of the mismatch between the specified signal and the feedback signal is amplified by the amplifier and enters the actuator, resulting in a change in the cutting mode, or command to stop the machine.

Therefore, the active control is the method of control, the results of which manually or automatically influence the course of the technological process.

Active control refers to, for example, control during processing by the method of test passes; control over the results of which manually adjusting machines - automatic machines; control the processing process by measuring the workpiece parameters (to obtain the desired dimensions, as well as to stabilize cutting forces or processing time).

Active controls include devices for automatically adjusting cutting modes.

Thus, any measurement that results in a particular impact on a particular process can be attributed to active control.

Particular attention is now being paid to the development of automatic active monitoring tools. Its implementation allows to improve the quality of products, reduce the time of machining of parts by intensifying cutting modes and

eliminating machine tool stops for intermediate measurements, reducing the costs of final postoperative control [9].

Depending on the measurement method, the active control means are divided into devices based on the direct measurement method and devices based on the indirect measurement method.

With the direct measurement method, the size of the workpiece or workpiece is controlled directly. The measurement base coincides with the surface of the controlled part.

The indirect method does not control the size of the workpiece, but the position of the surface of the workpiece, or the position of the cutting edge of the tool, or the actuators of the machine with respect to the base of the device installation [9].

In the course of the work, a device for controlling the outer diameters was designed.

The fixture consists of a table 8 on which two prisms with a part are mounted.

The amplitude sensor 2 controls the outer diameters of a continuously variable size by means of a stop 10, which is brought to a controlled size.

Then the signal is applied to the amplitude sensor and if the part is suitable - the corresponding light comes on.

This saves time on manually measuring the outer diameters and comparing data with the drawing.

4 STRENGTH CALCULATION AND OPTIMIZATION OF PART GEOMETRY

Raw data:

Detail – shaft;

Modulus of elasticity- $E = 1,15 \cdot 10^5 \text{ MPa}$;

Poisson's coefficient - $\mu = 0,3$;

Tensile strength- $\sigma_v = 900 \text{ MPa}$;

Statistical analysis is performed in Siemens NX.

We break the model into a finite element grid Solid186 according to average size of element 4 mm.

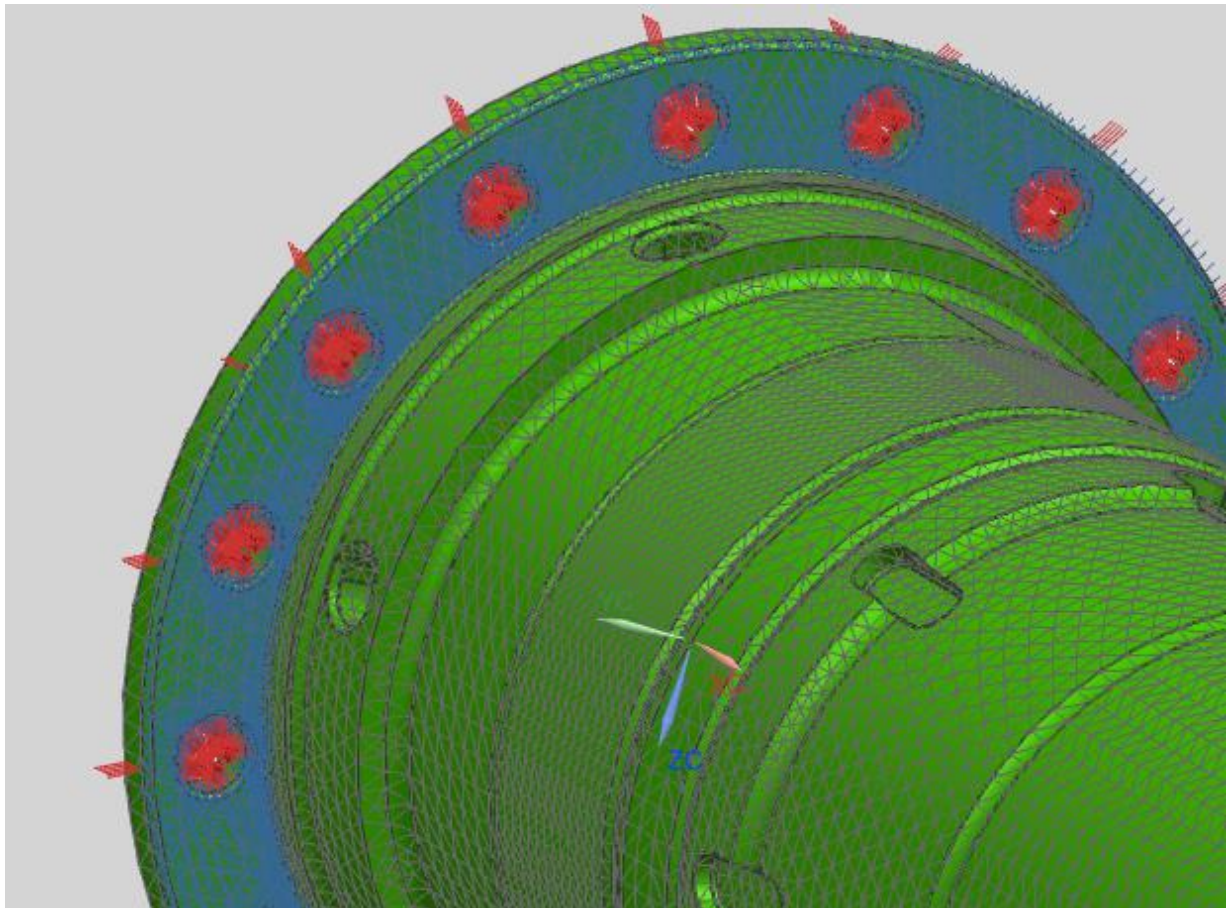


Figure 4.1 - The model is broken down into a grid of finite elements with applied load

Attaching a thickness to the wall 7 mm., we are pulling out 10 MPa on 16 holes Ø10 mm (fig. 4.1). We get a picture of the stress distribution in fig. 4.2.

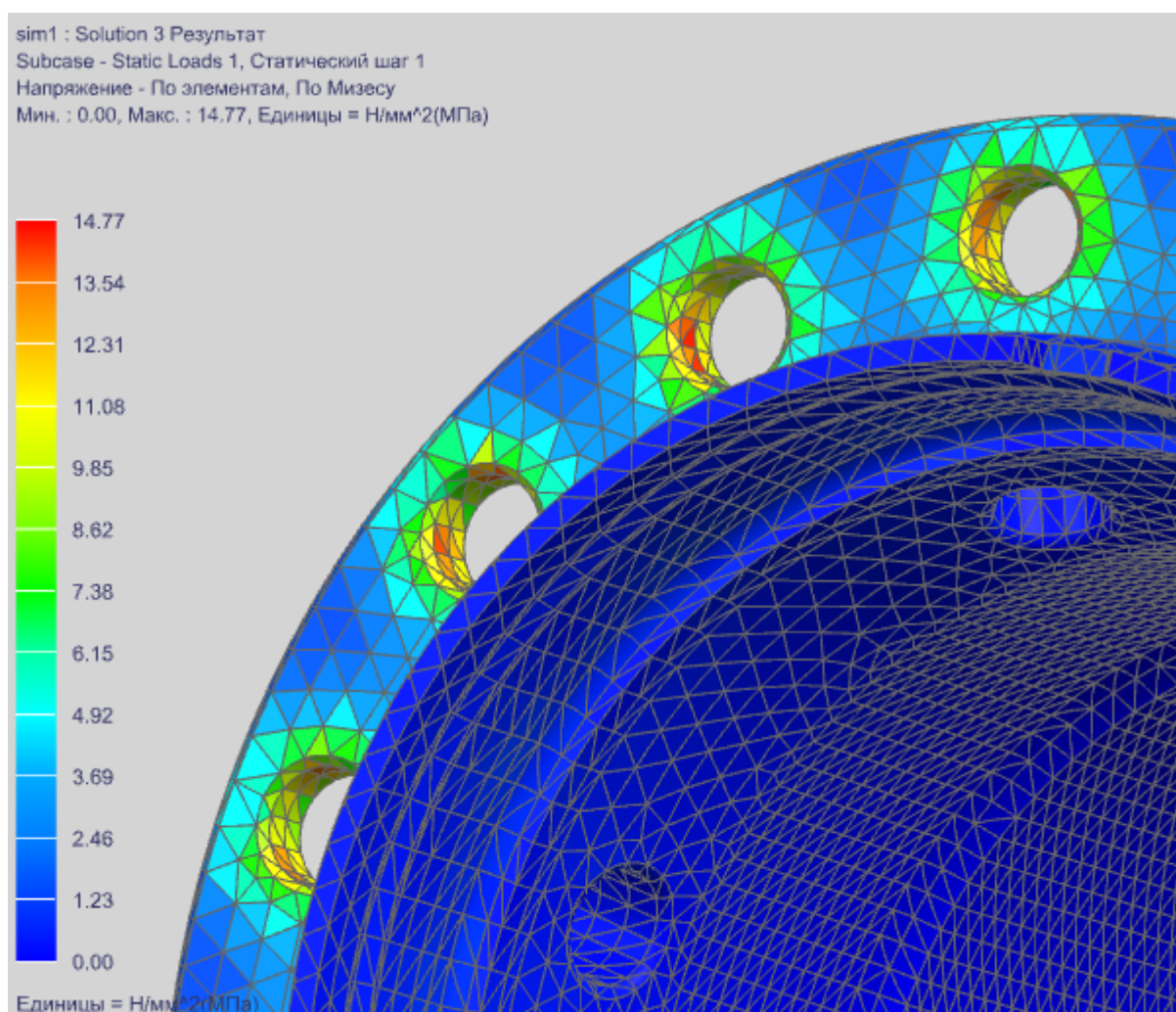


Figure 4.2 - Model stress distribution (10 MPa load)

Maximum voltage $\sigma_{max} = 14,77$ MPa.

Calculating the factor of safety margin:

$$n_{\sigma} = \frac{[\sigma_B]}{\sigma_{max}}$$

$$n_{\sigma} = \frac{900}{14,77} = 60,9$$

A valid value of floor-loading capacity for details for constant loads [n] = 1,3...2.

Since the value of the safety margin $n_\sigma = 60,9$ is greater than the allowable value, the workpiece is not destroyed and load can be added. We apply a load of 500MPa (fig. 4.3).

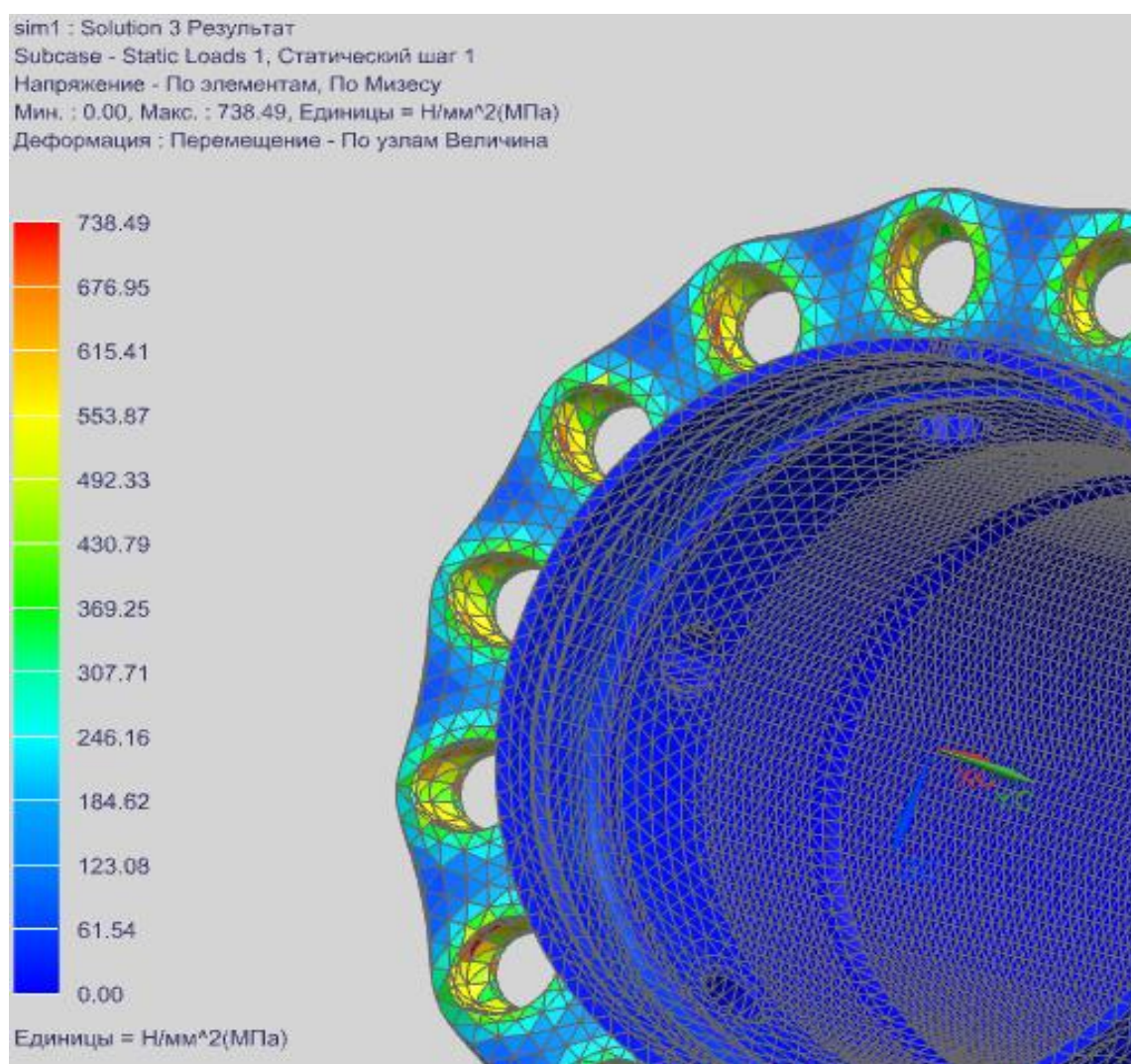


Figure 4.3 - Model stress distribution (voltage 500 MPa)

Maximum voltage $\sigma_{max} = 738,49$ MPa.

We calculate the factor of safety margin:

$$n_\sigma = \frac{900}{738,49} = 1,22$$

The resulting value of the safety margin $n_\sigma = 1,22$ is within the acceptable range.

We see that larger stresses occur in places of stress concentrators: holes, radii of rounding and chamfers.

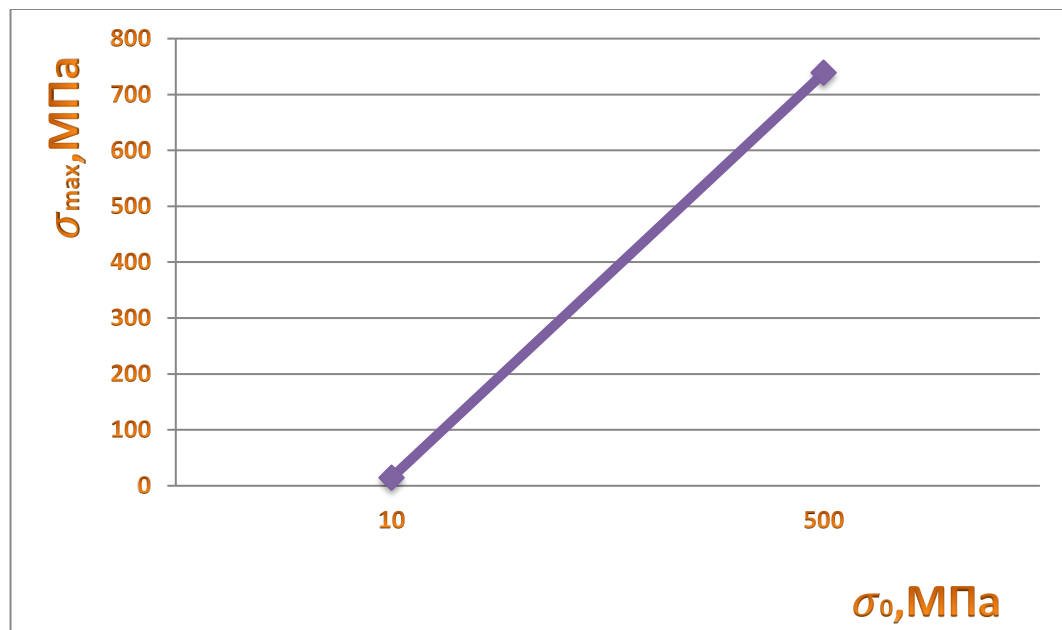


Figure 4.4 - Graph of the voltage versus effort

5 SHAFTS BALANCING

Trafficking of many details and assembly units (crankshafts, flywheels, pulleys, disks, driveshafts, drums, etc.) in the presence of unbalanced masses, centrifugal forces arise. The imbalance of parts and assembly units occurs due to the inaccuracies of their manufacture (even within the tolerance values), inaccurate assembly, uneven surface wear, etc. Unbalance is very harmful, as vibrations are occurring, sharply increasing the load on the parts and the machine as a whole, which ultimately lead to acceleration of bearing assembly wear and the destruction of many details.

There are static and dynamic unbalance and static and dynamic balancing.

Static balancing. Static unbalance due to the fact that the center of mass of the part does not lie on the axis of its rotation. As a result the details are turning around, an unbalanced centrifugal force of inertia.

Static balancing carried out without rotation, placing on the vertical plane and finding for them indifferent equilibrium position. On the fig. 5.1 a the vertically positioned disk is shown, which worms onto the shaft.

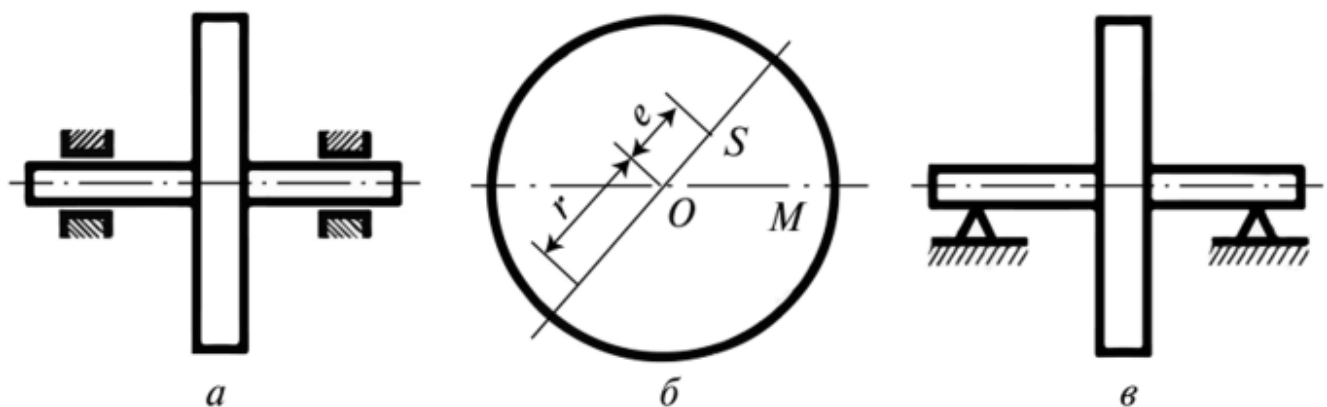


Figure 5.1 – The scheme of static balancing of disks:

a – disk, which is mounted on a shaft, which rests on two bearings; b - section of the disk; в - the shaft of the disk which is laid on long horizontal arranged prisms

When this disc will rotate (during operation), with angular velocity, there will be a centrifugal force of inertia. In the case of static balancing, determine the mass to be removed from the workpiece or added to it so that the center of mass of the workpiece is located on its axis of rotation. For this purpose, the part, which was mounted on a precisely machined and balanced frame, was mounted on horizontal prisms or rollers with low resistance in the supports (fig. 5.1, b). Under the action of the unbalanced mass, which creates a torque, the part will spontaneously return and settle so that this mass will be below. Eliminate the imbalance by removing metal from the burdened (lower) side of the workpiece by drilling, milling, or attaching the correcting load to the opposite side. The mass of metal, which is being removed or attached to the load is determined by experiment, ensuring that after turning the part at any angle, it would remain stationary (as if in a state of indifferent equilibrium). Static balancing on rollers is more accurate than prisms.

Dynamic balancing. Dynamic imbalance occurs when the axis of rotation of the workpiece does not coincide with its principal axis of inertia.

Suppose that we have to balance the assembly unit of the shaft type (fig. 5.2).

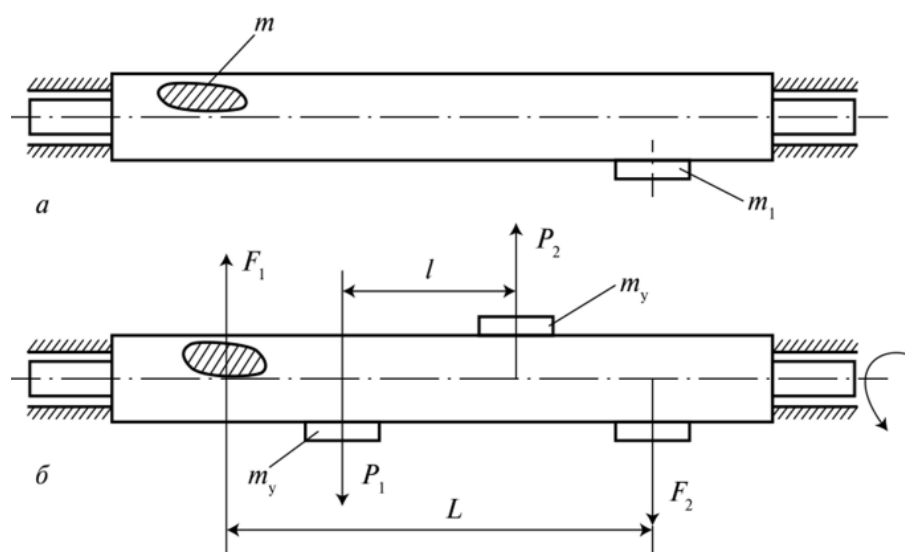


Figure 5.2 – The scheme of dynamic shaft balancing
a – after static balancing; b – after dynamic balancing [11]

Static balancing can't be considered final. If the mass after static balancing is the same as mass of the cargo (fig. 5.2, a), then when rotating the shaft will produce centrifugal, counter-directed forces (fig. 5.2, b), that is, there is a couple of forces, which is created torque.

Dynamic balancing of the details and assembly units are carried out on special stands, the principle of which is as follows. The detail is places on the elastic supports (tubes) of the stand and rotates. Under the influence of unbalanced centrifugal forces of inertia and their moments of the cradle 1 (fig. 5.3) will fluctuate in the horizontal plane.

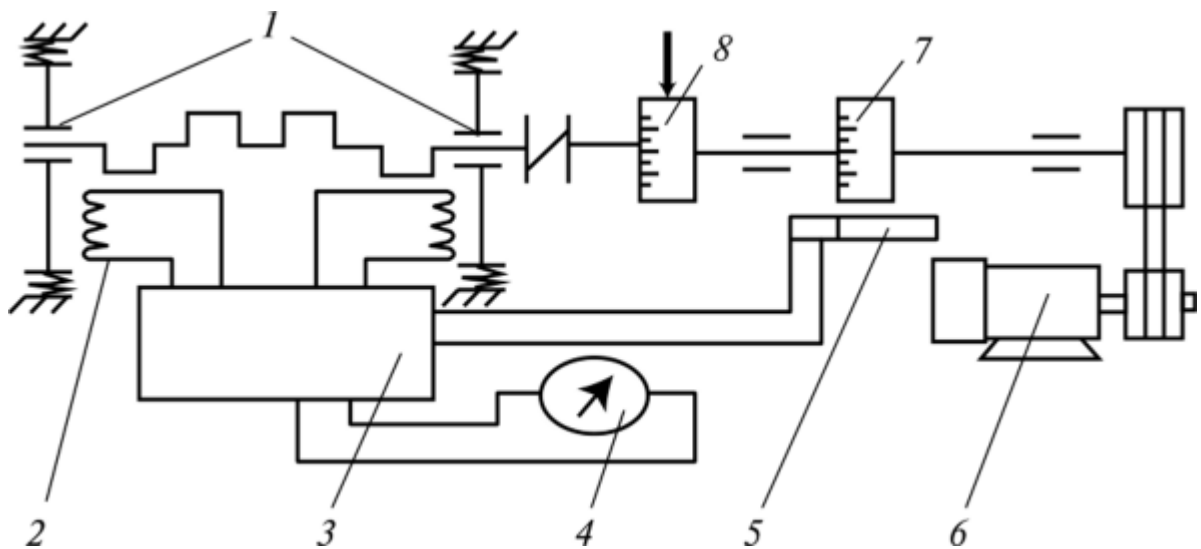


Figure 5.3 – The scheme of the machine for dynamic shaft balancing:

- 1 - cradle; 2 - oscillation sensor; 3 - block gain; 4 - milliammeter; 5 - strobe light;
6 - electric motor; 7 - limb of a stroboscope; 8 – flywheel [11]

The oscillations of the supports actuate the associated coils of the sensors 2, which are in the magnetic field of the permanent magnets, resulting in the windings of the coils give an electromotive force (EMF), the value of which will be proportional to the amplitude of the oscillations. Thus, the sensors 2 convert the mechanical vibrations of the cradles into electrical ones. The signals from the sensors are fed to the gain unit 3. They are then fed to the milliammeter 4, the scale of which is programmed in units of imbalance ($\text{g} \cdot \text{cm}$), and to the inertial strobe

lamp 5, which illuminates the numbers on the rotating limb 7. The numbers show the angle (in degrees) the location of the imbalance. The angular arrangement of the imbalance is deduced from the limb and set by the arrow on the flywheel 8.

The imbalance and its equilibrium are measured alternately for each of the supports (right and left). To do this, a switch is located on the control panel.

On this principle, the device is used in the repair enterprises universal balancing machine MB-U4. It consists of a mechanical part, a measuring device with a sensor and a stroboscope and an actuator with a device for automatic lubrication of the liners under the necks balanced parts.

Balancing is performed when the workpiece is rotating. Some time after reaching the desired speed of rotation of the workpiece with the help of electromagnets, the brakes automatically brake. Next, determine the imbalance and the angle of its location for one end of the workpiece. They remove some of the metal (from the crankshaft, for example, the counterweight) or set the corresponding additional load, achieving the acceptable value of the imbalance.

The same operations are then performed for the other end of the workpiece. When the engine is switched off, the electromagnets are de-energized and the tubes close. Static balancing sufficient for short parts (pulleys, flywheels, clutch discs, etc.) with lengths shorter than diameter. At the same time, due to the large diameter, their static imbalance can be large. Conversely, for longer length parts, it is much larger than the diameter (shafts, drums, etc.), dynamic imbalance is of paramount importance, and they are necessarily subject to dynamic balancing. Dynamic imbalance includes static imbalance, but not the other way around [12].

6 EFFICIENCY OF THE ECONOMY OF ADAPTATION

Applying the sophisticated special fixtures increases the productivity of labor, but with a small annual release of parts, such fixtures may not be economically feasible: from their use, the cost of the operation is not reduced, but rather increased.

The calculation of the cost-effectiveness of using of gadgets is based on a comparison of costs and cost savings that occur when it is used over a one-year period. Costs include depreciation of the fixtures and maintenance and operation costs. Savings are achieved by reducing the complexity of manufacturing parts.

An adjustment is considered cost-effective if the annual savings are greater than the annual cost.

The cost of using the device is calculated by the formula [14, p.12]:

$$C = Z \cdot \left(1 + \frac{H}{100}\right) + \frac{S}{P} \cdot \left(\frac{1}{A} + \frac{q}{100}\right)$$

where Z - salary of the employee in one detail, UAH;

H - work shop over head expenses in% of salary;

S - the cost of making the device, UAH;

P - annual program of production of parts, pcs;

A - the amortization period of the device in years;

q - costs associated with the operation of the devices in % of their cost.

The cost of manufacturing the device is calculated by the formula [14, p.13]:

$$S = C_p \cdot N$$

where N – the number of details in the devise, pcs;

C_p – the cost of one piece of fitting, UAH;

For counting salary of a worker we use formula [14, p.13]:

$$3 = t_{\text{pcs.}} \cdot Z_{\text{min.}}$$

where $t_{\text{pcs.}}$ - artificial calculation time;

$Z_{\text{min.}}$ - minute rate of the worker, UAH.

Cost depends mainly on the annual parts release program. Release program P_K – the program, in which the two compared options are economically equivalent [14, p.13].

$$P_K = \frac{(S_a - S_B) \cdot \left(\frac{1}{A} + \frac{q}{100}\right)}{(Z_B - Z_a) \cdot \left(1 + \frac{H}{100}\right)}$$

If an annual program is specified $P > P_K$, it is more advantageous to use a more sophisticated device (pneumatically actuated) and vice versa if $P < P_K$, it's better to use an old gadget.

So, let's first calculate the design of the pneumatic actuator. By the formula 6.2, we calculate the cost of manufacturing the device:

$$S_a = 450 \cdot 30 = 13500 \text{ UAH}$$

To calculate the salary of a worker we use the formula 6.3:

$$Z_a = 27,55 \cdot 0,75 = 20,66 \text{ UAH}$$

The cost of using the device is calculated by the formula 6.1:

$$C_a = 20,66 \cdot \left(1 + \frac{200}{100}\right) + \frac{13500}{7000} \cdot \left(\frac{1}{3} + \frac{2700}{100}\right) = 114,73 \text{ UAH}$$

where amortization period – $A=3$ years [14, p.13];
 annual loss $q = 0,2 \cdot S_a = 2700$ UAH;
 percent of workshop overhead $H = 200\%$ [14, p.13].

For a factory device according to formula 6.2, we calculate the cost of its manufacture:

$$S_B = 150 \cdot 10 = 1500 \text{ UAH}$$

To calculate the wage of a worker we use the formula 6.3:

$$Z_B = 40,36 \cdot 0,75 = 30,27 \text{ UAH}$$

The cost of using the device is calculated by the formula 6.1:

$$C_B = 30,27 \cdot \left(1 + \frac{200}{100}\right) + \frac{1500}{7000} \cdot \left(\frac{1}{1} + \frac{300}{100}\right) = 91,67 \text{ UAH}$$

where amortization period – $A=1$ year [14, p.13];
 annual loss $q = 0,2 \cdot S_a = 300$ UAH;
 percent of workshop overhead $H = 200\%$ [14, p.13].

By formula 6.4 we calculate the release program, in which both comparable options are economically equivalent:

$$P_K = \frac{(13500 - 1500) \cdot \left(\frac{1}{1} + \frac{300}{100}\right)}{(30,27 - 20,66) \cdot \left(1 + \frac{200}{100}\right)} = 1665 \text{ piece}$$

So, since $P > P_K$, the more advantageous it is to use a designed pneumatic actuator.

7 OCCUPATIONAL SAFETY AND EMERGENCY SITUATIONS SAFETY

7.1 Hazard assessment

At the time of technological process of shafts and other parts are likely to have the following potential hazards:

1. Electric traumas may result in the lack of the necessary knowledge for the personnel to perform a specific job or the lack of provided instruction;

2. Mechanical damage to the power supply leads to short circuits, which in turn can lead to damage to electrical equipment, personal injury, and even the occurrence and spread of fire;

3. Mechanical injuries due to organizational reasons:

- a) during mounting of shafts on special stands for balancing with insufficient attention of specialists or with their lack of qualification;

- b) cluttering of workpieces and workplace details;

- c) injuries and damages of the skin during unloading and loading of blanks of shafts and details;

- d) damage to the skin of the hands with sharp edges, roughness on the surface of the shafts, tools, equipment, waste when working without gloves.

4. During the turning of parts there is a possible to injure the eyes by particles of metal dust or chips that fly off during material processing. The causes of the injury - process of malfunction and work without goggles or face shields.

5. Inattention and carelessness of personnel when performing work on the machine tools of a cutting group can also lead to injuries of varying severity.

6. There is a certainty of the occurrence of common diseases in the event of a faulty or irrationally organized ventilation or heating system in the cold season.

7. Long-term discomfort while performing work in a monotonous posture promotes premature development of general fatigue, decrease of working capacity, and at systematic continuous work leads to diseases of the peripheral nervous system: neuritis, radiculitis.

8. Increased concentration of fine dust and gas in the air in the work area, in the event of a malfunction or lack of ventilation, can lead to bronchitis and impair the overall health of workers.

9. Insufficient illumination of industrial premises and workplaces due to a malfunction, or incorrect selection of lighting fixtures, resulting in impaired vision.

10. Increased noise level that accompanies the shaft balancing process leads to irritation and increased errors;

11. Prolonged negative impact of electromagnetic fields, which accompanies the process of shaft balancing, leads to deterioration of the vision of specialists, reducing the immunity of workers;

12. The likelihood of fire, due to a malfunction of electrical equipment, failure to observe, or violation of fire safety rules by service personnel leading to a fire;

13. Personnel misconduct in emergency situations that lead to panic and death.

7.2 Security measures

In order to avoid mechanical and electrical injuries while working on the equipment, training measures, checking of occupational health knowledge, providing first aid to the victims of accidents, as well as rules of behavior and actions in the event of emergencies, fires and natural disasters according to the NEAP are foreseen 0.00-4.12-05 "Typical provision on the procedure for training and testing knowledge on occupational safety". During recruitment, a representative of the labor protection service conducts an introductory briefing with all persons who have arrived at the enterprise. In the workplace, the immediate supervisor first conducts initial, and then repeated, unscheduled briefing. According to the Order of the Ministry of Health of Ukraine of May 21, 2007. No. 246 "On Approval of the Procedure of Medical Examination of

Employees of Certain Categories” Persons who have undergone a medical examination and have no contraindications to this work are allowed to work.

For the safety during the technological process equipment is used that complies with DSTU ENISO14159-2018 "Safety of machines. Hygienic requirements for the design of machines ", DSTU ENISO 23125-2018" Machine tools. Safety. Machine tools turning ”, DSTU ENISO 14119: 2017“ Machine safety. Locking devices connected to fences. Principles of design and selection ", DSTU ENISO 14120: 2017" Machine safety. Protective fences. General requirements for the design and construction of fixed and removable protective fences », DSTU EN547-2018.

Workers must be adherent to the rules of safety at work according to the NAPAA 0.00-1.71-13 "Rules of occupational safety while working with tools and devices", Technical regulation of signs of safety and health protection of workers approved by the Cabinet of Ministers of Ukraine of November 25, 2009 № 1262 (Official Bulletin of Ukraine, 2009, No. 92, Art. 3118).

The responsibility for maintaining the proper condition and safe operation of the metal-cutting machine rests with the head of the unit to which the machine is attached.

Each job provides job descriptions that set general and qualification requirements, requirements for knowledge, duties, rights, responsibilities of a specialist in accordance with the requirements of NAOP 1.4.32-2.01-82 (OST 11 090.028-82) "Occupational Safety Instruction. Procedure for development, design and use." In order to avoid dangerous situations, injuries to workers before starting work, the equipment, braking devices at idling should be checked, and the cutting tool and the tools for fixing the parts to prevent the possibility of their failure due to insufficient fastening should be checked for serviceability and defects. Do not allow for different changes in cutting modes when working, in order to avoid the possibility of tool destruction or failure of the part fixing.

Danger of electric shock when using machines, appliances or equipment may occur if safety precautions are not observed, as well as the failure or

malfunction of this equipment. The consequences of electric shock depend on many factors: the resistance of the organism, the magnitude, duration of action, genus and frequency of current, ways of its passage through vital organs, environmental conditions.

Category of production compartments, according to NAPPP 40.1-1.32-01 "Rules for the construction of electrical installations. Electrical equipment of special installations »- high risk (dry - relative humidity not more than 60%, metal dust in air, temperature up to 30 ° C, reinforced concrete floor).

In accordance with the requirements of the "Rules of arrangement of electrical installations" (hereinafter "PUE") to prevent possible damage to the operating personnel by electric shock, protective grounding is provided. Electrical power supply of electrical equipment of the mechanical section is carried out from the AC mains voltage 220 V and frequency 50 Hz. According to the requirements of "PUE", electrical equipment at a mechanical site is characterized as electrical installations up to 1000 V, therefore, according to the requirements of Chapter 1.7 "PUE", the value of the resistance of the circuit of the protective grounding of the electrical equipment of the room at any time of the year does not exceed - 4 Ohms.

In accordance with the requirements of PUE in the electrical equipment, the following systems of means are used: protective grounding of insulation of current-carrying parts, protective disconnection, voltage (up to 42 V) for portable lighting and operation of the power tool, complete inaccessibility of workers to uninsulated wires.

The equipment has double insulation: working - electrical insulation of current-carrying parts of electrical equipment, which ensures its normative work and protection against electric shock; additional insulation - to protect against electric shock in case of damage to the working insulation.

According to PUE, electrical equipment for human protection against electric shock belongs to Class I, since it has double insulation, a grounding element and a wire for connection to a power source having a grounding conductor and a plug with a grounding contact.

Protective equipment for the safety of electrical equipment of buildings is fulfilled in accordance with the requirement of PUE and DSTU B B.2.5-82: 2016 "Electrical safety in buildings and structures. Requirements for protection against electric shock." To increase the level of protection against ignition during short circuit on the ground parts, when the current value is not sufficient to activate the maximum current protection, it is recommended to use a RCD with a current of up to 400 mA.

Mechanical injury is likely to result from misplaced jobs, job losses, or due to carelessness or carelessness of service personnel. To eliminate injuries, more convenient and rational job placement was made, thus increasing the distance between them. The recommendations of DBN B.2.2-28: 2010 «Buildings and structures. Administrative and household buildings », the distance between the machines depends on the size of the machines and is not less than 0.9... 1.5 m, which ensures safety in the work process. The width of the section is 4.5 meters, the width of the aisles is 2-2.5 meters, which makes it possible to safely and comfortably move workpieces, parts, equipment, and in case of fire - guarantees a quick evacuation of people.

To protect against possible cuts, burns, and injuries associated with the departure of shavings, it is necessary to provide the worker with personal protective equipment (special clothing, special footwear, hand protection, eye protection) in accordance with DSTU 7239: 2011. Personal protective equipment. General requirements and classification ».

Collective protection measures should be provided in accordance with DSTU 7238: 2011 "SBBP. Means of collective protection of employees. General requirements and classification ».

Maintenance of universal machine tools with the elements of manual control is associated with prolonged stay in a forced working posture, static loading, stress of attention, which in turn, leads to increased fatigue and nervous and emotional stress. That is, during the work the person constantly feels energy and information tension.

7.3 Labor law on working time and rest for employees as one of the safety measures.

Working hours are determined in accordance with law and cannot be changed by agreement of the parties at the conclusion of the employment contract. The exceptions are cases where employees conclude a part-time or part-time work contract, or when in the course of work they conclude part-time or part-time work with the owner.

Working hours are determined in such a way that the work gives the opportunity to develop productive forces and the necessary time for rest in order to restore strength and energy. Therefore, legal regulation of working hours and rest time is of great importance. With the help of labor law, the state requires workers to use their working hours most efficiently, forbids them to evade their direct employment, does not allow overtime work.

Working hours is a legally prescribed period of time during which an employee, in accordance with the rules of the internal work schedule, work schedule or conditions of employment contract, has to fulfill his / her duties.

Article 45 of the Constitution of Ukraine provides that workers are guaranteed a statutory working time.

Working hours is set both in a centralized manner and at the level of local regulation. And if earlier norms regulating the length of working time were set at the legislative level, then in modern conditions there is a tendency of collective and contractual and individual (within the framework of an employment contract) regulation of working time. Thus, in accordance with Article 50 of the Labor Code (hereinafter Labor Code) of Ukraine, the normal working hours of employees may not exceed 40 hours per week. Such working time is called normal working time. Moreover, it should be noted that the guarantees provided by the legislature regarding the maximum working time extend to employees of enterprises of all forms of ownership.

In a collective agreement or other local acts may be stipulated as a provision for a 40-hour working week, as well as other, less time-consuming working hours of a given enterprise, institution, organization.

The standard of working time is a statutory, collective or employment contract for a given employee the length of his working time for a certain calendar period - day, week, month.

A work day is a length of working time, measured in hours and minutes during the day. Working Week - Working hours during the calendar week. Typically, two types of workweek apply: a 5-day with two days off and a 6-day work week accepted by the owner together with the union body, taking into account the specifics of the work, the views of the work team and in agreement with the local council. The 40-hour working time limit should be respected at 5 and 6 days. For a 6-day working week, the working day on the eve of the day off may not exceed 5 hours, and on the eve of holidays and non-working days - it is reduced by one hour.

Along with normal working hours, there are different types of working time, such as part-time and part-time.

Unregulated working day in enterprises, institutions, organizations, regardless of ownership, can be applied to managers, specialists and workers, namely:

- for persons whose work cannot be accurately accounted for in time;
- persons whose working time is divided into parts of indefinite duration (agriculture) by nature of work;
- for persons who distribute their working hours at their discretion.

Workers with non-working days are covered by the company's working time regime. In this regard, the owner or his authorized body is not entitled to systematically involve workers working with this regime to work beyond the established working hours. The duties of non-working day employees must be laid down in the employment contract, job descriptions, internal rules of employment so that they can normally be performed within normal working hours.

As compensation for the amount of work completed, the degree of tension, complexity and independence in the work, the need for periodic work in excess of the prescribed length of working time, an additional vacation of up to 7 calendar days is granted. At enterprises, institutions, organizations, regardless of ownership, the list of professions and positions to which the unregistered working day can apply, is defined by the collective agreement. It specifies the specific duration of additional leave for each type of work, profession, position, specification of leave can also be set in the employment contract. Unregulated working days should be distinguished from overtime.

The legislation establishes the following types of rest time:

- breaks during the working day (shifts);
- daily rest (breaks between shifts);
- weekends (weekly rest);
- holidays and non-business days;
- vacations.

According to the law, a break for rest and food is granted for a maximum duration of two hours. Such a break should be given as a rule, four hours after the start of work. The start and end time of the break is set by the rules of the internal routine. For those workplaces where a break cannot be established, the worker must be allowed to eat during working hours. The list of such works, the procedure and the place of eating shall be established by the owner or his authorized body in agreement with the trade union committee. Breaks and rest breaks are not included during working hours and are free of charge.

When working outdoors in cold weather, at the discretion of the employer, breaks for heating are established. The owner or the body authorized by him shall agree with the trade union committee the number and duration of such breaks, as well as the arrangement of the places of heating. Heating breaks are included during business hours.

The legislation provides for, in addition to the lunch break, special breaks for rest of the loaders included in working hours. The duration and the procedure for granting such breaks are determined by the rules of internal labor regulations.

7.4 Measures to ensure occupational health and hygiene

Measures on occupational health and hygiene for a mechanical site and work rooms are designed in accordance with the requirements of the State Sanitary Rules and Rules "Hygienic classification of labor by indicators of the harmfulness and danger of factors of the production environment, severity and intensity of the work process", MYU 06.05.2014 472/25249 (hereinafter - "Hygienic classification of labor"), SSANP in 3.3.2.007-98 "State standard rules and norms of work with visual display terminals of electronic computers" and NAPPP 0.00-7.15-18 health and safety at work on screen devices ».

Meteorological conditions at the site: air temperature, relative humidity and the speed of its movement meet the established sanitary and hygienic requirements of the State Standard 3.3.6.042-99 "State sanitary standards of the microclimate of production premises" and GN 2152-80 "Sanitary and hygienic production norms of air and public spaces. " The works at the site belong to the category IIa - medium work, so the following optimal values of the microclimate parameters are provided:

- in the cold season: temperature 18-20°C; relative humidity: 40-60%; air velocity: 0.2 m / s;
- in the warm season: temperature 21-23°C; relative humidity: 40-60%; air velocity: 0.2 m / s.

The provision of such microclimate parameters is achieved by equipping the premises with a heating system balanced with inflow and exhaust ventilation, according to DBN B.2.5-67: 2013 "Heating, ventilation and air conditioning".

To prevent dustiness and contamination of the room with dust and vapors of substances formed during the evaporation of lubricants and lubricants, it is

necessary to provide general inflow and exhaust ventilation, according to the requirements of DBN B.2.5-67: 2013 "Heating, ventilation and air-conditioning".

Sound pressure levels in octave frequency bands, sound levels and equivalent sound levels at workplaces of the premises meet the requirements of DSanPin 3.3.2.007-98 "State sanitary rules and regulations for work with visual display terminals of electronic computers" and DSN 3.3.6.037-99 " Sanitary standards of industrial noise, ultrasound and infrasound. " Noise reduction in the room is made by: using more modern equipment; the location of equipment that creates noise levels higher than the legal limit (over 80dBa), at a considerable distance from most workplaces.

Vibration levels during machine work exceed the admissible values, which are defined in SIT 3.3.6.039-99 "State sanitary standards of industrial general and local vibration". Personal protective equipment is used to reduce the negative effects of vibration (vascular spasm, circulatory and thermoregulatory disorders, joint pain, limb tremors) when working with a manual mechanical, electric and pneumatic instrument.

DSTU 7239: 2011 «UPS. Personal protective equipment. General requirements and classification ».

Indoor lighting plays a crucial role in maintaining the health and well-being of workers who are constantly working under the stress of the visual organ. According to DBN B.2.5-28-2018 "Natural and artificial lighting" provides natural and artificial lighting. Natural illumination is done through light apertures that provide a natural illumination ratio (KPO) of at least 1.5%.

Indoor lighting, provided by a general uniform lighting system. The illumination rate on the work surface is 200-300 lux. Fluorescent lamps such as LB, LD, which are installed in LPO-type lamps, are used as sources of artificial light in the design office and in the work rooms. To provide normalized lighting at the site of the machine shop are used lamps type RSP, with discharge lamps type DRL. The lamps are highly efficient, economical, reliable, with a lifetime of more than 8000-14000 hours.

Natural lighting has an important physiological and hygienic value for workers. It has a beneficial effect on the organs of vision, stimulates physiological processes, promotes the metabolism of substances and improves the development of the organism as a whole. Solar radiation warms and disinfects the air, cleansing it from many pathogens (such as the flu virus). In addition, the natural light also has a psychological effect, creating a sense of direct connection with the environment in the workers' room.

The disadvantages of natural lighting are: it is unstable in different periods of day and year, in different weather; unevenly distributed over the production area; in poor yoga, it can cause blindness of the organs of vision.

The illumination level of a room in natural light is influenced by the following factors: light climate; area and orientation of light openings; the degree of purity of the glass in the light openings; painting of walls and ceilings of premises; depth of the room; the presence of objects that populate the window from the inside as well as from the outside.

Since natural lighting is not stable during the day, a quantitative assessment of this type of lighting is carried out by a relative indicator - the coefficient of natural illumination (illumination).

According to the requirements of DBNV.2.5-28-2018 "Natural and artificial lighting" a room with a permanent stay of people should, as a rule, have natural lighting.

Without natural lighting the design of impurities is allowed, which are determined by government regulations to build buildings and structures, regulatory documentation of construction design and structures of some sectors of production which are approved in due form and premises, which accommodation is allowed in basements of buildings.

7.5 Fire safety measures

Fires are a major threat to the lives and health of workers and can result in serious material loss. The issue of ensuring the fire safety of buildings and structures is of great importance and is regulated by special state regulations and decisions.

Fire safety is ensured by the fire prevention system and the fire protection system in accordance with NAPS A.01.001-2014 "Rules of Fire Safety in Ukraine". These rules set the general requirements for fire safety for buildings, equipment, property.

In accordance with the requirements of DSTU B B.1.1-36: 2016 "Determination of categories of premises, buildings and exterior installations for explosive and fire danger", the mechanical section belongs to the category "D" from the fire hazard (space in the room containing solid flammable substances and materials).

According to DSTU EN 2: 2014 "Classification of fires (EN 2: 1992, EN 2: 1992 / A1: 2004, IDT)" at a mechanical site, a class A fire (accompanied by fire may be possible in the premises of a research laboratory equipped with VDT PC). burning of solid materials) and E (combustion of electrical installations up to 1000 V);

The causes of the fire may be: malfunction of electrical equipment (short circuit, overload); prolonged overload of engines, drives; breaking insulation, getting sparks or high-temperature shavings on flammable materials or workwear.

As the mechanical site and the premises of the research laboratory equipped with the VDT PC belong to the category "D" of the fire hazard, therefore, according to the requirements of the DBN B.1.1-7: 2016 "Fire safety of construction objects. «General Requirements »It has II degree of fire resistance.

In case of fire in the personnel evacuation room in accordance with the requirements of DBN B.1.1-7: 2016 "Fire safety of construction objects. General requirements "provided exits, on both sides of the premises. According to item

2.29 (table. 2) SNiP 2.09.02-85 *" Production buildings " the distance from the farthest workplace to the nearest evacuation exit is 70 meters.

According to the requirements of DBN B.2.5-56: 2014 "Fire protection systems", a fire alarm and alarm system "Signal-VK6" is installed in the premises (research laboratory, design bureau) of the equipped PC with VDT. Which provides detection of thermal and smoke signs of fire and location of fire to the location of the sensor.

It is recommended for this category of premises and class of fire to equip the premises with powder fire extinguishers with a capacity of 1 l in the amount of 1 pc according to the "Rules of operation and standard norms of fire extinguishers", approved by the order of the Ministry of Internal Affairs 15.01.2018 № 25 and registered in the Ministry of State on February 23, 2018/2018 31677. In powder extinguishers, dry powder is the source of extinguishing. They are intended for extinguishing solids, liquids and gases, as well as for materials that are smoldering. It is recommended to extinguish electrical installations with a voltage of up to 1000 V. It should be stored in an upright position in an easily accessible place, protected from direct sunlight and away from heating appliances.

7.6 Safety procedures in emergency situations

Hydrodynamic accidents

Hydrodynamic accidents and related emergencies occur after accidents involving hydrodynamic structures. Hydrodynamic accidents are an extraordinary event related to the failure of a hydrodynamic structure or a part of it and the unmanaged movement of large masses of water that carry the destruction and flooding of large areas.

The destruction of hydrodynamic structures occurs as a result of forces of nature (earthquakes, hurricanes, blurring of dams) or human impact (striking nuclear or conventional weapons on hydraulic structures or large natural dams), as

well as structural defects or design errors. The main hydrodynamic structures, the destruction of which leads to hydrodynamic accidents include dams, water intakes and drainage structures (floodgates). Dam-hyrotechnical structures (artificial or natural), which create a difference in levels along the river bed. Artificial dams are man-made hydraulic structures for their needs, which include the dam of hydroelectric power stations, water intakes in irrigation systems, dams, jumpers, fences and more. Natural dams are created by the action of natural forces, for example, as a result of landslides, villages, avalanches, landslides, earthquakes. Before the dam upstream, water accumulates and forms an artificial or natural reservoir.

A river section between two adjacent dams on a river or a channel section between two floodgates is called a beef (upper or lower).

The reservoirs can be long-term, such as the reservoirs of the upper dam of a hydroelectric power station, irrigation system, or the short-term ones that result from the river being covered with loose soil, snow or ice.

Dams have water courses: for artificial - directed, for natural - accidentally formed. The breakthrough of the dam is the initial phase of a hydrodynamic accident and is the process of formation of a propane and an uncontrolled flow of water from the upper spout, which flows through the propane into the lower spout.

Proran - A narrow channel in the body of a dam, a spit, a shoal, in a delta of a river or a straightened section of a river, which was formed as a result of the erosion of a twist into a flood. Breakthrough wave is a wave that forms at the front of a stream of water that flows into the propane and has a significant comb height, speed of movement and great destructive force. The height of the breakthrough wave and the speed of its propagation depends on the size of the propane, the difference in water levels in the upper and lower beams, the hydrological and topographical conditions of the river bed and its floodplain. Breakthrough water movement speeds range from 3 to 25 km / h, and for mountains to 100 km / h. The height of the breakout wave is in the range from 2 to 12 meters. The main consequence of the accident is catastrophic flooding.

Catastrophic flooding is a hydrodynamic disaster that results from the destruction of an artificial or natural dam and consists in the persistent flooding of a breakthrough wave below the locality and the occurrence of a flood. It is characterized by parameters:

- The maximum possible height and velocity of the breakthrough wave;
- Estimated time of arrival of the dam and the front of the breakthrough wave in the respective dam;
- The boundaries of the zone of possible flooding;
- The maximum depth of flooding of a particular area;
- Flood duration.

Large areas are flooded with a layer of water from 0.5 to 10 meters, the duration of flooding can vary from 4 hours to several days. The parameters of the flood zone depend on the size of the reservoir, the head of water and other characteristics of a specific hydroelectric site, as well as on the hydrological and topological features of the area. Breakthrough time prediction is based on predicting the rise of water up to 80-85% of the height of the body of the reservoir, taking into account the forecast data of the nearest weather station.

The consequences of hydrodynamic accidents are:

- o Damage and destruction of hydroelectric units and short-term or long-term suspension of their functions;
- o Damage to people and destruction of structures by the breakthrough wave;
- o Flooding large areas.

The worst consequences are catastrophic flooding. The magnitude of the consequences depends on the parameters and technical condition of the hydroelectric station, the nature and size of the dam, the volume of water reserves in the reservoir, the characteristics of the breakthrough wave and catastrophic flood, terrain, season and time of day of the event. The main drivers of catastrophic flooding are the devastating breakthrough wave, water flow and calm waters that have flooded land and land. The action of a breakout wave is similar to the effect

of a shock wave during an explosion. The significant differences between these striking factors are the much lower velocity and higher density of the substance in the breakthrough wave.

During major hydrodynamic accidents, power supply is interrupted, irrigation and other water management systems are shut down, pond fisheries facilities are being destroyed or destroyed. Settlements and industrial enterprises, decommissioning communication and other elements of infrastructure, crops and livestock are lost, land is removed from agriculture, the vital activity of the population is disturbed. Secondary consequences are pollution of water and terrain by substances from destroyed storage facilities, industrial and agricultural enterprises, mass diseases of people and animals, accidents on highways, landslides and landslides. The long-term effects are related to residual factors of flooding - sediment, pollution, changes in the elements of the environment. In general, the consequences are characterized by the magnitude of the damage to the national economy.

Conclusions

The need to address security issues leads to the formation of a comprehensive system of knowledge on occupational safety, necessary for making informed decisions about safety at all levels, at the level of the individual, collective, enterprise, industry, region and society as a whole. In the field of industrial activity, the level of occupational injuries remains high, which is a consequence of a number of factors. In order to prevent accidents, occupational injuries and other dangerous phenomena, the construction of equipment at a mechanical site must comply with the requirements of national standards and technical regulations, compliance with legal acts makes it possible to avoid the risk of injury and maintain health for a long time.

CONCLUSIONS

The result of this master's thesis is the technological process of manufacturing the shaft. Working and control fixture are designed.

An automated beating control device has been designed to reduce sizing time.

In order to eliminate the imbalance of the parts, it is necessary to balance them, so the basic methods of balancing are considered and the method of dynamic balancing of the shaft on the balancing machine is chosen.

The efficiency of usage of the device with a pneumatic actuator is calculated in comparison with the universal one.

Occupational health and emergency situations safety have been developed and proposed to ensure comfortable and safe working conditions.

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