The Ministry of Education and Science of the Russian Federation
Federal state autonomous educational institution of higher education
“NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY”

The School of Advanced Manufacturing Technology
Major15.03.01 “Mechanical engineering”
Division for Materials Science

Bachelor work

Worktheme
Master schedule projection of the conical shaft manufacturing **(**Проектирование технологического процесса изготовления конического вала**)**

UDC 621.824.8.002.2

The student:

Group	Last, First name	Signature	Date
8Л4И	Sabavath Sai Kiran (Сабават Саи Киран)		

The supervisor:

Post	Last, first , middlename	Scientific degree	Signature	Date
Associate Professor of Division for Materials Science	Kozlov V.N.	Ph.D. (Engineering)		

Consultants (Advisers):

The section «Financial management»

Post	Last, first , middlename	Scientificdegree	Signature	Date
Senior Lecturer	Potekhina N.V.	-		

The section «Socialresponsibility»

Post	Last, first , middlename	Scientificdegree	Signature	Date
Professor of Department of Control and Diagnostic	Nazarenko O.B.	D.Sc.		

Permission for the defense:

The Head of the Major	Last, first , middlename	Scientific degree, a rank	Signature	Date
15.03.01 “Mechanical Engineering”	Efremenkov E.A.	Ph.D. (Engineering), Associate Professor		

Tomsk – 2018

RECOGNIZED SCHEDULE RESULTS of TRAINING
on SEP (Standard Educational Programmer)

Result code	Result of training (the graduate should be ready)
	Professional competences
R1	To apply profound natural-science, mathematical and engineering knowledge to creation and machining of new materials
R2	To apply profound knowledge in the field of modern technologies of engineering manufacture to the decision of interdisciplinary engineering problems
R3	To formulate and solve the innovative problems of the engineering assaying related with creation and machining of materials and articles, with use of the systems analysis and simulation of plants and machine industry processes
R4	To develop master schedules, to design and use the new equipment and instruments for machining of materials and articles, competitive in the world market of engineering manufacture
R5	To carry out theoretical and experimental researches in the field of the modern technologies of materials machining, nano-technologies, creations of new materials in complex and uncertain conditions
R6	To introduce, operate and serve modern hi-tech lines of a computer aided production, to ensure their high performance, to observe rules of health protection and a labor safety on engineering manufacture, to fulfill requirements on environment guard
	Multiple-purpose competences
R7	To use profound knowledge on design management for support of innovative engineering activity taking into account legal aspects of guard of intellectual property
R8	Actively to own a foreign language at the level, allowing to work in the environment speaking another language, to develop the documentation, to present and protect results of innovative engineering activity
R9	Effectively to work individually, as a member and the principal of the group consisting of experts of various directions and qualifications, to show responsibility for results of operation and readiness to follow corporate culture of organization (of enterprise)
R10	To show profound knowledge of social, ethical and cultural aspects of innovative engineering activity, competence of sustainable development questions
R11	Independently to learn and to raise continuously qualification during all period of professional work

РЕФЕРАТ

выпускной квалификационной работы

студента гр. 8Л4И Сабават Саи Киран

«Проектирование технологического процесса изготовления конического вала»

Выпускная квалификационная работа выполнена на 113 с. пояснительной записки, содержит 56 рис., 12 табл., 13 источников, 2 листов прил.

Ключевые слова: вал конический, припуск, технологический размер, размерный анализ, режим резания, технологический процесс, нормирование технологического процесса, закрепление вала для фрезерования паза, пневматический цилиндр, расчёт приспособления, технологическая себестоимость, социальная ответственность.

Объектом исследования является технология изготовления детали “Вал конический”.

Цель работы – подтверждение квалификации «бакалавр техники и технологии» по направлению 15.03.01 «Машиностроение», по профилю подготовки «Технология, оборудование и автоматизация машиностроительных производств».

В процессе исследования проводились: анализ чертежа и технологичности детали, выбор заготовки, проектирование технологического процесса механической обработки детали “Вал конический”, расчёт припусков на обработку всех поверхностей, размерный анализ технологического процесса и расчёт технологических размеров, расчёт режимов резания и требуемой мощности станков, расчёт времени выполнения каждой операции и всего технологического процесса, проектирование специального приспособления для фрезерования шпоночного паза, расчёт необходимой силы закрепления, описание конструкции приспособления, расчёт технологической себестоимости изготовления детали, анализ вредных факторов на производстве и решение вопросов безопасности работы, действия при чрезвычайных ситуациях и мероприятия по их предотвращению, анализ влияния производственных факторов на окружающую среду.

В результате исследования был спроектирован технологический процесс и специальное приспособление, рассчитана технологическая себестоимость изготовления детали, которая составила 966,46 руб., решены вопросы безопасности работы, разработаны мероприятия по предотвращению чрезвычайных ситуаций.

Основные конструктивные, технологические и технико-эксплуатационные характеристики: при организации крупносерийного производства штучно-калькуляционное время обработки одной детали составит 49,39 минут. Для производства детали «Вал конический» потребуется следующее оборудование: фрезерно-центровальный станок МР-76М, токарный станок с ЧПУ 16К20Ф3, фрезерный станок ФУ251, круглошлифовальный станок 3М153.

Степень внедрения: по результатам защиты работы на государственной аттестационной комиссии будет решено, следует ли рекомендовать разработки к внедрению на производстве.

Область применения: производство машиностроительной продукции.

Экономическая значимость работы достаточно высокая.

В будущем планируется участвовать в организации производства детали.

THE ABSTRACT

Diploma Thesis

of the student Sabavath Sai Kiran, gr. 8Л4И

“Master schedule projection of the conical shaft manufacturing”

Diploma Thesis is executed on 113 p. of the explanatory note, containing 56 fig., 12 tab., 13 references, 2 sheets in appendix.

Keywords: conical shaft, allowance, technological size, dimensional assaying, cutting mode, master schedule, master schedule valuation, clamping of a shaft for milling of a key slot, pneumatic cylinder, work-holding device calculation, technological cost price, social responsibility.

Object is the manufacturing technology of part “Conical Shaft”.

The operation purpose - qualification affirming «The bachelor of engineering and technology» in a major 15.03.01 “Mechanical Engineering” in a profile of training “Technique, the equipment and automation of engineering manufactures”.

During the research work were carried out: the assaying of the drawing and manufacturability of the part, an initial workpiece choice, projection of a master schedule of the part “The Conical Shaft” machining, calculation of allowance in machining of all surfaces, the dimensional analysis of the master schedule and calculation of technological sizes, calculation of cutting mode and demanded power of machine tools, calculation of time of part machining of each operation and all master schedule, projection of special work-holding device for milling of key slot, calculation of necessary force of fixing, the description of work-holding device, calculation of the technological cost price of manufacture of the part, the assaying of harmful factors on manufacture and the decision of safety issues of operation, operation at emergency situations and actions for their prevention, the assaying of influence of production factors on environment.

As a result of probe the master schedule and the special work-holding device have been designed, the technological cost price of manufacture of the part is calculated which is 966.46 rub, operation safety issues are solved, and actions for prevention of emergency situations are developed.

The basic constructive, technological and technique-operational parameters: at business lot production the standard time of one part manufacturing will be 49.39 minutes. For the part “The Conical Shaft” manufacturing is required following equipment: the milling-center drilling machine MP-76M, the lathe with DNC 16К20Ф3, the milling machine ФУ-251, the circular grinding machine 3M153.

Introduction degree: by results of defense of Diploma Thesis on the state certifying commission it will be solved, whether it is necessary to recommend workings out to introduction on manufacture.

Field of application: manufacture of engineering production.

Economic significance of Diploma Thesis is high enough.

In the future, it is planned to participate in organization of part manufacturing.

The Ministry of Education and Science of the Russian Federation

Federal state autonomous educational institution of higher education
“**National Research Tomsk Polytechnic University”**

School	The School of Advanced Manufacturing Technology (ScAMT)
Major	15.03.01 “Mechanical engineering”
Division of School	Division for Materials Science (DMS)

Approved
The Head of the Major
15.03.01 “Mechanical Engineering”

__________________ Efremenkov E.A..
«_____» ___. 2018

Assignment

For executing of final qualification work

In the form:

Bachelor Degree Project

To the student:

Group	Name
8Л4И	Sabavath Sai Kiran (Сабават Саи Киран)

Work theme:

Master schedule projection of the conical shaft manufacturing **(**Проектирование технологического процесса изготовления конического вала**)**	
It is approved by the director’s ScAMT order	N 1753/c «14» 03. 2018 г.

Deadline for submission of the final copy by the student	05.06.18

The technical task:

Initial data to work:	The detail drawing; the annual program of release N_a=9000 pieces
The list of section to research, designing and working out of questions:	
1. The technological part:	To execute the analysis of manufacture-ability of a detail; to prove of a initial blank choice; to design technological process; to calculate allowances for machining of all surfaces; to execute the dimensional analysis of technological process and to calculate the technological sizes; to calculate cutting modes and demanded power of machine tools, time for performance of each operation and all technological process
2. The design part:	To design the special fixture for one of operations; to define necessary force of a clamping; to write the design description

The list of a graphics:	1. The detail drawing - format A2; 2. Operational cards of technological process - format A1; 3. Complex scheme of the dimensional analysis - format A1 or A2; 4. The assembly drawing of a fixture – format A1 or A2; 5. The specification of an assembly drawing of a fixture – format A4; 6. Calculation of the technological cost of manufacturing of a detail - format A1.

Advisers for sections of final qualification work

Section	The Adviser
Technological part	Associate Professor of DMS Kozlov V.N.
Design part	Associate Professor of DMS Kozlov V.N.
Financial management	Senior Lecturer Potekhina N.V.
Social responsibility	Professor of Department of Control and Diagnostic Nazarenko O.B.
The summary in Russian and English languages	Associate Professor of DMS Kozlov V.N.

Names of sections which should be written in Russian and foreign (English) languages
The summary

Date when the individual assignment was issued to the student under the linear schedule	29.01.18

Individual assignment was issued to the student by the supervisor:

Post	**Name**	**Scientific degree, a rank**	**Signature**	**Date**
Associate Professor of Division for Materials Science	Kozlov V.N.	Ph.D. (Engineering), Associate Professor		29.01.2018

Date when the individual assignment was issued to the student:

Group	**Name**	**Signature**	**Date**
8Л4И	Sabavath Sai Kiran		29.01.2018

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INTRODUCTION

Mechanical Engineering is concerned with the understanding and application of Engineering Procedures in Manufacturing Processes and Production Methods. It requires the ability to plan the practices of manufacturing; to research and to develop tools, processes, machines and equipment; and to integrate the facilities and systems for producing quality product with the optimum expenditure of capital.

In addition to these, we use tools such as computer-aided design (CAD), and product life cycle management to design and analyze manufacturing plants, industrial equipment and machinery etc. It is the branch of engineering that involves design, production and operation of machinery.

The main aim of this Diploma work is to develop the manufacturing process and design the work holding device which is used in the manufacturing of the given part.

1. Technological part (Manufacturing process design)

1.1. Initial data

The task is to develop manufacturing process for the product shown in Fig. 1. The annual volume of production is 9000 pieces.

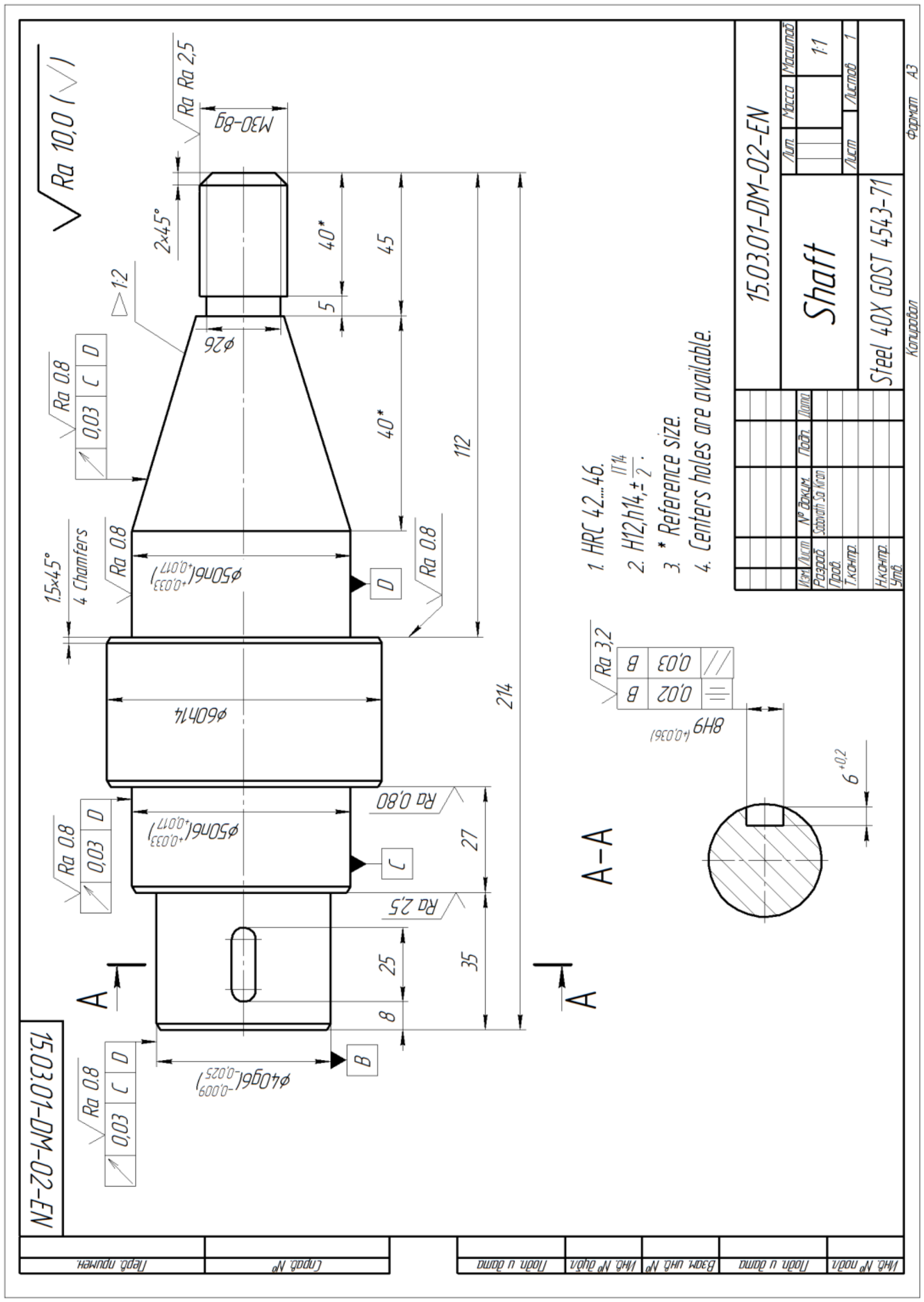


Fig.1. Drawing of the part

1.2. Manufacturability analysis

The part is made of Steel 40X which consists of 0.4% carbon *C*, 1% chromium *Cr*, sulfur *S*<0.09%, phosphorus *P*<0.035%. The production of this part can be obtained in different ways: by hot or cold rolling, die forging or by casting. Since the part has a large difference of diameters, using rolled stock or casting makes the production of the part complex. Therefore, using die forging in our case is the best possible way as we can avoid cracks in the body of the blank. The material structure would be more uniform and the allowance to be removed would be minimized making the tool life longer.

We use Centre milling-drilling machine to mill the face ends and drill the centre holes on both sides which will later be used to hold the part while the external surfaces are being machined on a lathe. We use a vertical milling machine to mill a key slot of size 8H9. A special purpose fixture made of V-block and a pneumatic drive is used to hold the part during the milling operation. The machining of thread M30-8g followed by groove-cutting is done by a die and a grove cutting tool on the lathe respectively.

The conical surface of the part with conicity C= 1:2 should be machined on a CNC lathe.

The final machining is made with the help of the cylindrical grinding machine to achieve the required tolerance for ϕ40g6, ϕ50n6 (with 6^{th} grade of tolerance) and required roughness of surfaces (Ra $\leq$ 0.8 microns). The conical surface should also undergo the process of grinding as it also has the roughness of Ra $\leq$ 0.8 microns.

The shape of the part is convenient for manufacturing. The machining of the external surfaces should be performed in rough and semi-finish operations. Centre holes are used in order to provide higher accuracy of the peripheral surfaces Ø40g6, Ø50n6, the conical surface with conicity C=1:2 (tolerance is 0.03 mm) and ease clamping of the shaft. The shaft is machined between two centers; therefore, centre holes are drilled in the first operation.

The application of thermal operation is required. Material (Steel 40X) allows carrying out quenching with the specified hardness (it is better to use steel 40X for reduction of required speed of cooling and the possibility of warping of the part). Final processing of surfaces with the exact sizes (Ø40g6, Ø 50n6 and the conical surface C=1:2) should be carried out after thermal operation for the elimination of the possibility of warping of the part. Thus, for the final processing, sufficient stock (allowance) should be left in the point of view of the part warping.

1.3. Calculation of type of production

The total number of products per year N=9000 pieces.

The actual available hours of equipment operation is taken from the table no.4 [4, page23] to work in two shifts F_r=4015 hours.

To determine the time for processing step (manufacturing) is given by:

$$t_m = \frac{F_r \cdot 60}{N} = \frac{4015 \cdot 60}{9000} = 26.76\left(\frac{\min}{piece}\right)$$

where F_r is the actual available hours of the equipment operation [hours],

N – is the total number of parts per year.

Table 1. Duration of operations of the existing factory manufacturing process

№ of operation	The name of operation	T_f, min.
1	Centre Mill-Drilling	1.1
2	Turning	2.6
3	Turning	1.1
4	Cylindrical Grinding	1.3
5	Cylindrical Grinding	0.63
	Total floor-to-floor time $\sum T_f$ = 6.73min.	6.73

Total number of operations n=5.

We can determine the average floor-to-floor time by the given formula:

$T_{f(avg.)} = \sum T_f /n = 6.73/5 = 1.346$ min.

We can define the factor of manufacturing type by:

$K_m = t_m / T_{f(avg.)} = 26.76/1.346 = 19.88$

Since $10 \le K_m \le 20$, the manufacturing type is ***medium-batch*** production.

1.3.1 Calculation of quantity of parts in a set (batch size)

The total number of parts per year N= 9000 pieces; $T_{f(avg.)}$=1.346 min.

Periodicity of start-release of products *a*=5 days.

Number of working days in one year is *F*=240 days.

We define the settlement quantity of parts in a set according to the given formula:

$n = N \times a / F = 9000 \times 5/240 = 188$ pieces,

where *a* is the quantity of storage in days. For small and inexpensive parts it is 5-10 days but more storage days indicate more unfinished manufacturing, so we accept *a*=5 days.

The settlement number of shifts for processing of parts set in machine shop is defined as:

$c = (T_{f\,(avg)} \times n) / (480 \times 0.8) = (1.346 \times 188) / (480 \times 0.8) = 0.66.$

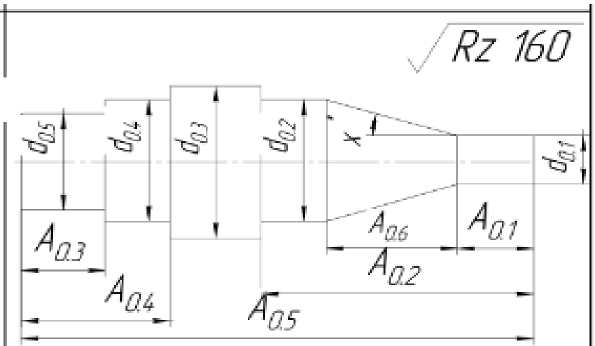
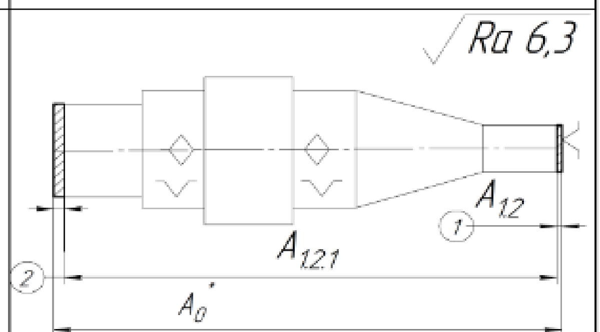
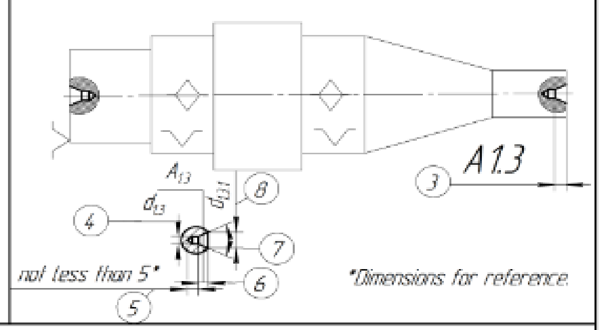
The customary number of shifts for processing of parts on a site: c_{ac}=2 shifts.

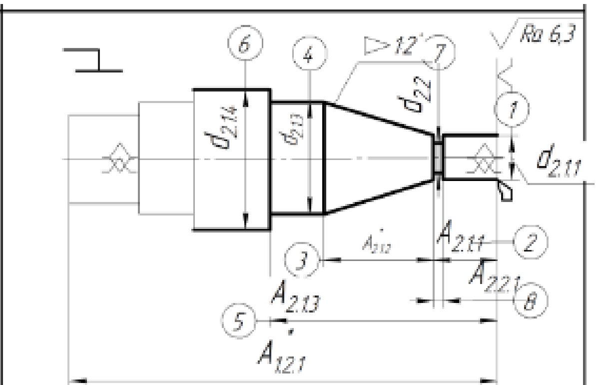
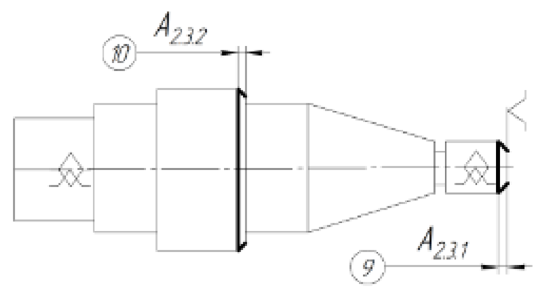
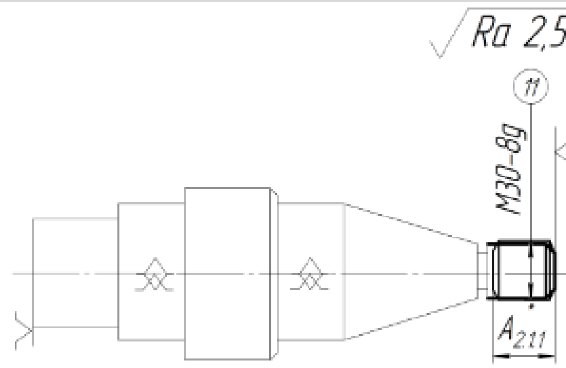
The accepted number of parts in a set is:

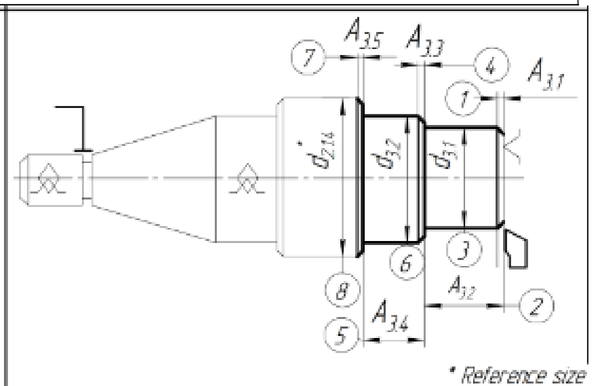
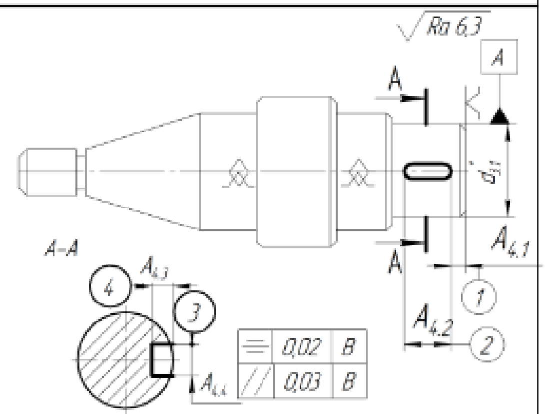
$n_{ac} = c_{ac} \times 480 \times 0.8 / T_{f\,av} = 2 \cdot 480 \times 0.8 / 1.346 \approx 570$ pieces.

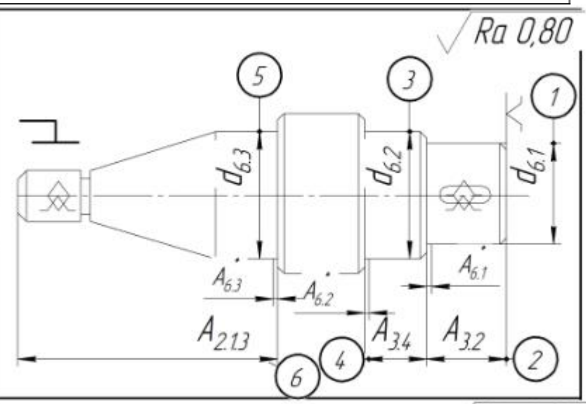
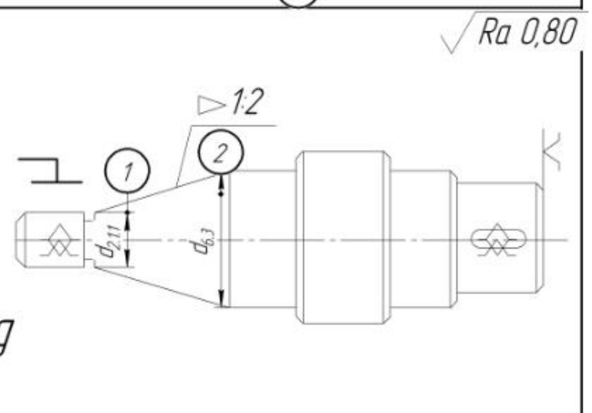
1.4. Manufacturing process

Table 1.1. Manufacturing process of a conical shaft

Number		Name and content of operation and transition	Operation scheme
Operation	Transition		
0		<u>die forge the workpiece to dimensions given on the sketch</u>	
1		<u>Center drill–Milling</u>	
	1	Clamp and unclamp the workpiece	
	2	Mill both faces simultaneously to obtain sizes 1 and 2	
	3	Drill two centre holes ensuring sizes 3 – 8.	

Number: Operation	Number: Transition	Name and content of operation and transition	Operation scheme
2		Turning	
	A	Clamp and unclamp the workpiece	
	1	Turn the contour ensuring ensuring the dimensions 1–6.	
	2	Make a Groove ensuring sizes 7 and 8.	
	3	Machine chamfer ensuring size 9	
	4	Machine chamfer ensuring size 10.	
	5	Cut the thread ensuring size 11.	

Number: Operation	Number: Transition	Name and content of operation and transition	Operation scheme
3	A 1	Turning operation Clamp and unclamp the workpiece. Turn the contour to obtain the sizes 1–8.	
4	A 1	Milling Clamp and unclamp the workpiece. Mill key-slot ensuring the sizes 1–4.	
5		Heat treatment Quenching Tempering the part to HRC 42….46	

Number: Operation	Number: Transition	Name and content of operation and transition	Operation scheme
6	A 1 2 3	Cyindrical grinding Clamp and unclamp the workpiece. Grind surface ensnsuring sizes 1–2. sizes3–4. sizes 5–6.	
7	A 1	Cylindrical grinding Clamp and unclamp the workpiece. Grind surface ensuring size 1 and 2.	

1.5. Construction of a dimension diagram and graph tree

The dimensional scheme for manufacturing a product is a set of manufacturing dimensional chains. The resulting dimensions in operational manufacturing chains are allowances and design dimensions directly taken from the drawing. In addition to the resulting dimensions in the chain, there are dimensions that are the manufacturing dimensions obtained during all operations (processing steps) of the product manufacturing [2, p. 21].

Based on the manufacturing route of the shaft with a conical surface, a dimensional diagram is compiled (shown in Figure 2), which contains all axial manufacturing dimensions, machining allowances and design dimensions.

In the dimensional diagram given below (Fig. 2), the number of surfaces is 25, the number of manufacturing dimensions is 24, the number of allowances is 11, and the number of design dimensions is 13. Therefore, the dimensional diagram is constructed correctly.

In order to facilitate the compilation of dimensional chains, a graph-tree is constructed. The method for constructing a graph-tree is described in detail in [2, p. 29]. The graph-tree for the dimensional diagram for manufacturing the shaft with a conical surface is shown in Fig. 3.

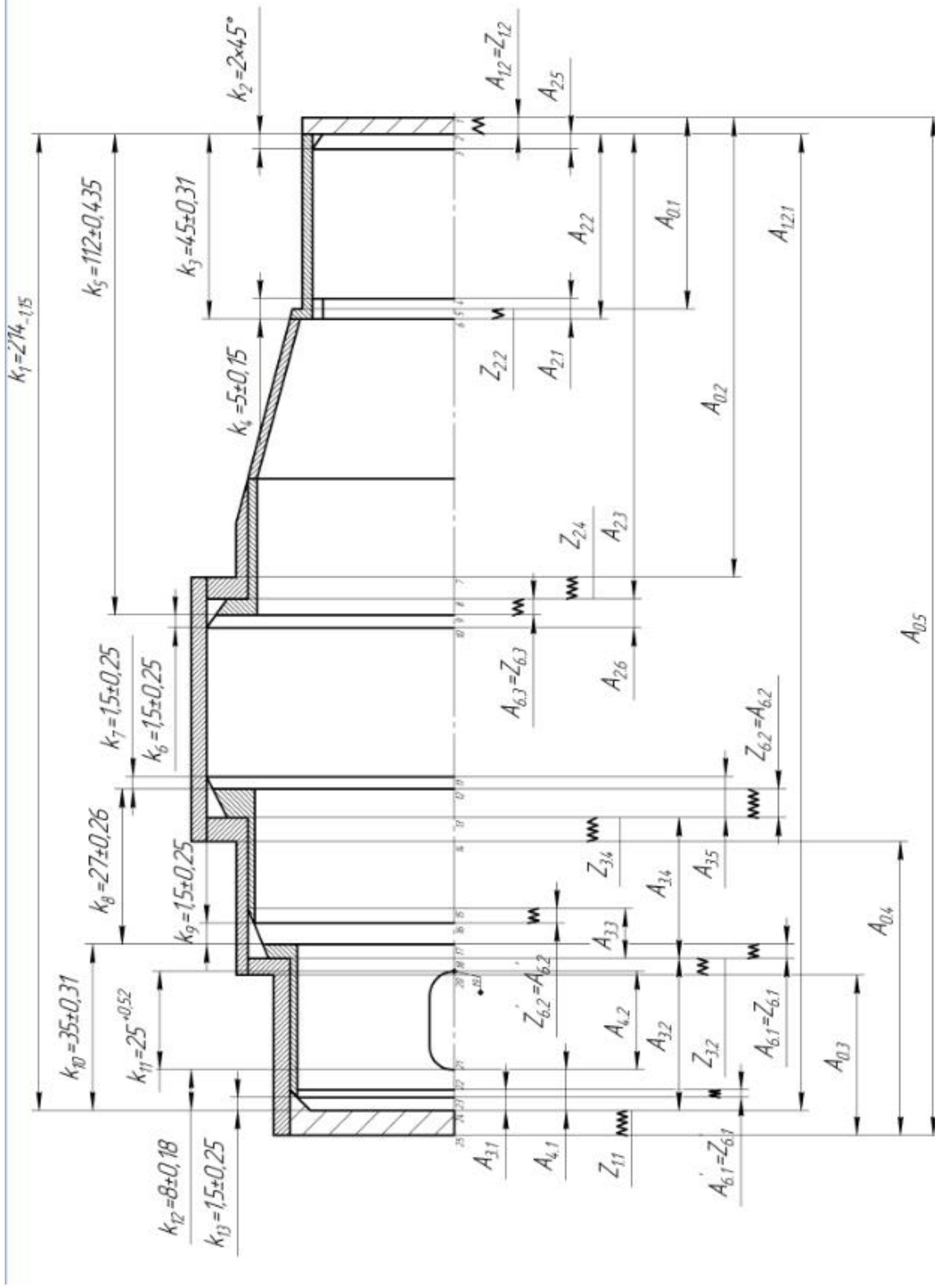


Fig. 2. Dimensional diagram

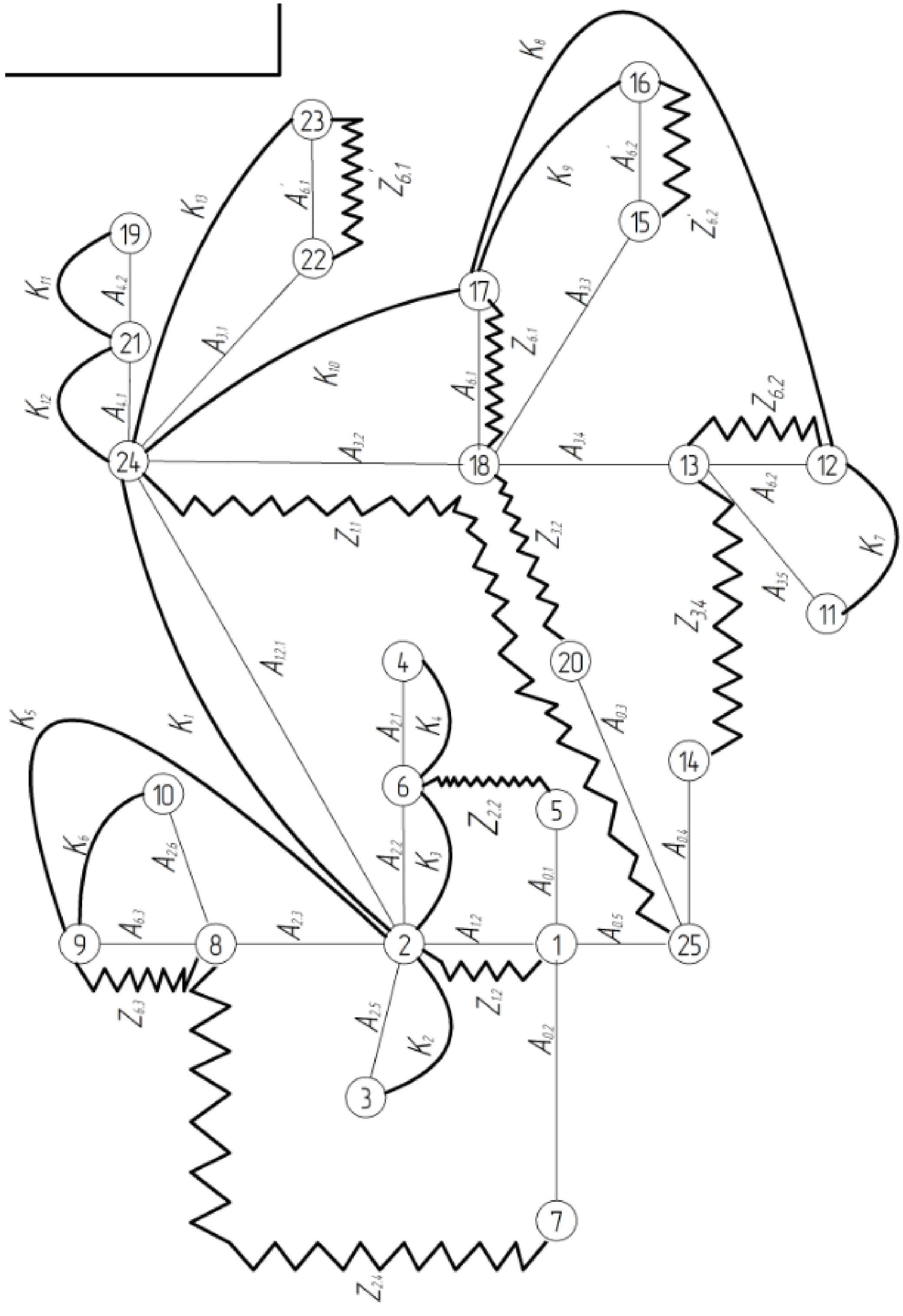


Fig. 3. Graph-tree of manufacturing process of the conical shaft

1.6. Tolerance Analysis

Tolerances are assigned to dimensions for manufacturing purposes, as boundaries for suitable manufacture. No machine can hold dimensions precisely to the nominal value, so there must be acceptable degrees of size variation. If a part is manufactured, but has dimensions that are out of tolerance, it is not a usable part according to the design intent. Tolerances can be applied to any dimension.

Table 1.2. Tolerances of designer's sizes

K-sizes in **axial** direction	Tolerances of K-sizes in **axial** direction
K_i, mm	**TK_i, mm**
$K_1=214_{-1.15}$	$TK_1=1.15$
$K_2=2x45^{\circ}$	$TK_2=0.50$
$K_3=45\pm0.31$	$TK_3=0.62$
$K_4=5\pm0.15$	$TK_4=0.30$
$K_5=112\pm0.435$	$TK_5=0.87$
$K_6=1.5x45^{\circ}$	$TK_6=0.50$
$K_7=1.5x45^{\circ}$	$TK_7=0.50$
$K_8=27\pm0.26$	$TK_8=0.52$
$K_9=1.5x45^{\circ}$	$TK_9=0.50$
$K_{10}=35\pm0.31$	$TK_{10}=0.62$
$K_{11}=25^{+0.52}$	$TK_{11}=0.52$
$K_{12}=8\pm0.18$	$TK_{12}=0.36$
$K_{13}=1.5x45^{\circ}$	$TK_{13}=0.50$
K-sizes in **radial** direction, mm	Tolerances for K-sizes in **radial** direction, mm
$K_{14}=\phi26h14$	$TK_{14}=0.21$
$K_{15}=\phi50n6$	$TK_{15}=0.016$
$K_{16}=\phi60h14$	$TK_{16}=0.74$
$K_{17}=\phi50n6$	$TK_{17}=0.016$
$K_{18}=\phi40g6$	$TK_{18}=0.016$
$K_{19}=\phi8H9$	$TK_{19}=0.036$

Tolerances for **manufacturing** sizes are given by [2, pg. 38]:

$$T_i = \omega_{ci} + \rho_{i-1}$$

where, ω_c– statistical error of machining;

ρ – geometrical deviation of the datum surface of the part.

Residual spatial deviation of forgings on one side:

$$\boldsymbol{\rho_0} = 0.4mm.$$

We find the value of the residual spatial deviation after the rough turning through the coefficient of residual warping:

$$\boldsymbol{\rho_1} = k_{y1} \times \rho_0 = 0.06*0.4 = 0.02mm.$$

We find the value of the residual spatial deviation after the grinding through the coefficient of residual warping:

$$\boldsymbol{\rho_2} = k_{y2} \times \rho_1 = 0.05*0.02 = 0.001mm.$$

Tolerances for **manufacturing** sizes $A_{i.j}$ (where *i* – is a number of manufacturing (technological) operation on which workpiece' surface is machined and ensuring of the technological size $A_{i.j}$ is executed, *j* – is a number of processing step) are given as follows:

$$TA_{1.2} = \omega_c + \rho_0 = 0.25 + 0.4 = 0.65 \text{ mm.}$$

$$TA_{1.2.1} = \omega_c + 0 = 0.25 \text{ mm.}$$

$$TA_{2.1} = \omega_c + 0 = 0.1 \text{ mm.}$$

$$TA_{2.2} = \omega_c + \rho_1 = 0.2 + 0.02 = 0.22 \text{ mm.}$$

$$TA_{2.3} = \omega_c + \rho_1 = 0.2 + 0.02 = 0.22 \text{ mm.}$$

$$TA_{2.5} = \omega_c + \rho_1 = 0.2 + 0.02 = 0.22 \text{ mm.}$$

$$TA_{2.6} = \omega_c + 0 = 0.2 \text{ mm.}$$

$$TA_{3.1} = \omega_c + \rho_1 = 0.2 + 0.02 = 0.22 \text{ mm.}$$

$$TA_{3.2} = \omega_c + \rho_1 = 0.2 + 0.02 = 0.22 \text{ mm.}$$

$$TA_{3.3} = \omega_c + 0 = 0.2 \text{ mm.}$$

$$TA_{3.4} = \omega_c + 0 = 0.2 \text{ mm.}$$

$$TA_{3.5} = \omega_c + 0 = 0.2 \text{ mm.}$$

$$TA_{4.1} = \omega_c + \rho_1 = 0.2 + 0.02 = 0.22 \text{ mm.}$$

$$TA_{4.2} = \omega_c + 0 = 0.2 \text{ mm.}$$

$$TA_{6.1} = \omega_c + \rho_1 = 0.1 + 0.02 = 0.12 \text{ mm.}$$

$$TA_{6.2} = \omega_c + \rho_1 = 0.1 + 0.02 = 0.12 \text{ mm.}$$

$$TA_{6.3} = \omega_c + \rho_1 = 0.1 + 0.02 = 0.12 \text{ mm.}$$

1.6.1. Ensuring accuracy of design dimensions

When using the maximum-minimum method, the condition for ensuring the accuracy of the design size is verified by the formula [2, p. 60]:

$$TK \geq \sum_{i=1}^{n} TA_i.$$

Let us consider dimensional chain for K_1 size (Fig. 4).

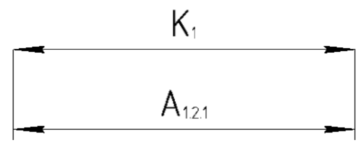


Fig. 4. Dimensional chain for size K_1

TK_1=1.15 mm >$TA_{1.2.1}$=0.25 mm.

The size K_1 is ensured directly.

Let us consider dimensional chain for K_2 size (Fig. 5).

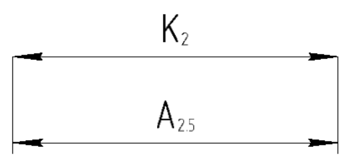


Fig. 5. Dimensional chain for size K_2

TK_2=0.5 mm>$TA_{2.5}$=0.22 mm.

The size K_2 is ensured directly.

Let us consider dimensional chain for K_3 size (Fig. 6).

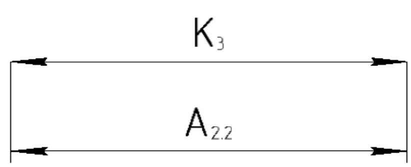


Fig. 6. Dimensional chain for size K_3

TK_3=0.62 mm>$TA_{2.2}$=0.22 mm.

The size K_3 is ensured directly.

Let us consider dimensional chain for K_4 size (Fig. 7).

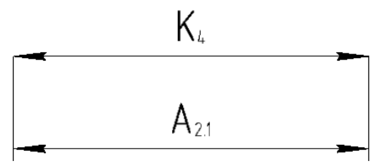


Fig. 7. Dimensional chain for size K_4

TK_4=0.3 mm>$TA_{2.1}$=0.1 mm

The size K_4 is ensured directly.

Let us consider dimensional chain for K_5 size (Fig. 8).

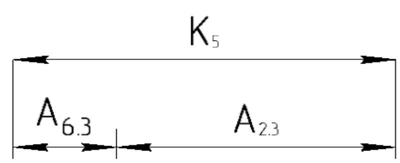


Fig. 8. Dimensional chain for size K_5

TK_5=0.87 mm; $TA_{6.3}$ +$TA_{2.3}$ =0.12 mm+0.22 mm=0.34 mm.

The size K_5 can be ensured.

Let us consider dimensional chain for K_6 size (Fig. 9).

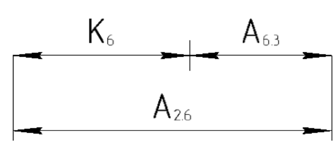


Fig. 9. Dimensional chain for size K_6

TK_6=0.5 mm; $TA_{6.3}$ +$TA_{2.6}$ =0.12 mm+0.2 mm=0.32 mm.

The size K_6 can be ensured.

Let us consider dimensional chain for K_7 size (Fig. 10).

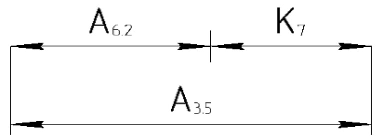


Fig. 10. Dimensional chain for size K_7

TK_7=0.5 mm; $TA_{6.2}$ +$TA_{3.5}$ =0.12 mm+0.2 mm=0.32 mm.

The size K_7 can be ensured.

Let us consider dimensional chain for K_8 size (Fig. 11).

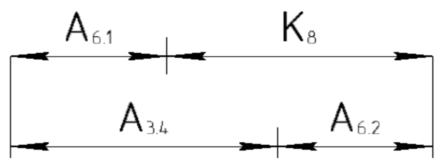


Fig. 11. Dimensional chain for size K_8

TK_8=0.52 mm; $TA_{6.2}$ +$TA_{3.4}$+$TA_{6.1}$ =0.12 mm+0.2 mm+0.12 mm=0.44 mm.

The size K_8 can be ensured.

Let us consider dimensional chain for K_9 size (Fig. 12).

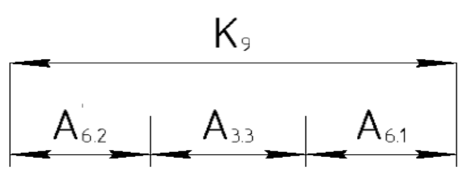


Fig. 12. Dimensional chain for size K_9

TK_9=0.5 mm; $TA'_{6.2}$ +$TA_{3.3}$+$TA_{6.1}$ =0.016 mm+0.2 mm+0.12 mm=0.336 mm.

The size K_9 can be ensured.

Let us consider dimensional chain for K_{10} size (Fig. 13).

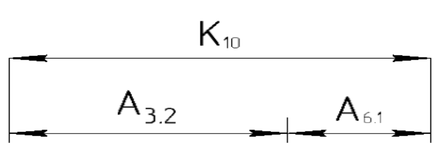


Fig. 13. Dimensional chain for size K_{10}

TK_{10}=0.62 mm; $TA_{3.2}$+$TA_{6.1}$ =0.22 mm+0.12 mm=0.34 mm.

The size K_{10} can be ensured.

Let us consider dimensional chain for K_{11} size (Fig. 14).

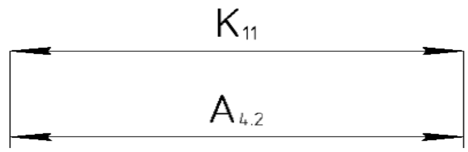


Fig. 14. Dimensional chain for size K_{11}

TK_{11}=0.52 mm; $TA_{4.2}$=0.2 mm.

The size K_{11} is ensured directly.

Let us consider dimensional chain for K_{12} size (Fig. 15).

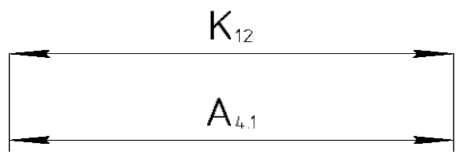


Fig. 15. Dimensional chain for size K_{12}

TK_{12}=0.36 mm; $TA_{4.1}$=0.22 mm.

The size K_{12} is ensured directly.

Let us consider dimensional chain for K_{13} size (Fig. 16).

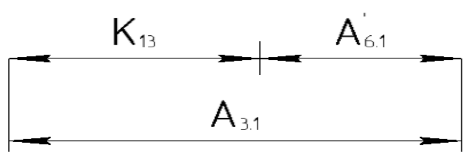


Fig. 16. Dimensional chain for size K_{13}

TK_{13}=0.4 mm; $TA_{3.1}$+$TA'_{6.1}$ =0.22 mm+0.016 mm=0.236mm.

The size K_{13} can be ensured.

Let us consider dimensional chain for K_{14} size (Fig. 17).

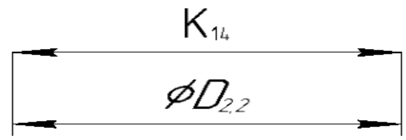


Fig. 17. Dimensional chain for size K_{14}

TK_{14}=0.21 mm; $TD_{2.2}$=0.21 mm.

The size K_{14} is ensured directly.

Let us consider dimensional chain for K_{15} size (Fig. 18).

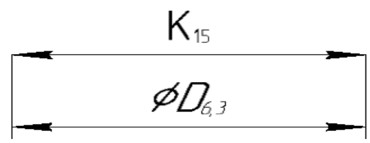


Fig. 18. Dimensional chain for size K_{15}

TK_{15}=0.016 mm; $TD_{6.3}$=0.016 mm.

The size K_{15} is ensured directly.

Let us consider dimensional chain for K_{16} size (Fig. 19).

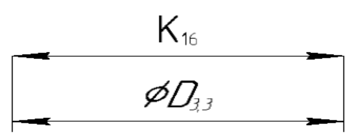


Fig. 19. Dimensional chain for size K_{16}

TK_{16}=0.74 mm; $TD_{6.3}$=0.74 mm.

The size K_{16} is ensured directly.

Let us consider dimensional chain for K_{17} size (Fig. 20).

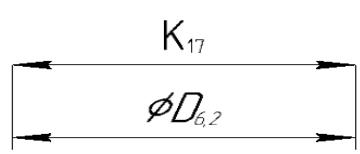


Fig. 20. Dimensional chain for size K_{17}

TK_{17}=0.016 mm; $TD_{6.2}$=0.016 mm.

The size K_{17} is ensured directly.

Let us consider dimensional chain for K_{18} size (Figure 21).

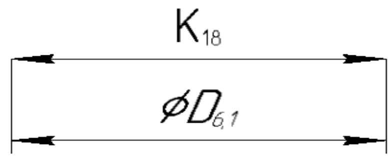


Fig. 21. Dimensional chain for size K_{18}

TK_{18}=0.016 mm; $TD_{6.1}$=0.016 mm.

The size K_{18} is ensured directly.

1.6.2 Calculation of work-piece machining allowance

The establishment of optimal machining allowances and manufacturing tolerances on the dimensions of blanks for all processing steps (transitions) has an important technical and economic significance in the development of manufacturing processes for the manufacture of machine parts. Exaggerated allowances cause an excessive waste of material in the manufacture of parts and the need to introduce additional manufacturing transitions, increase the laboriousness of machining processes, consumption of energy and cutting tools, increase the prime cost of machining the part. As a result of insufficient allowances, defect increases, which raises the cost of manufactured products.

On the basis of optimal allowances, it is possible to reasonably determine the mass of the initial blanks, the cutting parameters, as well as the time norms for performing machining operations.

The allowances for machining the workpiece are selected depending on the economically accepted method of machining, the configuration of the product and its weight. Calculation of allowances can be made by statistical and analytical method.

The analytical method consists in the analysis of manufacturing errors that occur under specific conditions for the machining of the workpiece and in determining the values of the elements that make up the allowance and their summation.

In general, allowance is a layer of metal for machining and obtaining the necessary geometry and roughness of the product. Intermediate allowance can be described as a layer of metal for the machining transition. The size of the allowance should be sufficient to remove the defective layer of metal from the workpiece, as well as to compensate for the error in locating and clamping the part.

The calculation-analytical method approximates the workpiece to the dimensions of the part, reducing the metal layer to the allowance before other methods.

1.6.3 Calculation of allowances for diametrical sizes

The minimum allowance for the diameter to be machined is determined by the formula from [2, p. 47]:

$$2 \cdot z_{i\,\min} = 2 \cdot (Rz_{i-1} + h_{i-1} + \sqrt{\rho_{i-1}^2 + \varepsilon^2}),$$

where $z_{i\,\min}$ – is minimum allowance for cutting the surface of rotation, µm;

Rz_{i-1} – is roughness from the previous machining of this surface, µm;

h_{i-1} – is thickness of the defective surface layer formed from the previous machining of this surface, µm;

ρ_{i-1} – is the total form error of form and position of surface obtained at the previous machining of this surface, µm;

ε – error of clamping (ε=0 for clamping between two centers).

Allowance $2Z_{0.2}$

Calculated minimum allowance:

$$2 \cdot Z_{0.2_{min}} = 2 \cdot (100 + 300 + 160) = 920 \text{ µm}.$$

The sum of the tolerances of the components in the chain:

$$T2Z_{0.2} = TD_{2.3} + TD_{0.2} = 300 + 800 = 1100 \text{ µm}.$$

Calculated maximum allowance:

$$2 \cdot Z_{0.2_{max}} = 2 \cdot Z_{0.2_{min}} + T2Z_{0.2} = 920 + 1100 = 2020 \text{ µm}.$$

Calculated average allowance:

$$2 \cdot Z_{0.2_{avg}} = \frac{2 \cdot Z_{0.2_{max}} + 2 \cdot Z_{0.2_{min}}}{2} \pm \frac{T2Z_{0.2}}{2} = \frac{2020 + 920}{2} \pm \frac{1100}{2}$$

$$= 1470 \pm 550 \text{ µm}.$$

Allowance 2Z$_{0.3}$

Calculated minimum allowance:

$$2 \cdot Z_{0.3_{min}} = 2 \cdot (100 + 300 + 160) = 920 \text{ µm}.$$

The sum of the tolerances of the components in the chain:

$$T2Z_{0.3} = TD_{3.3} + TD_{0.3} = 740 + 800 = 1540 \text{ µm}.$$

Calculated maximum allowance:

$$2 \cdot Z_{0.3_{max}} = 2 \cdot Z_{0.3_{min}} + T2Z_{0.3} = 920 + 1540 = 2460 \text{ µm}.$$

Calculated average allowance:

$$2 \cdot Z_{0.3_{avg}} = \frac{2 \cdot Z_{0.3_{max}} + 2 \cdot Z_{0.3_{min}}}{2} \pm \frac{T2Z_{0.3}}{2} = \frac{2460 + 920}{2} \pm \frac{1540}{2}$$

$$= 1690 \pm 770 \text{ µm}.$$

Allowance 2Z$_{0.4}$

Calculated minimum allowance:

$$2 \cdot Z_{0.4_{min}} = 2 \cdot (100 + 300 + 160) = 920 \text{ µm}.$$

The sum of the tolerances of the components in the chain:

$$T2Z_{0.4} = TD_{3.2} + TD_{0.4} = 300 + 800 = 1100 \text{ µm}.$$

Calculated maximum allowance:

$$2 \cdot Z_{0.4_{max}} = 2 \cdot Z_{0.4_{min}} + T2Z_{0.4} = 920 + 1100 = 2020 \text{ µm}.$$

Calculated average allowance:

$$2 \cdot Z_{0.4_{avg}} = \frac{2 \cdot Z_{0.4_{max}} + 2 \cdot Z_{0.4_{min}}}{2} \pm \frac{T2Z_{0.4}}{2} = \frac{2020 + 920}{2} \pm \frac{1100}{2}$$

$$= 1470 \pm 550 \text{ µm.}$$

Allowance 2Z$_{0.5}$

Calculated minimum allowance:

$$2 \cdot Z_{0.5_{min}} = 2 \cdot (100 + 300 + 160) = 920 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$T2Z_{0.5} = TD_{3.1} + TD_{0.5} = 250 + 800 = 1050 \text{ µm.}$$

Calculated maximum allowance:

$$2 \cdot Z_{0.5_{max}} = 2 \cdot Z_{0.5_{min}} + T2Z_{0.5} = 920 + 1050 = 1970 \text{ µm.}$$

Calculated average allowance:

$$2 \cdot Z_{0.5_{avg}} = \frac{2 \cdot Z_{0.5_{max}} + 2 \cdot Z_{0.5_{min}}}{2} \pm \frac{T2Z_{0.5}}{2} = \frac{1970 + 920}{2} \pm \frac{1050}{2}$$

$$= 1445 \pm 525 \text{ µm.}$$

Allowance 2Z$_{6.1.1}$

Calculated minimum allowance:

$$2 \cdot Z_{6.1.1_{min}} = 2 \cdot (20 + 50 + 20) = 180 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$T2Z_{6.1.1} = TD_{6.1} + TD_{3.1} = 160 + 250 = 410 \text{ µm.}$$

Calculated maximum allowance:

$$2 \cdot Z_{6.1.1_{max}} = 2 \cdot Z_{6.1.1_{min}} + T2Z_{6.1.1} = 40 + 410 = 450 \text{ µm.}$$

Calculated average allowance:

$$2 \cdot Z_{6.1.1_{avg}} = \frac{2 \cdot Z_{6.1.1_{max}} + 2 \cdot Z_{6.1.1_{min}}}{2} \pm \frac{T2Z_{6.1.1}}{2} = \frac{450 + 40}{2} \pm \frac{410}{2}$$

$$= 245 \pm 205 \text{ µm.}$$

Allowance $2Z_{6.2.1}$

Calculated minimum allowance:

$$2 \cdot Z_{6.2.1_{min}} = 2 \cdot (20 + 50 + 20) = 180 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$T2Z_{6.2.1} = TD_{6.2} + TD_{3.2} = 190 + 300 = 490 \text{ µm.}$$

Calculated maximum allowance:

$$2 \cdot Z_{6.2.1_{max}} = 2 \cdot Z_{6.2.1_{min}} + T2Z_{6.2.1} = 40 + 490 = 530 \text{ µm.}$$

Calculated average allowance:

$$2 \cdot Z_{6.2.1_{avg}} = \frac{2 \cdot Z_{6.2.1_{max}} + 2 \cdot Z_{6.2.1_{min}}}{2} \pm \frac{T2Z_{6.2.1}}{2} = \frac{530 + 40}{2} \pm \frac{490}{2}$$

$$= 285 \pm 245 \text{ µm.}$$

Allowance $2Z_{6.3.1}$

Calculated minimum allowance:

$$2 \cdot Z_{6.3.1_{min}} = 2 \cdot (20 + 50 + 20) = 180 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$T2Z_{6.3.1} = TD_{6.3} + TD_{3.3} = 190 + 300 = 490 \text{ µm.}$$

Calculated maximum allowance:

$$2 \cdot Z_{6.3.1_{max}} = 2 \cdot Z_{6.3.1_{min}} + T2Z_{6.3.1} = 40 + 490 = 530 \text{ µm.}$$

Calculated average allowance:

$$2 \cdot Z_{6.3.1_{avg}} = \frac{2 \cdot Z_{6.3.1_{max}} + 2 \cdot Z_{6.3.1_{min}}}{2} \pm \frac{T2Z_{6.3.1}}{2} = \frac{530 + 40}{2} \pm \frac{490}{2}$$

$$= 285 \pm 245 \text{ µm.}$$

Table 1.3. Allowances for diametrical technological sizes

Calculated allowance	Elements of allowance			Calculated minimum allowance, μm	Sum of tolerances in the chain, μm	Calculated maximum allowance, μm	Calculated average allowance, μm
	Rz_{i-1}	h_{i-1}	ρ_{i-1}				
$2Z_{0.2}$	100	300	160	920	1100	2020	1470±400
$2Z_{0.3}$	100	300	160	920	1540	2460	1690±770
$2Z_{0.4}$	100	300	160	920	1100	2020	1470±400
$2Z_{0.5}$	100	300	160	920	1050	1970	1445±400
$2Z_{6.1.1}$	20	50	20	180	410	450	245±205
$2Z_{6.2.1}$	20	50	20	180	490	530	285±245
$2Z_{6.3.1}$	20	50	20	180	490	530	285±245

1.6.4 Calculation of allowances for axial dimensions

The minimum allowance for the axial sizes to be machined is determined by the formula from [2, p. 47]:

$$z_{i\min} = Rz_{i-1} + h_{i-1} + \rho_{i-1}$$

Allowance $Z_{1.2}$

Calculated minimum allowance:

$$Z_{1.2_{min}} = (100 + 300 + 330) = 730 \text{ μm}.$$

The sum of the tolerances of the components in the chain:

$$TZ_{1.2} = TA_{1.2} = 650 \text{ μm}.$$

Calculated maximum allowance:

$$Z_{1.2_{max}} = Z_{1.2_{min}} + TZ_{1.2} = 730 + 650 = 1380 \text{ μm}.$$

Calculated average allowance:

$$Z_{1.2_{avg}} = \frac{Z_{1.2_{max}} + Z_{1.2_{min}}}{2} \pm \frac{TZ_{1.2}}{2} = \frac{1380 + 730}{2} \pm \frac{650}{2} = 1055 \pm 325 \text{ μm}.$$

Allowance $Z_{1.1}$

Calculated minimum allowance:

$$Z_{1.1_{min}} = (100 + 300 + 330) = 730 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{1.1} = TA_{1.2.1} + TA_{1.2} + TA_{0.5} = 250 + 650 + 2400 = 3300 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{1.1_{max}} = Z_{1.1_{min}} + TZ_{1.1} = 730 + 3300 = 4030 \text{ µm.}$$

Calculated average allowance:

$$Z_{1.1_{avg}} = \frac{Z_{1.1_{max}} + Z_{1.1_{min}}}{2} \pm \frac{TZ_{1.1}}{2} = \frac{4030 + 730}{2} \pm \frac{3300}{2} = 2380 \pm 1650 \text{ µm.}$$

Allowance $Z_{2.2}$

Calculated minimum allowance:

$$Z_{2.2_{min}} = (100 + 300 + 330) = 730 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{2.2} = TA_{0.1} + TA_{1.2} + TA_{2.2} = 1200 + 650 + 220 = 2070 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{2.2_{max}} = Z_{2.2_{min}} + TZ_{2.2} = 730 + 2070 = 2800 \text{ µm.}$$

Calculated average allowance:

$$Z_{2.2_{avg}} = \frac{Z_{2.2_{max}} + Z_{2.2_{min}}}{2} \pm \frac{TZ_{2.2}}{2} = \frac{2800 + 730}{2} \pm \frac{2070}{2} = 1760 \pm 1035 \text{ µm.}$$

Allowance $Z_{2.4}$

Calculated minimum allowance:

$$Z_{2.4_{min}} = (100 + 300 + 330) = 730 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{2.4} = TA_{0.2} + TA_{1.2} + TA_{2.3} = 1200 + 650 + 220 = 2070 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{2.4_{max}} = Z_{2.4_{min}} + TZ_{2.4} = 730 + 2070 = 2800 \text{ µm.}$$

Calculated average allowance:

$$Z_{2.4_{avg}} = \frac{Z_{2.4_{max}} + Z_{2.4_{min}}}{2} \pm \frac{TZ_{2.4}}{2} = \frac{2800 + 730}{2} \pm \frac{2070}{2} = 1760 \pm 1035 \text{ µm.}$$

Allowance $Z_{3.2}$

Calculated minimum allowance:

$$Z_{3.2_{min}} = (100 + 300 + 330) = 730 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{3.2} = TA_{0.5} + TA_{1.2} + TA_{1.2.1} + TA_{3.2} + TA_{0.3} = 2400 + 650 + 250 + 220 + 1500$$
$$= 5020 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{3.2_{max}} = Z_{3.2_{min}} + TZ_{3.2} = 730 + 5020 = 5750 \text{ µm.}$$

Calculated average allowance:

$$Z_{3.2_{avg}} = \frac{Z_{3.2_{max}} + Z_{3.2_{min}}}{2} \pm \frac{TZ_{3.2}}{2} = \frac{5750 + 730}{2} \pm \frac{5020}{2} = 3240 \pm 2510 \text{ µm.}$$

Allowance $Z_{3.4}$

Calculated minimum allowance:

$$Z_{3.4_{min}} = (100 + 300 + 330) = 730 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{3.4} = TA_{0.5} + TA_{1.2} + TA_{1.2.1} + TA_{3.2} + TA_{3.4} + TA_{0.4}$$
$$= 2400 + 650 + 250 + 220 + 200 + 1200 = 4920 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{3.4_{max}} = Z_{3.4_{min}} + TZ_{3.4} = 730 + 4920 = 5650 \text{ µm.}$$

Calculated average allowance:

$$Z_{3.4_{avg}} = \frac{Z_{3.4_{max}} + Z_{3.4_{min}}}{2} \pm \frac{TZ_{3.4}}{2} = \frac{5650 + 730}{2} \pm \frac{4920}{2} = 3190 \pm 2460 \text{ µm.}$$

Allowance $Z_{6.1}$

Calculated minimum allowance:

$$Z_{6.1_{min}} = (100 + 50 + 20) = 170 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{6.1} = TA_{6.1} = 120 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{6.1_{max}} = Z_{6.1_{min}} + TZ_{6.1} = 170 + 120 = 290 \text{ µm.}$$

Calculated average allowance:

$$Z_{6.1_{avg}} = \frac{Z_{6.1_{max}} + Z_{6.1_{min}}}{2} \pm \frac{TZ_{6.1}}{2} = \frac{290 + 170}{2} \pm \frac{120}{2} = 230 \pm 60 \text{ µm.}$$

Allowance $Z_{6.2}$

Calculated minimum allowance:

$$Z_{6.2_{min}} = (100 + 50 + 20) = 170 \text{ µm.}$$

The sum of the tolerances of the components in the chain:

$$TZ_{6.2} = TA_{6.2} = 120 \text{ µm.}$$

Calculated maximum allowance:

$$Z_{6.2_{max}} = Z_{6.2_{min}} + TZ_{6.2} = 170 + 120 = 290 \text{ µm.}$$

Calculated average allowance:

$$Z_{6.2_{avg}} = \frac{Z_{6.2_{max}} + Z_{6.2_{min}}}{2} \pm \frac{TZ_{6.2}}{2} = \frac{290 + 170}{2} \pm \frac{120}{2} = 230 \pm 60 \text{ µm.}$$

Allowance $Z_{6.3}$

Calculated minimum allowance:

$$Z_{6.3_{min}} = (100 + 50 + 20) = 170 \text{ µm}.$$

The sum of the tolerances of the components in the chain:

$$TZ_{6.3} = TA_{6.3} = 120 \text{ µm}.$$

Calculated maximum allowance:

$$Z_{6.3_{max}} = Z_{6.3_{min}} + TZ_{6.3} = 170 + 120 = 290 \text{ µm}.$$

Calculated average allowance:

$$Z_{6.3_{avg}} = \frac{Z_{6.3_{max}} + Z_{6.3_{min}}}{2} \pm \frac{TZ_{6.3}}{2} = \frac{290 + 170}{2} \pm \frac{120}{2} = 230 \pm 60 \text{ µm}.$$

Table 1.4. Allowances for axial technological sizes

Calculated allowance	Elements of allowance			Calculated minimum allowance, µm	Sum of tolerances in the chain, µm	Calculated maximum allowance, µm	Calculated average allowance, µm
	Rz_{i-1}	h_{i-1}	ρ_{i-1}				
$Z_{1.2}$	100	300	330	730	650	1380	1055±325
$Z_{1.1}$	100	300	330	730	3300	4030	2380±1650
$Z_{2.2}$	100	300	330	730	2070	2800	1760±1035
$Z_{2.4}$	100	300	330	730	2070	2800	1760±1035
$Z_{3.2}$	100	300	330	730	5020	5750	3240±2510
$Z_{3.4}$	100	300	330	730	4920	5650	3190±2460
$Z_{6.1}$	100	50	20	170	120	290	230±60
$Z_{6.2}$	100	50	20	170	120	290	230±60
$Z_{6.3}$	100	50	20	170	120	290	230±60

1.6.5 Calculation of manufacturing sizes for diametrical dimensions

The calculation of manufacturing dimensions is determined from the tolerance analysis of the manufacturing process, for which we make dimensional chains.

Consider dimensional chains for machining the outer surface $\varnothing\, 50n6\left(^{+0.033}_{-0.017}\right)$ (Fig. 22).

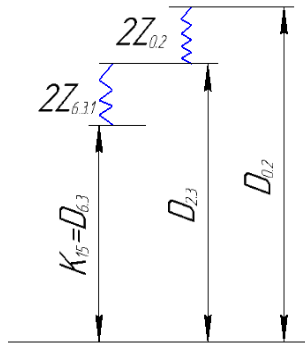


Fig. 22. Dimensional chain for calculation of manufacturing dimensions $D_{2.3}$ and $D_{0.2}$

The manufacturing size of $D_{6.3}$ must be equal to the design size K_{15}, i.e.: $D_{6.3}$ = = K_{15} = $\varnothing\, 50n6\left(^{+0.033}_{-0.017}\right)$ mm - the considered manufacturing size, which is obtained after grinding the outer surface (IT6).

1. We find the manufacturing size $D_{2.3}$:

$D_{6.3_{avg}} = 49.984 \pm 0.008\, mm.$

$D_{2.3_{avg}} = D_{6.3_{avg}} + 2 \cdot Z_{6.3.1_{avg}} = (49.984 \pm 0.008) + (0.285 \pm 0.245) =$ $50.269 \pm 0.15\, mm,$ since $TD_{2.3} = 0.3\, mm,$

We get $D_{2.3_{avg}} = 50.269 \pm 0.15\, mm.$

2. We find the manufacturing size $D_{0.2}$:

$D_{2.3_{avg}} = 50.269 \pm 0.15\, mm.$

$D_{0.2_{avg}} = D_{2.3_{avg}} + 2 \cdot Z_{0.2_{avg}} = (50.269 \pm 0.15) + (1.4 \pm 0.4) = 51.739 \pm$ $0.4\, mm,$ since $TD_{0.2} = 0.8\, mm,$

We round out the nominal size to within a tenth of a millimeter:

We get $D_{0.2_{avg}} = 51.8 \pm 0.4\, mm.$

Consider dimensional chains for machining the outer surface Ø60h14 $_{(-0.74)}$ (Fig. 23).

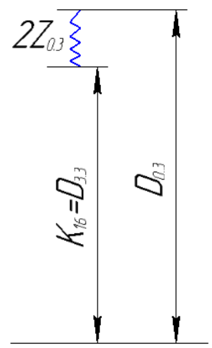


Fig. 23. Dimensional chain for the calculation of manufacturing dimensions $D_{0.3}$

The manufacturing size of $D_{3.3}$ must be equal to the design size K_{16}, i.e.: $D_{3.3}$ = K_{16} = Ø60h14 $_{(-0.74)}$ mm - the considered manufacturing size.

1. We find the manufacturing size $D_{0.3}$:

$D_{3.3_{avg}} = 59.63 \pm 0.37\ mm.$

$D_{0.3_{avg}} = D_{3.3_{avg}} + 2 \cdot Z_{0.3_{avg}} = (59.63 \pm 0.37) + (1.69 \pm 0.77) = 61.32 \pm 0.4\ mm.$

Since$TD_{0.3} = 0.8(^{+0.5}_{-0.3})\ mm$, then $D_{0.3_{cal}} = 61.32(^{+0.5}_{-0.3})\ mm.$

We round out the nominal size to within a tenth of a millimeter:

$$D_{0.3_{cal}} = 61.3(^{+0.5}_{-0.3})\ mm.$$

Consider dimensional chains for machining the outer surface Ø $50\text{n}6(^{+0.033}_{-0.017})$ (Fig. 24).

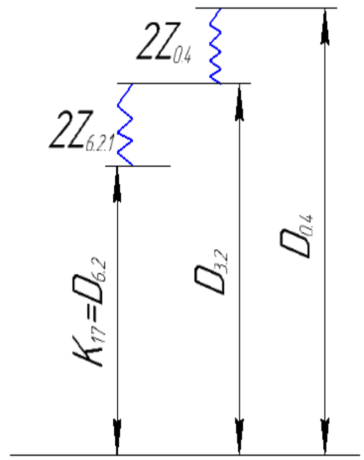


Fig. 24. Dimensional chain for the calculation of manufacturing dimensions $D_{3.2}$ and $D_{0.4}$:

The manufacturing size of $D_{6.3}$ must be equal to the design size K_{17}, i.e.: $D_{6.2}$ = K_{17} = Ø $50n6(^{+0.033}_{-0.017})$ mm - the considered manufacturing size, which is obtained after grinding the outer surface (IT grade 6).

1. We find the manufacturing size $D_{3.2}$:

$D_{6.2_{avg}} = 49.984 \pm 0.008\, mm.$

$D_{3.2_{avg}} = D_{6.2_{avg}} + 2 \cdot Z_{6.2.1_{avg}} = (49.984 \pm 0.008) + (0.285 \pm 0.245) = 50.269 \pm 0.15\, mm$,since$TD_{2.3} = 0.3\, mm$,

We get$D_{3.2_{avg}} = 50.269 \pm 0.15\, mm.$

2. We find the manufacturing size $D_{0.4}$:

$D_{3.2_{avg}} = 50.269 \pm 0.15\, mm.$

$D_{0.4_{avg}} = D_{3.2_{avg}} + 2 \cdot Z_{0.4_{avg}} = (50.269 \pm 0.15) + (1.47 \pm 0.4) = 51.739 \pm 0.4\, mm$, since $TD_{0.4} = 0.8\, mm$,

We round out the nominal size to within a tenth of a millimeter:

We get$D_{0.4_{avg}} = 51.8 \pm 0.4\, mm.$

Consider dimensional chains for machining the outer surface Ø $40g6(^{-0.009}_{-0.025})$ (Figure 25).

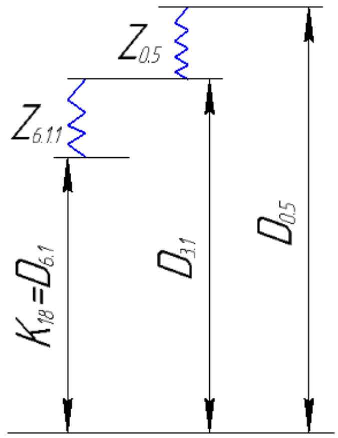


Fig.25. Dimensional chain for the calculation of manufacturing dimensions $D_{3.1}$: and $D_{0.5}$

The manufacturing size of $D_{6.3}$ must be equal to the design size K_{18}, i.e.: $D_{6.1}$ = = K_{18} = Ø $40g6(^{-0.009}_{-0.025})$mm - the considered manufacturing size, which is obtained after grinding the outer surface (IT grade 6).

1. We find the manufacturing size $D_{3.1}$:

$D_{6.1_{avg}} = 39.984 \pm 0.008\, mm.$

$D_{3.1_{avg}} = D_{6.1_{avg}} + 2 \cdot Z_{6.1.1_{avg}} = (39.984 \pm 0.008) + (0.245 \pm 0.205) =$ $40.229 \pm 0.125\, mm$,since$TD_{3.1} = 0.25\, mm$,

We get$D_{3.1_{avg}} = 40.229 \pm 0.125\, mm.$

2. We find the manufacturing size $D_{0.5}$:

$D_{3.1_{avg}} = 40.229 \pm 0.125\, mm.$

$D_{0.5_{avg}} = D_{3.1_{avg}} + 2 \cdot Z_{0.5_{avg}} = (40.229 \pm 0.125) + (1.445 \pm 0.4) =$ $41.674 \pm 0.4\, mm$,since$TD_{0.5} = 0.8\, mm$,

We round out the nominal size to within a tenth of a millimeter:

We get$D_{0.5_{avg}} = 41.7 \pm 0.4\ mm$.

Table 1.5. Calculated diametrical manufacturing sizes

Manufacturing size	Calculated (avg.) size, mm
$D_{0.2}$	51.8 ± 0.4
$D_{0.3}$	61.32 ± 0.4
$D_{0.4}$	51.8 ± 0.4
$D_{0.5}$	41.7 ± 0.4
$D_{2.3}$	50.269 ± 0.15
$D_{3.1}$	40.229 ± 0.125
$D_{3.2}$	50.269 ± 0.15
$D_{3.3}$	59.63 ± 0.37
$D_{6.1}$	39.984 ± 0.008
$D_{6.2}$	49.984 ± 0.008
$D_{6.3}$	49.984 ± 0.008

1.6.6 Calculation of manufacturing sizes for axial dimensions

Consider dimensional chain for manufacturingsize$A_{1.2.1}$ (Fig. 26).

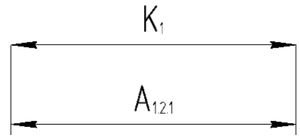


Fig. 26. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{1.2.1}$is equal to the design K_1, i.e.:

$A_{1.2.1} = K_1 = 214(_{-1.14})$ mm.

1. We find the manufacturing size $A_{1.2.1}$:

$$K_{1_{avg}} = 213.425 \pm 0.575 \text{ mm.}$$

$$A_{1.2.1_{avg}} = 213.425 \pm 0.125 \text{ mm; } TA_{1.2.1}=0.25 \text{ mm.}$$

Consider dimensional chain for manufacturing size$A_{2.5}$ (figure 27).

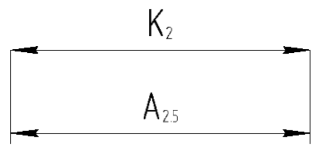


Fig. 27. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{2.5}$is equal to the design K_2, i.e.:$A_{2.5} = K_2$ =2x 45° mm.

1. We find the manufacturing size $A_{2.5}$:

$$K_2 = 2\text{x } 45°\text{mm.}$$

$$A_{2.5_{avg}} = 2 \pm 0.25 \text{ mm; } \quad TA_{2.5}=0.50 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{2.2}$ (Fig. 28).

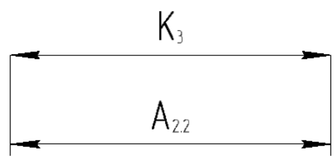


Fig. 28. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{2.2}$is equal to the design K_3, i.e.:$A_{2.2} = K_3 = 45 \pm 0.31$ mm.

1. We find the manufacturing size $A_{2.5}$:

$$K_{3_{avg}} = 45 \pm 0.31 \text{ mm.}$$

$$A_{2.2_{avg}} = 45 \pm 0.11 \text{ mm}; \quad TA_{2.5} = 0.22 \text{ mm}$$

Consider dimensional chain for manufacturing size $A_{2.2}$ (Fig. 29).

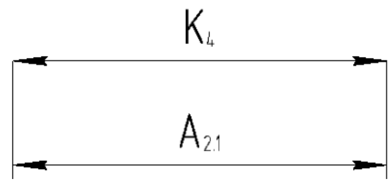


Fig. 29. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{2.1}$ should be equal to the design K_4, i.e.:

$A_{2.1} = K_4 = 5 \pm 0.15$ mm.

1. We find the manufacturing size $A_{2.1}$:

$$K_{4_{avg}} = 4.85 \pm 0.15 \text{ mm.}$$

$$A_{2.1_{avg}} = 4.85 \pm 0.05 \text{ mm}; \ TA_{2.1} = 0.1 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{6.3}$ (figure 30).

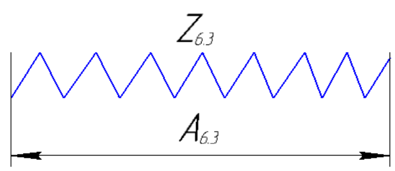


Fig. 30. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{6.3}$ is equal to the allowance $Z_{6.3}$, i.e.:

$A_{6.3} = Z_{6.3} = 0.23 \pm 0.06$ mm.

$$Z_{6.3_{avg}} = 0.23 \pm 0.06 \text{ mm.}$$

$$A_{6.3_{avg}} = 0.23 \pm 0.06 \text{ mm}; \quad TA_{6.3} = 0.12 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{2.3}$ (figure 31).

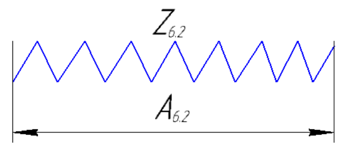


Fig. 31. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{6.2}$ is equal to the allowance $Z_{6.2}$, i.e.:

$A_{6.2}= Z_{6.2} =0.23 \pm 0.06$ mm.

$$Z_{6.2_{avg}} = 0.23 \pm 0.06 \text{ mm.}$$

$$\mathrm{A}_{6.2_{\mathrm{avg}}} = 0.23 \pm 0.06 \text{ mm}; \quad TA_{6.2}=0.12 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{6.1}$ (Fig. 32).

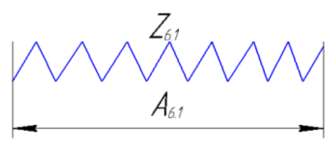


Fig. 32. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{6.1}$ is equal to the allowance $Z_{6.1}$, i.e.:

$A_{6.1}= Z_{6.1} =0.23 \pm 0.06$ mm.

$$Z_{6.1_{avg}} = 0.23 \pm 0.06 \text{ mm.}$$

$$\mathrm{A}_{6.1_{\mathrm{avg}}} = 0.23 \pm 0.06 \text{ mm}; \quad TA_{6.1}=0.12 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{2.3}$ (Fig. 33).

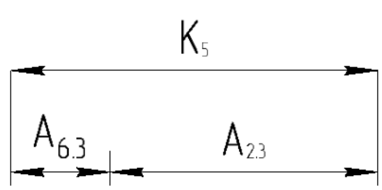


Fig. 33. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{2.3}$:

$$K_{5_{avg}} = 112 \pm 0.435; \quad \mathrm{A}_{6.3_{\mathrm{avg}}} = 0.23 \pm 0.06\, mm.$$

$$A_{2.3_{avg}} = K_{5_{avg}} - A_{6.3_{avg}} = (112 \pm 0.435) - (0.23 \pm 0.06) = 111.77mm.$$

$$A_{2.3_{avg}} = 111.77 \pm 0.11 \text{ mm}; \quad TA_{2.3}=0.22 \text{ mm}.$$

Consider dimensional chain for manufacturing size $A_{1.2}$ (Fig. 34).

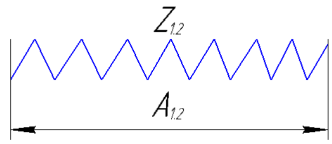


Fig. 34. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{1.2}$ is equal to the allowance $Z_{1.2}$, i.e.:

$A_{1.2}= Z_{1.2} =1.055 \pm 0.325$ mm.

$$Z_{1.2_{avg}} = 1.055 \pm 0.325 \text{ mm}.$$

$$A_{1.2_{avg}} = 1.06 \pm 0.325 \text{ mm}; \quad TA_{1.2}=0.65 \text{ mm}.$$

Consider dimensional chain for manufacturing size $A_{0.5}$ (Fig. 35).

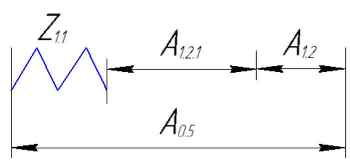


Fig. 35. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{0.5}$:

$$Z_{1.1_{avg}} = 2.38 \pm 1.65; \; A_{1.2.1_{avg}} = 213.425 \pm 0.125 \,; A_{1.2_{avg}} = 1.06 \pm 0.325 \text{ mm}.$$

$$A_{0.5_{avg}} = Z_{1.1_{avg}} + A_{1.2.1_{avg}} + A_{1.2_{avg}}$$
$$= (2.38 \pm 1.65) + (213.425 \pm 0.125\,) + (1.06 \pm 0.325) = 216.985mm.$$

$$A_{0.5_{avg}} = 217 \pm 1.2 \text{ mm}; \quad TA_{0.5}=2.4 \text{ mm}.$$

Consider dimensional chain for manufacturing size $A_{2.6}$ (Fig. 36).

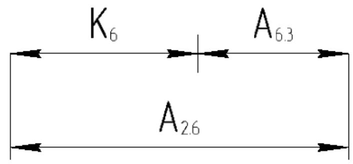


Fig. 36. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{2.6}$:

$K_{6_{avg}} = 1.5 \pm 0.25; \quad \mathrm{A}_{6.3_{\mathrm{avg}}} = 0.23 \pm 0.06\, mm.$

$\mathrm{A}_{2.6_{\mathrm{avg}}} = \mathrm{K}_{6_{\mathrm{avg}}} + \mathrm{A}_{6.3_{\mathrm{avg}}} = (1.5 \pm 0.25) + (0.23 \pm 0.06) = 1.73 \pm 0.1\mathrm{mm}.$

$\mathrm{A}_{2.6_{\mathrm{avg}}} = 1.73 \pm 0.1$ mm; $TA_{2.6}$=0.2 mm.

Consider dimensional chain for manufacturing size $A_{3.5}$ (Fig. 37).

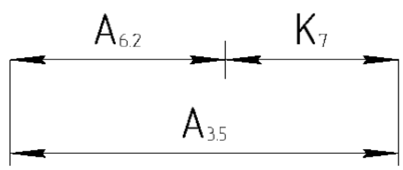


Fig. 37. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{3.5}$:

$K_{7_{avg}} = 1.5 \pm 0.25; \quad \mathrm{A}_{6.2_{\mathrm{avg}}} = 0.23 \pm 0.06\, mm.$

$\mathrm{A}_{3.5_{\mathrm{avg}}} = \mathrm{K}_{7_{\mathrm{avg}}} + \mathrm{A}_{6.2_{\mathrm{avg}}} = (1.5 \pm 0.25) + (0.23 \pm 0.06) = 1.73 \pm 0.1\mathrm{mm}.$

$\mathrm{A}_{3.5_{\mathrm{avg}}} = 1.73 \pm 0.1$ mm; $TA_{3.5}$=0.2 mm.

$K_{7\ avg} = A_{3.5\ avg} – A_{6.2\ avg}; \rightarrow A_{3.5\ avg} = K_{7\ avg} + A_{6.2\ avg} = 1.5 + 0.23 = 1.73$ mm.

$U_{K\ 7}=U_{A3.5} - L_{A\ 6.2}; \rightarrow\ +0.25=U_{A\ 3.5} - (-0.06); \rightarrow UA_{3.5}=0.25 - 0.06 = +0.09$ mm;

$L_{K\ 7}=L_{A3.5} - U_{A\ 6.2}; \rightarrow\ -0.25 = L_{A\ 3.5} - (+0.06); \rightarrow LA_{3.5}=-0.25 + 0.06 = -0.09$ mm;

$A_{3.5\ avg} = 1.73 \pm 0.09$ mm; $TA_{3.5}$=0.18 mm ≈ 0.2 mm. → $A_{3.5\ avg} \approx \mathbf{1.7} \pm 0.1$ mm;

More right and accurate: $A_{3.5\ avg} = 1.73 \pm 0.09 = \mathbf{1.7}^{+0.12}_{-0.06}$ mm.

We accept: $A_{3.5} = 1.73 \pm 0.1$ mm.

Consider dimensional chain for manufacturing size $A_{3.4}$ (Fig. 38).

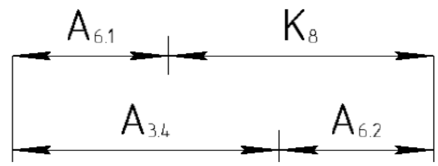


Fig. 38. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{3.4}$:

$K_{8_{avg}} = 27 \pm 0.26;\ \mathrm{A}_{6.1_{\mathrm{avg}}} = 0.23 \pm 0.06;\ \mathrm{A}_{6.2_{\mathrm{avg}}} = 0.23 \pm 0.06\ mm.$

$$\mathrm{A}_{3.4_{\mathrm{avg}}} = \mathrm{K}_{8_{\mathrm{avg}}} + \mathrm{A}_{6.1_{\mathrm{avg}}} - \mathrm{A}_{6.2_{\mathrm{avg}}} = (27 \pm 0.26) + (0.23 \pm 0.06) - (0.23 \pm 0.06) = 1.73 \pm 0.1\mathrm{mm}.$$

$\mathrm{A}_{3.4_{\mathrm{avg}}} = 27 \pm 0.1$ mm; $TA_{3.4}$=0.2 mm.

Consider dimensional chain for manufacturing size $A_{3.2}$ (Fig. 39).

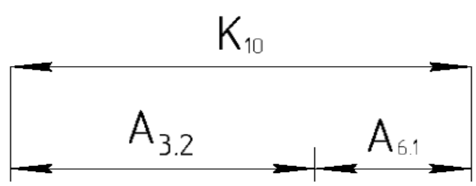


Fig. 39. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{3.2}$:

$K_{10_{avg}} = 35 \pm 0.31;\quad \mathrm{A}_{6.1_{\mathrm{avg}}} = 0.23 \pm 0.06\ mm.$

$$\mathrm{A}_{3.2_{\mathrm{avg}}} = \mathrm{K}_{10_{\mathrm{avg}}} - \mathrm{A}_{6.1_{\mathrm{avg}}} = (35 \pm 0.31) - (0.23 \pm 0.06) = 34.77 \pm 0.11\mathrm{mm}.$$

$\mathrm{A}_{3.2_{\mathrm{avg}}} = 34.77 \pm 0.11$ mm; $TA_{3.2}$=0.22 mm.

Consider dimensional chain for manufacturing size $A'_{6.1}$(figure 40).

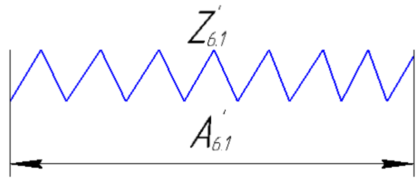


Fig. 40. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A'_{6.1}$ is equal to the allowance $Z'_{6.1}$, i.e.: $A'_{6.1} = Z'_{6.1} = 0.245 \pm 0.20$ mm.

$$Z'_{6.1_{avg}} = 0.245 \pm 0.20 \text{ mm.}$$

$$\mathrm{A'}_{6.1_{\mathrm{avg}}} = 0.245 \pm 0.008 \text{ mm;} \quad TA'_{6.1}=0.016 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{0.1}$ (Fig. 41).

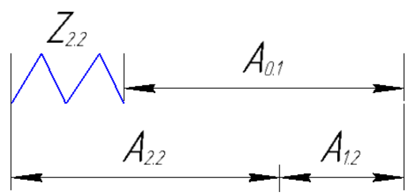


Fig. 41. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{0.1}$:

$Z_{2.2_{avg}} = 1.76 \pm 1.03$; $\mathrm{A}_{2.2_{\mathrm{avg}}} = 45 \pm 0.11$; $\mathrm{A}_{1.2_{\mathrm{avg}}} = 1.06 \pm 0.325$ mm.

$$\mathrm{A}_{0.1_{\mathrm{avg}}} = \mathrm{A}_{2.2_{\mathrm{avg}}} + \mathrm{A}_{1.2_{\mathrm{avg}}} - Z_{2.2_{avg}} = (45 \pm 0.11) + (1.06 \pm 0.325) - (1.76 \pm 1.03) = 44.29 \text{mm.}$$

$$\mathrm{A}_{0.1_{\mathrm{avg}}} = 44.29 \pm 0.6 \text{ mm; } TA_{0.1}=1.2 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{0.2}$ (Fig. 42).

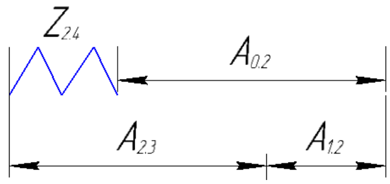


Fig. 42. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{0.2}$:

$Z_{2.3_{avg}} = 1.76 \pm 1.03$; $\mathrm{A}_{2.3_{\mathrm{avg}}} = 111.77 \pm 0.11$; $\mathrm{A}_{1.2_{\mathrm{avg}}} = 1.06 \pm 0.325$ mm.

$$\mathrm{A}_{0.2_{\mathrm{avg}}} = \mathrm{A}_{2.3_{\mathrm{avg}}} - Z_{2.4_{avg}} + \mathrm{A}_{1.2_{\mathrm{avg}}}$$

$$= (111.77 \pm 0.11) - (1.76 \pm 1.03) + (1.06 \pm 0.325) = 111.075\text{mm}.$$

$$\mathrm{A}_{0.2_{\mathrm{avg}}} = 111.1 \pm 0.6 \text{ mm}; \quad TA_{0.2}=1.2 \text{ mm}.$$

Consider dimensional chain for manufacturing size $A_{4.2}$ (Fig. 43).

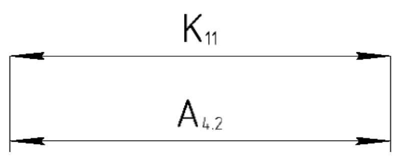


Fig. 43. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{4.2}$ should be equal to the design K_{11}, i.e.:

$A_{4.2} = K_{11} = 25.26 \pm 0.26$ mm.

1. We find the manufacturing size $A_{2.1}$:

$$K_{11_{avg}} = 25.26 \pm 0.26 \text{ mm}.$$

$$\mathrm{A}_{4.2_{\mathrm{avg}}} = 25.26 \pm 0.1 \text{ mm}; \quad TA_{4.2}=0.2 \text{ mm}.$$

Consider dimensional chain for manufacturing size $A_{4.1}$ (Fig. 44).

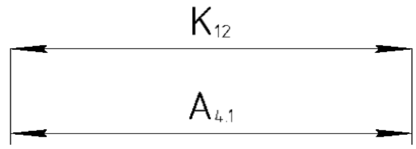


Fig. 44. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A_{4.1}$ should be equal to the design K_{11}, i.e.:$A_{4.1} = K_{12}$ $=8 \pm 0.18$ mm.

1. We find the manufacturing size $A_{2.1}$:

$$K_{12_{avg}} = 8 \pm 0.18 \text{ mm.}$$

$$\mathrm{A}_{4.1_{\mathrm{avg}}} = 8 \pm 0.11 \text{ mm}; \quad TA_{4.1}=0.22 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{3.1}$ (Fig. 45).

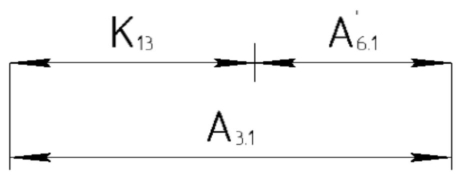


Fig. 45. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{3.1}$:

$K_{13_{avg}} = 1.5 \pm 0.25; \quad \mathrm{A'}_{6.1_{\mathrm{avg}}} = 0.245 \pm 0.20\ mm.$

$\mathrm{A}_{3.1_{\mathrm{avg}}} = \mathrm{K}_{13_{\mathrm{avg}}} + \mathrm{A'}_{6.1_{\mathrm{avg}}} = (1.5 \pm 0.25) + (0.245 \pm 0.20) = 1.745\text{mm.}$

$$\mathrm{A}_{3.2_{\mathrm{avg}}} = 1.745 \pm 0.11 \text{ mm}; \quad TA_{3.2}=0.22 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A'_{6.2}$ (figure 46).

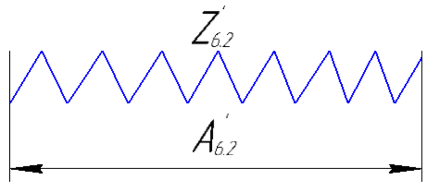


Fig. 46. Dimensional chain for the calculation of manufacturing dimension

The manufacturing size of $A'_{6.2}$is equal to the allowance $Z'_{6.2}$, i.e.:

$A'_{6.2} = Z'_{6.2} = 0.285 \pm 0.24$ mm.

$$Z'_{6.2_{avg}} = 0.285 \pm 0.24 \text{ mm.}$$

$$A'_{6.2_{avg}} = 0.285 \pm 0.008 \text{ mm}; \quad TA'_{6.1}=0.016 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{3.3}$ (Fig. 47).

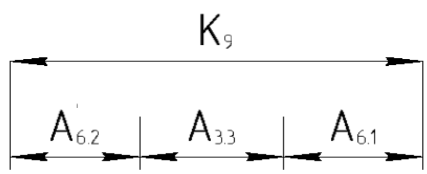


Fig. 47. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{3.3}$:

$$K_{9_{avg}} = 1.5 \pm 0.25; \quad A'_{6.2_{avg}} = 0.285 \pm 0.24; A_{6.1_{avg}} = 0.23 \pm 0.06 \, mm.$$

$$A_{3.3_{avg}} = K_{9_{avg}} - A'_{6.2_{avg}} - A_{6.1_{avg}} = (1.5 \pm 0.25) - (0.285 \pm 0.24) - (0.23 \pm 0.06)$$
$$= 0.985 \pm 0.05 \text{ mm;}$$

$$A_{3.3_{avg}} = 0.985 \pm 0.05 \text{ mm}; \quad TA_{3.3}=0.1 \text{ mm}$$

$K_9 = A_{3.3} + A_{6.1} + A_{6.2}$;

$+0.25 = U_{A\,3.3} +(+0.06) + (+0.24); \quad \rightarrow \; U_{A\,3.3} = +0.25 -0.06 - 0.24 = -0.05$ mm;

$-0.25 = L_{A\,3.3} + (-0.06) + (-0.24); \quad \rightarrow \; L_{A\,3.3} = -0.25 + 0.06 + 0.24 = +0.05$ mm.

$A_{3.3} = 0.985 \pm 0.05 \approx 0.99 \pm 0.05 \approx 1 \pm 0.05$ mm; $T_{A\,3.3} = 0.1$ mm.

Consider dimensional chain for manufacturing size $A_{0.3}$ (Fig. 48).

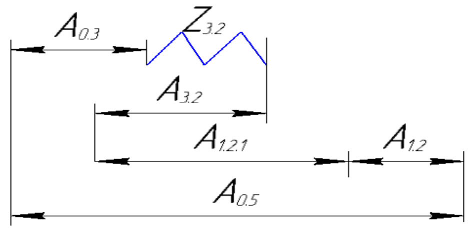


Fig.48. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{0.3}$:

$$Z_{3.2_{avg}} = 3.24 \pm 2.5;\ \mathrm{A}_{1.2.1_{\mathrm{avg}}} = 213.425 \pm 0.125\ ; \mathrm{A}_{1.2_{\mathrm{avg}}} = 1.06 \pm 0.325; \mathrm{A}_{3.2_{\mathrm{avg}}} = 34.77 \pm 0.11; \mathrm{A}_{0.5_{\mathrm{avg}}} = 217 \pm 1.2\ \text{ mm.}$$

$$\mathrm{A}_{0.3_{\mathrm{avg}}} = \mathrm{A}_{0.5_{\mathrm{avg}}} + \mathrm{A}_{3.2_{\mathrm{avg}}} - Z_{3.2_{avg}} - \mathrm{A}_{1.2.1_{\mathrm{avg}}} - \mathrm{A}_{1.2_{\mathrm{avg}}} = (217 \pm 1.2) + (34.77 \pm 0.11) - (3.24 \pm 2.5) - (213.425 \pm 0.125\ ) - (1.06 \pm 0.325) = 34.045\text{mm.}$$

$$\mathrm{A}_{0.3_{\mathrm{avg}}} = 34.1 \pm 0.75 \text{ mm};\quad TA_{0.3}=1.5 \text{ mm.}$$

Consider dimensional chain for manufacturing size $A_{0.4}$ (Fig. 49).

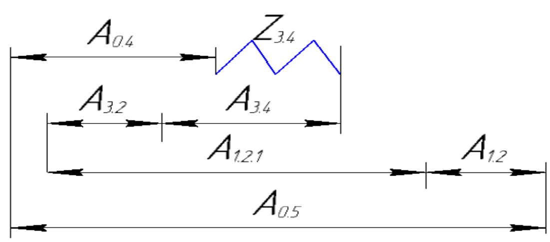


Fig.49. Dimensional chain for the calculation of manufacturing dimension

1. We find the manufacturing size $A_{0.4}$:

$$Z_{3.4_{avg}} = 3.19 \pm 2.46;\ \mathrm{A}_{1.2.1_{\mathrm{avg}}} = 213.425 \pm 0.125\ ; \mathrm{A}_{1.2_{\mathrm{avg}}} = 1.06 \pm 0.325;\ \mathrm{A}_{3.2_{\mathrm{avg}}} = 34.77 \pm 0.11;\ \mathrm{A}_{3.4_{\mathrm{avg}}} = 27 \pm 0.1;\ \mathrm{A}_{0.5_{\mathrm{avg}}} = 217 \pm 1.2\ \text{ mm.}$$

$$A_{0.4_{avg}} = A_{0.5_{avg}} + A_{3.2_{avg}} + A_{3.4_{avg}} - Z_{3.4_{avg}} - A_{1.2.1_{avg}} - A_{1.2_{avg}}$$
$$= (217 \pm 1.2) + (34.77 \pm 0.11) + (27 \pm 0.1) - (3.19 \pm 2.46)$$
$$- (213.425 \pm 0.125) - (1.06 \pm 0.325) = 34.045\text{mm}.$$

$$A_{0.4_{avg}} = 61.1 \pm 0.6 \text{ mm}; \quad TA_{0.4}=1.2 \text{ mm}.$$

1.7 Calculation of cutting parameters

When assigning elements of cutting parameters, take into account the nature of machining, the type, dimensions and material of the tool, material and surface condition of the workpiece, the type and condition of the equipment.

Cutting parameters are usually set in the order indicated below:

1. depth of cut (*t*);
2. feed (*s*);
3. cutting speed (*v*).

The following are calculated:

1. the number of revolutions (*n*);
2. actual cutting speed;
3. the main component of the cutting force (P_z);
4. cutting power (N_e);

1.7.1 Face milling on both face ends

The material of the cutting tool is selected in accordance with the recommendations [3, p. 116] - T15K6.

1. The cutting depth for roughing is equal to the maximum machining allowance: $t = z_{1.2max.} = 4$ mm.

2. The feed *s* is assigned according to table 11 [3, p.266]. For a given cutting depth: s_z= 0.1 mm / rev.

3. The cutting speed is determined by the formula:

$$V = \frac{C_V . D^q}{T^m \cdot t^x \cdot s_z^y \cdot B^u \cdot z^p} \cdot K_V$$

The tool life is: T= 60 min.

Values of the coefficients: C_V = 332; m = 0.2; x = 0.1; y = 0.4; q=0.2; u=0.2; p=0– are taken from table17 [3, p.269].

Coefficient K_V:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV},$$

where K_{MV} –coefficient that takes into account the quality of the machined material;

$K_{ПV}$ –coefficient reflecting the state of the surface of the workpiece;

$K_{ИV}$ –coefficient that takes into account the quality of the tool material.

According to Table. 1, 5, 6 [3, p.261]:

$$K_{MV} = K_{Г}\left(\frac{750}{\sigma_B}\right)^{n_v},$$

The value of the coefficient of $K_Г$ and the exponent n_v for the material of the tool from the hard alloy when processing the workpiece is taken from Table 2 [3, p.262]:

$$K_Г = 1.0 \quad n_V = 1.0$$

Then:

$$K_{MV} = K_Г\left(\frac{750}{\sigma_B}\right)^{n_v} = 1.0 \cdot \left(\frac{750}{980}\right)^{1.0} = 0.76$$

Hence, K_{MV}= 0.76; $K_{ПV}$ = 0.8; $K_{ИV}$ =1.0.

Finally, the coefficient K_V is defined as:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV} = 0.76 \cdot 0.8 \cdot 1.0 = 0.61$$

The cutting speed is determined for t = $z_{1.2max.}$ = 4 mm.

$$\mathrm{V} = \frac{\mathrm{C_V} . \mathrm{D^q}}{\mathrm{T^m} \cdot \mathrm{t^x} \cdot \mathrm{s_z^y} \cdot \mathrm{B^u} \cdot \mathrm{z^p}} \cdot \mathrm{K_V} = \frac{332 \cdot 100^{0.2}}{60^{0.2} \cdot 4^{0.1} \cdot 0.1^{0.4} \cdot 40^{0.2} \cdot 10^{0}} \cdot 0.61 = 235.5 \ \frac{\mathrm{m}}{\mathrm{min}}$$

4. Calculated speed of spindle:

$$\mathrm{n} = \frac{1000 \cdot \mathrm{V}}{\pi \cdot \mathrm{d}} = \frac{1000 \cdot 235.5}{3.14 \cdot 100} = 764.3 \text{ rpm.}$$

We take the actual number of revolutions, taking into account the type of machine, the type of machining and the machining tool material:

$$\mathrm{n} = 630 \text{ rpm.}$$

5. Actual cutting speed:

$$\mathrm{V} = \frac{\pi \cdot \mathrm{d} \cdot \mathrm{n}}{1000} = \frac{3.14 \cdot 100 \cdot 630}{1000} = 197 \ \frac{\mathrm{m}}{\mathrm{min}}.$$

6. Determine the main component of the cutting force by the formula:

$$\mathrm{P_z} = \frac{10 \cdot \mathrm{C_P} \cdot \mathrm{t^x} \cdot \mathrm{S^y} \cdot \mathrm{B^u} \cdot \mathrm{z}}{\mathrm{D^q} \cdot \mathrm{n^w}} \cdot \mathrm{K_{MP}}$$

Values of the coefficients: C_P = 825; n = 630; x = 1.0; y = 0.75; u=1.1; q=1.3; w=0.2; t=4 mm – are taken from table 22 [3, p.273].

Coefficient $\mathrm{K_P} = \mathrm{K_{MP}}$

The coefficients in the formula take into account the actual conditions of cutting. According to tables 9, 23 [3, p.264]:

$$\mathrm{K_{мр}} = \left(\frac{\sigma_B}{750}\right)^{n} = \left(\frac{980}{750}\right)^{0.3} = 1.08 .$$

The main component of the cutting force, formula

$$P_z = \frac{10 \cdot C_P \cdot t^x \cdot S^y \cdot B^u \cdot z}{D^q \cdot n^w} \cdot K_{MP} = \frac{10 \cdot 825 \cdot 4^{1.0} \cdot 0.1^{0.75} \cdot 40^{1.1} \cdot 10}{100^{1.3} \cdot 630^{0.2}} \cdot 1.08 = 2440.5 \text{ N}$$

7. Cutting power:

$$N = \frac{P_z \cdot V}{1020 \cdot 60} = \frac{2440.5 \cdot 197}{1020 \cdot 60} = 7.2 \text{ kW}.$$

1.7.2 Turning of contour in operation 2

The material of the cutting tool is selected in accordance with the recommendations [3, p. 116] - T15K6.

1. The cutting depth for roughing is equal to the maximum machining allowance: $2z_{0.1max.}$ = 2.5 mm i.e., *t* = 1.25mm.

2. The feed *s* is assigned according to table 11 [3, p.266]. For a given cutting depth: *s* = 0.5 mm / rev.

3. The cutting speed is determined by the formula:

$$V = \frac{C_V}{T^m \cdot t^x \cdot S^y} \cdot K_V$$

The tool life is: *T*= 30 min.

Values of the coefficients: C_V = 290; m = 0.2; x = -0.15; y = 0.35– are taken from table17 [3, p.269].

Coefficient K_V:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV},$$

where K_{MV} –coefficient that takes into account the quality of the machined material;

$K_{ПV}$ –coefficient reflecting the state of the surface of the workpiece;

$K_{ИV}$ –coefficient that takes into account the quality of the tool material.

According to Table. 1, 5, 6 [3, p.261]:

$$К_{MV} = К_{Г}\left(\frac{750}{σ_{B}}\right)^{n_v},$$

The value of the coefficient of $К_{Г}$ and the exponent n_v for the material of the tool from the hard alloy when processing the workpiece is taken from Table 2 [3, p. 262]:

$$К_{Г} = 1.0 \quad n_V = 1.0$$

Then:

$$К_{MV} = К_{Г}\left(\frac{750}{σ_{B}}\right)^{n_v} = 1.0 \cdot \left(\frac{750}{980}\right)^{1.0} = 0.76$$

Hence, $К_{MV}$= 0.76; $К_{ПV}$ = 0.8; $К_{ИV}$ =1.0.

Finally, the coefficient $К_{V}$ is defined as:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV} = 0.76 \cdot 0.8 \cdot 1.0 = 0.61$$

The cutting speed is determined for t = 1.25 mm.

$$V = \frac{C_V}{T^m \cdot t^x \cdot S^y} \cdot К_V = \frac{290}{30^{0.2} \cdot 1.25^{0,15} \cdot 0.5^{0.35}} \cdot 0.61 = 110.5 \ \frac{m}{min}$$

4. Calculated speed of spindle:

$$n = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 110.5}{3.14 \cdot 50} = 703.5 \text{ rpm.}$$

We take the actual number of revolutions, taking into account the type of machine, the type of machining and the machining tool material:

$$n = 630 \text{ rpm.}$$

5. Actual cutting speed:

$$V = \frac{\pi \cdot d \cdot n}{1000} = \frac{3.14 \cdot 50 \cdot 630}{1000} = 98\ \frac{m}{min}.$$

6. Determine the main component of the cutting force by the formula:

$$P_z = 10 \cdot C_P \cdot t^x \cdot S^y \cdot V^n \cdot K_P$$

Values of the coefficients: $C_P = 300$; $n = -0.15$; $x = 1.0$; $y = 0.75$; – are taken from table 22 [3, p.273].

Coefficient $K_P = K_{MP}$

The coefficients in the formula take into account the actual conditions of cutting. According to tables 9, 23 [3, p.264]:

$$K_{mp} = \left(\frac{\sigma_B}{750}\right)^n = \left(\frac{980}{750}\right)^{0.75} = 1.22.$$

The main component of the cutting force, formula

7. $P_z = 10 \cdot C_P \cdot t^x \cdot S^y \cdot V^n \cdot K_P =$

$$= 10 \cdot 300 \cdot 1.25^1 \cdot 0.5^{0.75} \cdot 98^{(-0.15)} \cdot 1.22 = 1235.7\ N$$

8. Cutting power:

$$N = \frac{P_z \cdot V}{1020 \cdot 60} = \frac{1235.7 \cdot 98}{1020 \cdot 60} = 2\ kW.$$

1.7.3 Threading with a cutter

The material of the cutting tool is selected in accordance with the recommendations [3, p. 116] - T15K6.

1. The cutting depth for roughing is equal to the maximum machining allowance: $2z_{0.1max.} = 2.5$ mm i.e., $t = 1.25$mm.

2. The feed s is assigned according to table 11 [3, p.266]. For a given cutting depth: s =P= 3.5 mm / rev.

3. The cutting speed is determined by the formula:

$$V = \frac{C_V}{T^m \cdot t^x \cdot S^y} \cdot K_V$$

The tool life is: T= 70 min.

Values of the coefficients: C_V = 244; m = 0.2; x = 0.23; y = 0.3– are taken from table17 [3, p.269].

Coefficient K_V:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV},$$

where K_{MV} –coefficient that takes into account the quality of the machined material;

$K_{ПV}$ –coefficient reflecting the state of the surface of the workpiece;

$K_{ИV}$ –coefficient that takes into account the quality of the tool material.

According to Table. 1, 5, 6 [3, p.261]:

$$K_{MV} = K_{Г}\left(\frac{750}{\sigma_B}\right)^{n_v},$$

The value of the coefficient of $K_{Г}$ and the exponent n_v for the material of the tool from the hard alloy when processing the workpiece is taken from Table 2 [3, p.262]:

$$K_{Г} = 1.0 \quad n_V = 1.0$$

Then:

$$K_{MV} = K_{Г}\left(\frac{750}{\sigma_B}\right)^{n_v} = 1.0 \cdot \left(\frac{750}{980}\right)^{1.0} = 0.76$$

Hence, K_{MV}= 0.76; $K_{ПV}$ = 0.8; $K_{ИV}$ =1.0.

Finally, the coefficient K_V is defined as:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV} = 0.76 \cdot 0.8 \cdot 1.0 = 0.61$$

The cutting speed is determined for$t$ =P= 3.5 mm.

$$V = \frac{C_V \cdot i^x}{T^m \cdot S^y} \cdot K_V = \frac{244}{70^{0.2} \cdot 3.5^{0.3}} \cdot 0.61 = 63.3\ \frac{m}{min}$$

4. Calculated speed of spindle:

$$n = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 63.3}{3.14 \cdot 30} = 672 \text{ rpm.}$$

We take the actual number of revolutions, taking into account the type of machine, the type of machining and the machining tool material:

$$n = 630 \text{ rpm.}$$

5. Actual cutting speed:

$$V = \frac{\pi \cdot d \cdot n}{1000} = \frac{3.14 \cdot 30 \cdot 630}{1000} = 59\ \frac{m}{min}.$$

1.7.4 Slot milling

The material of the cutting tool (end milling cutter) is selected in accordance with the recommendations [3, p. 116] – high speed steel P6M5.

1. The cutting depth for roughing is equal to the maximum machining allowance: $t = z_{max.} = 8$ mm.
2. The feed *s* is assigned according to table 11 [3, p.266]. For a given cutting depth: s_z= 0.02 mm / tooth; s_m= 0.02*2*1250 = 50mm/ min.
3. The vertical feed s_z= 0.007 mm/tooth; s_m=0.007*2*1250= 17.5 mm/min.
4. The cutting speed is determined by the formula:

$$V = \frac{C_V . D^q}{T^m \cdot t^x \cdot s_z^y \cdot B^u \cdot z^p} \cdot K_V$$

The tool life is: *T*= 30 min; B= 1 (i =6 passes)

Values of the coefficients: C_V = 467; m = 0.33; x = 0.5; y = 0.5; q=0.45; u=0.1;p=0.1; – are taken from table17 [3, p.269].

Coefficient K_V:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV},$$

where K_{MV} –coefficient that takes into account the quality of the machined material;

$K_{ПV}$ –coefficient reflecting the state of the surface of the workpiece;

$K_{ИV}$ –coefficient that takes into account the quality of the tool material.

According to Table. 1, 5, 6 [3, p.261]:

$$\mathrm{K_{MV}} = \mathrm{K_{\Gamma}}\left(\frac{750}{\sigma_B}\right)^{n_v},$$

The value of the coefficient of K_{Γ} and the exponent n_v for the material of the tool from the hard alloy when processing the workpiece is taken from Table 2 [3, p.262]:

$$\mathrm{K_{\Gamma}} = 1.0 \quad \mathrm{n_V} = 1.0$$

Then:

$$\mathrm{K_{MV}} = \mathrm{K_{\Gamma}}\left(\frac{750}{\sigma_B}\right)^{n_v} = 1.0 \cdot \left(\frac{750}{980}\right)^{1.0} = 0.76$$

Hence ,K_{MV}= 0.76; $K_{ПV}$ = 0.8; $K_{ИV}$ =1.0.

Finally, the coefficient K_V is defined as:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV} = 0.76 \cdot 0.8 \cdot 1.0 = 0.61$$

The cutting speed is determined for t = 8 mm.

$$\mathrm{V} = \frac{\mathrm{C_V.D^q}}{\mathrm{T^m{\cdot}t^x{\cdot}s_z^y{\cdot}B^u{\cdot}z^p}} \cdot \mathrm{K_V} = \frac{46.7{\cdot}8^{0.45}}{30^{0.33}{\cdot}8^{0.5}{\cdot}0.04^{0.5}{\cdot}1^{0.1}{\cdot}2^{0.1}} \cdot 0.61 = 36.35\ \frac{\mathrm{m}}{\mathrm{min}}$$

5. Calculated speed of spindle:

$$n = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 36.35}{3.14 \cdot 8} = 1447 \text{ rpm}.$$

We take the actual number of revolutions, taking into account the type of machine, the type of machining and the machining tool material:

$$n = 1250 \text{ rpm}.$$

6. Actual cutting speed:

$$V = \frac{\pi \cdot d \cdot n}{1000} = \frac{3.14 \cdot 8 \cdot 1250}{1000} = 31.4 \ \frac{m}{min}.$$

7. Determine the main component of the cutting force by the formula:

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

Values of the coefficients: C_P = 62.8; n = 1250; x = 0.86; y = 0.72; u=1; q=0.86; w=0; t=8 mm – are taken from table 22 [3, p.273].

Coefficient $K_P = K_{MP}$

The coefficients in the formula take into account the actual conditions of cutting. According to tables 9, 23 [3, p.264]:

$$K_{mp} = \left(\frac{\sigma_B}{750}\right)^n = \left(\frac{980}{750}\right)^{0.3} = 1.08\,.$$

The main component of the cutting force, formula

8. $P_z = \frac{10 \cdot C_P \cdot t^x \cdot S^y \cdot B^u \cdot z}{D^q \cdot n^w} \cdot K_{MP} = \frac{10 \cdot 68.2 \cdot 8^{0.86} \cdot 0.02^{0.72} \cdot 6^1 \cdot 2}{8^{0.86} \cdot 1250^0} \cdot 1.08 = 528.6$ N.

9. Cutting power:

$$N = \frac{P_z \cdot V}{1020 \cdot 60} = \frac{528.6 \cdot 31.4}{1020 \cdot 60} = 0.27 \text{ kW}.$$

1.7.5 Groove cutting

The material of the cutting tool is selected in accordance with the recommendations [3, p. 116] - T5K10.

1. The cutting depth for roughing is equal to the maximum machining allowance i.e., *t* = 5mm.

2. The feed *s* is assigned according to table 11 [3, p.266]. For a given cutting depth: *s* = 0.15 mm / rev.

3. The cutting speed is determined by the formula:

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

The tool life is: *T*= 60 min.

Values of the coefficients: C_V = 47; m = 0.2y = 0.8– are taken from table17 [3, p.269].

Coefficient K_V:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV},$$

where K_{MV} –coefficient that takes into account the quality of the machined material;

$K_{ПV}$ –coefficient reflecting the state of the surface of the workpiece;

$K_{ИV}$ –coefficient that takes into account the quality of the tool material.

According to Table. 1, 5, 6 [3, p.261]:

$$K_{MV} = K_{\Gamma}\left(\frac{750}{\sigma_B}\right)^{n_v},$$

The value of the coefficient of K_{Γ} and the exponent n_v for the material of the tool from the hard alloy when processing the workpiece is taken from Table 2 [3, p.262]:

$$K_{\Gamma} = 1.0 \quad n_V = 1.0$$

Then:

$$K_{MV} = K_{\Gamma}\left(\frac{750}{\sigma_B}\right)^{n_v} = 1.0 \cdot \left(\frac{750}{980}\right)^{1.0} = 0.76$$

Hence, K_{MV}= 0.76; $K_{ПV}$ = 0.8; $K_{ИV}$ =1.0.

Finally, the coefficient K_V is defined as:

$$K_V = K_{MV} \cdot K_{ПV} \cdot K_{ИV} = 0.76 \cdot 0.8 \cdot 1.0 = 0.61$$

The cutting speed is determined for t = 1.25 mm.

$$V = \frac{C_V}{T^m \cdot S^y} \cdot K_V = \frac{47}{60^{0.2} \cdot 0.15^{0.8}} \cdot 0.61 = 57.3 \ \frac{m}{min}$$

4. Calculated speed of spindle:

$$n = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 57}{3.14 \cdot 26} = 698 \text{rpm}.$$

We take the actual number of revolutions, taking into account the type of machine, the type of machining and the machining tool material:

$$n = 630 \text{ rpm}.$$

5. Actual cutting speed:

$$V = \frac{\pi \cdot d \cdot n}{1000} = \frac{3.14 \cdot 26 \cdot 630}{1000} = 51 \ \frac{m}{min}.$$

6. Determine the main component of the cutting force by the formula:

$$P_z = 10 \cdot C_P \cdot t^x \cdot S^y \cdot V^n \cdot K_P$$

Values of the coefficients: C_P = 408; n = 0; x = 0.72; y = 0.8; – are taken from table 22 [3, p.273].

Coefficient $K_P = K_{MP}$

The coefficients in the formula take into account the actual conditions of cutting. According to tables 9, 23 [3, p.264]:

$$K_{мр} = \left(\frac{\sigma_B}{750}\right)^n = \left(\frac{980}{750}\right)^{0.75} = 1.22\,.$$

The main component of the cutting force, formula

7. $P_z = 10 \cdot C_P \cdot t^x \cdot S^y \cdot V^n \cdot K_P =$

$$= 10 \cdot 408 \cdot 5^{0.72} \cdot 0.15^{0.8} \cdot 51^{(0)} \cdot 1.22 = 3476.5\ \text{N}$$

8. Cutting power:

$$N = \frac{P_z \cdot V}{1020 \cdot 60} = \frac{3476.5\ \cdot 51}{1020 \cdot 60} = 2.89\ \text{kW}.$$

1.7.6 Cylindrical grinding

1. Allowance for grinding $z_{max.}$ = 0.14 mm.

We chose t = 0.014 mm in one pass.

2. Designation of grinding wheel ПВД 100x40x40,

24A 32 CT2 5 K5 30 m/s ГОСТ 2424-83.

3. $V_{wheel(k)}$=35 m/s.

4. $V_{work(з)}$=30m/min.

5. Calculated speed of spindle:

$$n_{work.} = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 30}{3.14 \cdot 50} = 191\ \text{rpm}.$$

$n_{accepted}$ = 200 rpm.

6. Calculated speed of spindle of the wheel:

$$n_{wheel} = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 35 \cdot 60}{3.14 \cdot 100} = 6687.89\ \text{rpm}.$$

7. $V_{accepted}$ is calculated: $V_{accp} = \frac{n_{accp} \cdot \pi \cdot d}{1000} = \frac{200 \cdot 3.14 \cdot 50}{1000} = 31.4\ \text{m/min}.$

8. Cutting power :

$$N_e = C_N \cdot V_з^r \cdot t^x \cdot s^y \cdot d^q = 1.3 \cdot 30^{0.75} \cdot 0.014^{0.85} \cdot 12^{0.7} \cdot 40 = 2.52\ \mathrm{kW}$$

V – rotational speed of workpiece;

t – depth of cut = 0.014 (i= z/t = 0.14/0.014=10);

s = 0.3·B = 0.3·40 = 12 (mm/rev of work spindle);

where B is width of the wheel (B = 40 mm).

1.8 Calculation of standard time

The basic time for turning operations is determined by the formula [4, p. 603]:

$$T_o = \frac{L \cdot i}{n \cdot S},$$

where L - calculated machining length, mm;

i– number of working passes;

n – frequency of rotation of the spindle, rpm;

S – feed, mm / rev.

Estimated machining length:

$$L = l + l_в + l_{cx} + l_{nд}$$

We accept: $l_{cx} = l_{nд} = 1mm$.

The main time for the first milling and center drilling operation 1:

$$T_{o1} = \frac{L \cdot i}{n \cdot S} = \frac{40+1+1}{630 \cdot 0.1} = 0.66\text{min}.$$

$$T_{o2} = \frac{L \cdot i}{n \cdot S} = \frac{4+5}{1250 \cdot 0.15} = 0.05\text{min}.$$

The main time for turning operation 2:

$$T_{o1} = \frac{L \cdot i}{n \cdot S} = \frac{30+40+27+1+1}{630 \cdot 0.6} = 0.26\text{min}.$$

$$T_{o2} = \frac{L \cdot i}{n \cdot S} = \frac{2+1+1}{630 \cdot 0.6} = 0.01\text{min}.$$

The main time for grove cutting operation 2:

$$T_{o3} = \frac{L \cdot i}{n \cdot S} = \frac{2+1}{630 \cdot 0.15} = 0.031\text{min}.$$

The main time for thread cutting operation 2:

$$T_{o4} = \frac{L \cdot i}{n \cdot S} = \frac{7 \cdot 40+1+1}{630 \cdot 3.5} = 0.13\text{min.}$$

The main time for turning operation 3:

$$T_{o1} = \frac{L \cdot i}{n \cdot S} = \frac{1.5+1+1}{630 \cdot 0.6} = 0.009\text{min.}$$

$$T_{o2} = \frac{L \cdot i}{n \cdot S} = \frac{(35 \cdot 1+35 \cdot 4)+(27 \cdot 1+27 \cdot 4)+40+1+1}{630 \cdot 0.6} = 0.93\text{min.}$$

The main time for turning operation 4:

$$T_{o1} = \frac{L \cdot i}{n \cdot S} = \frac{8 \cdot 6}{1250 \cdot 0.04} = 0.98\text{min.}$$

The main time for grinding operation 6:

$$T_{o1} = \frac{L \cdot i}{n \cdot S} = \frac{(35.10)+1}{200 \cdot 0.3} = 5.93\text{min.}$$

$$T_{o2} = \frac{L \cdot i}{n \cdot S} = \frac{(27.10)+1}{200 \cdot 0.3} = 4.5\text{min.}$$

The main time for grinding operation 7:

$$T_{o1} = \frac{L \cdot i}{n \cdot S} = \frac{(40.10)+1}{200 \cdot 0.3} = 6.6\text{min.}$$

$$T_{aux}=T_{m/d}+T_{c/u}+T_{control}+T_{measur.}$$

where,

T_{aux}= Auxiliary time

$T_{m/d}$=Time to mount and dismount the cutting tool.

$T_{c/u}$=Time to clamp and unclamp the work-piece.

$T_{control}$=Time for control.

T_{measur}= Time for measurement.

therefore we get,

$$T_{aux}=0.15+0.1+0.2+0.8=1.25\text{min.}$$

Calculation of operation time

Operation time is calculated by the given formula $T_{op}=\sum T_o+T_{aux}$

Operation cycle is calculated by the given formula $T_{oc}=T_{op}+T_{rest}+T_{maint.}$

where T_{rest}=3% of T_{op}(Time for rest).

$T_{maint.}$=10% of T_{op}(Time for maintenance).

Operation time for operation 1:

$T_{op}=(T_{o1}+T_{o2})+T_{aux}=0.66+0.05+1.25=1.96$ min.

T_{rest}=3% of 1.96 =0.06 min

$T_{maint.}$=10% of 1.96=0.196 min

$T_{oc}=T_{op}+T_{rest}+T_{maint}=1.96+0.06+0.196=2.2$ min.

Total time is given by,

$H_t=\frac{T_s}{n}+T_{oc}=\frac{8}{200}+2.2=2.24$ min.

where n is the lot size .

Operation time for operation 2:

$T_{op}=(T_{o1}+T_{o2}+T_{o3}+T_{o4}+T_{o5})+T_{aux}=$

$=0.26+0.031+0.01+0.009+0.13+1.25=1.69$ min.

T_{rest}=3% of 1.69 =0.05min

$T_{maint.}$=10% of 1.69=0.169 min

$T_{oc}=T_{op}+T_{rest}+T_{maint}=1.69+0.05+0.169=1.91$ min.

Total time is given by,

$H_t=\frac{T_s}{n}+T_{oc}=\frac{8}{200}+1.91=1.95$ min.

where n is the lot size .

Operation time for operation 3:

$T_{op}=(T_{o1}+T_{o2}+T_{o3}+T_{o4})+T_{aux}=0.93+0.009+0.009+0.009+1.25=2.2$ min.

T_{rest}=3% of 2.2 =0.06 min

$T_{maint.}$=10% of 2.2=0.22 min

T_{oc}= T_{op}+T_{rest}+T_{maint}=2.2+0.06+0.22 =2.48min.

Total time is given by,

$H_t=\frac{T_s}{n}+T_{oc}=\frac{8}{200}$+2.48 =2.52 min.

where n is the lot size .

Operation time for operation 4:

T_{op}=(T_{o1})+ T_{aux}=0.98+1.25=2.23 min.

T_{rest}=3% of 2.23 =0.06min

$T_{maint.}$=10% of 2.23=0.223 min

T_{oc}= T_{op}+T_{rest}+T_{maint}=2.23+0.06+0.223=2.5min.

Total time is given by,

$H_t=\frac{T_s}{n}+T_{oc}=\frac{8}{200}$+2.5 =2.54 min.

where n is the lot size .

Operation time for operation 6:

T_{op}=(T_{o1}+T_{o2}+T_{o3})+ T_{aux}=5.93+4.5+4.5+1.25=16.1 min.

T_{rest}=3% of 16.1 =0.48min

$T_{maint.}$=10% of 16.1=1.61 min

T_{oc}= T_{op}+T_{rest}+T_{maint}=16.1+0.48+1.61=18.1min.

Total time is given by,

$H_t=\frac{T_s}{n}+T_{oc}=\frac{8}{200}$+18.1 =18.14 min.

where n is the lot size .

Operation time for operation 7:

T_{op}=(T_{o1})+ T_{aux}=6.6+1.25=7.85 min.

T_{rest}=3% of 7.85 =0.23min

$T_{maint.}$=10% of 7.85=0.785 min

T_{oc}= T_{op}+T_{rest}+T_{maint}=7.85+0.23+0.785=8.86min.

Total time is given by,

$H_t=\frac{T_s}{n}+T_{oc}=\frac{8}{200}+8.86=9.0$ min.

where n is the lot size .

1.9. Conclusion of technological part

In this part of work I've gained the knowledge to design manufacturing process for the given complex part. During the work I've learnt to calculate the dimension chain analysis, tolerance analysis, allowances, and manufacturing sizes. I've also studied how to choose the cutting parameter which includes cutting speed, speed of spindle rotation, and main component of the cutting force and the power of the machine tool by using different types of handbooks and literature.

2. Design part

In this section, two V-blocks are designed with the help of which the workpiece is located, a pneumatic drive which supports the V-block by clamping the workpiece. In addition, a base plate is also designed where the V-block and the pneumatic drive are placed. This base plate is located on the working bed of the universal milling machine ФУ251 where the key slot is milled.

2.1. Initial data for designing of work-holding device

Material of the workpiece – Steel 40X with tensile strength $\sigma_в = 980$ MPa and hardness HB 210...220. Diameter of the shaft where the key slot is made ϕ 40mm; diameter of the key slot is 8H9; depth of cut t= 8mm; width of cut B= 6mm; number of passes i = 1; time of machining T=0.98 min. We choose the cutter high speed steel end mill with the mark P6M5. Machining tool is universal milling machine ФУ251.

Selecting the cutting mode

We choose the following parameters from section 7.4 manufacturing part:

depth of cut $t=z_{max}$= 8mm.

feed rate s_z=0.02 mm/ tooth.

rotational speed of the spindle n=1250rpm.

accepted cutting speed : V=31.4m/min.

Determination of torque, axial force and power

We choose the following parameters from section 7.4 manufacturing part:

The main component of the cutting force, formula

$$P_z = \frac{10 \cdot C_P \cdot t^x \cdot S^y \cdot B^u \cdot z}{D^q \cdot n^w} \cdot K_{MP} = \frac{10 \cdot 68.2 \cdot 8^{0.86} \cdot 0.02^{0.72} \cdot 6^1 \cdot 2}{8^{0.86} \cdot 1250^0} \cdot 1.08 =$$

$$= 528.6 \text{ N.}$$

Torque: $M_{кр} = 2.11$ Nm.

Axial cutting force for one pass: $P_h = 0.4 \cdot P_z = 0.4 \cdot 528.6 = 211.44$ N.

The cutting power: $N_e = 0.27$ kW.

2.2. Pneumatic Drive

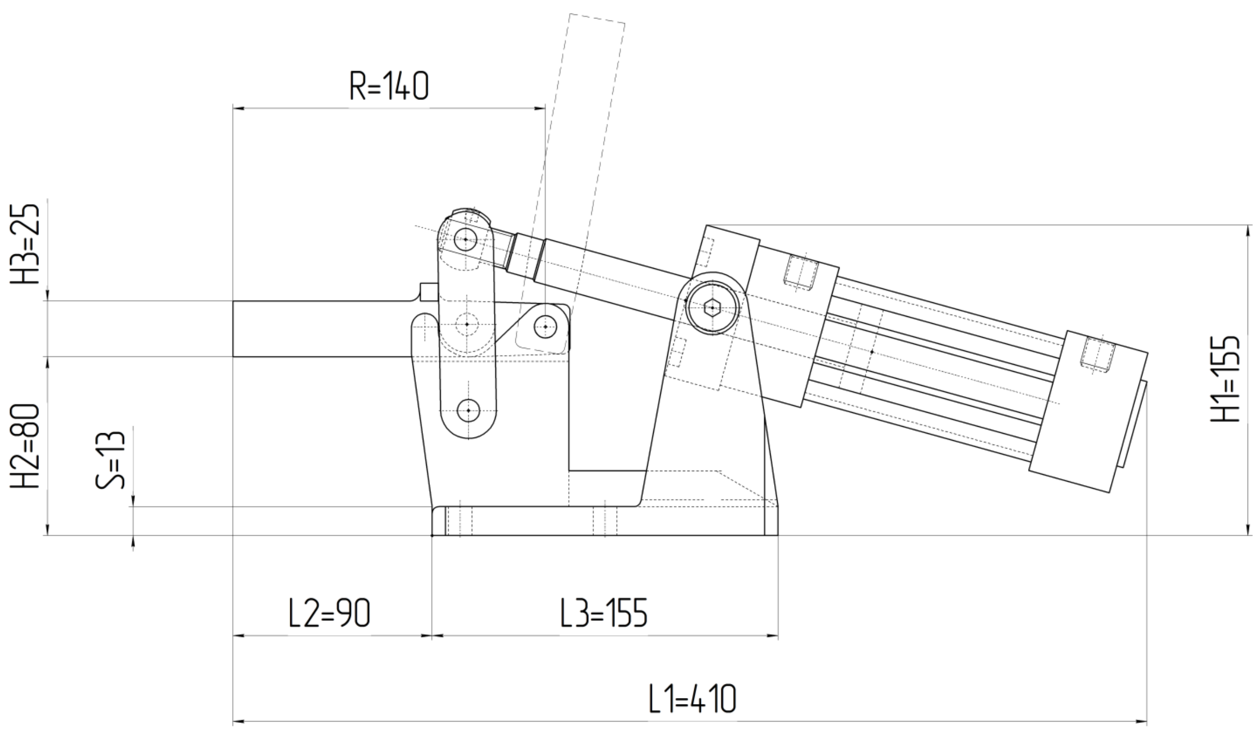


Fig. 1. Pneumatic drive front (closed) view

The above figure shows the pneumatic drive with a single stroke piston at its maximum position which helps the arm to hold the workpiece on the V-block.

This system of the drive is clamped to the base plate with the help of four M10 bolts.

The tolerances between all the assemblies are H9/h9 as we don't need a very high accuracy.

The diameter of cylinder, rod and other parameters are chosen from table IV.I [pg.205,5].

$D_{cylnd.}$ =70 mm=0.07m

d_{rod} = 21mm.

Pressure P =5 Kg/cm^2 ≈ 5bar=500000 Pa.

The force exerted by a single acting pneumatic cylinder can be expressed as $Q=P \cdot A$

where A= $\frac{\pi D^2}{4} - \frac{\pi d^2}{4}$

we get

$$Q_{piston} = \left(\frac{D^2 * \pi}{4} - \frac{d^2 * \pi}{4}\right) * p = \left(\frac{0.25^2 * \pi}{4} - \frac{0.03^2 * \pi}{4}\right) * 0.4 * 10^6 = 19352 \text{ N}$$

$$16333.3 \text{ N}$$

Calculation of clamping force:

$$W = \frac{K * M_{cut.}}{r\left(f * \sin\frac{\alpha}{2} + f_3\right)} = \frac{2 * 10.5}{0.025\left(0{,}1 * \sin\frac{90}{2} + 0{,}1\right)} = 5250 \text{ N.}$$

$$M_{cut.} = P_Z * \frac{d}{2} = 528.6 * \frac{40}{2 * 1000} = 10.572 \text{ Nm}$$

$M_{\text{Frict requered.}} = M_{cut.} \cdot K = 10.5 \cdot 2 = 21$ Nm

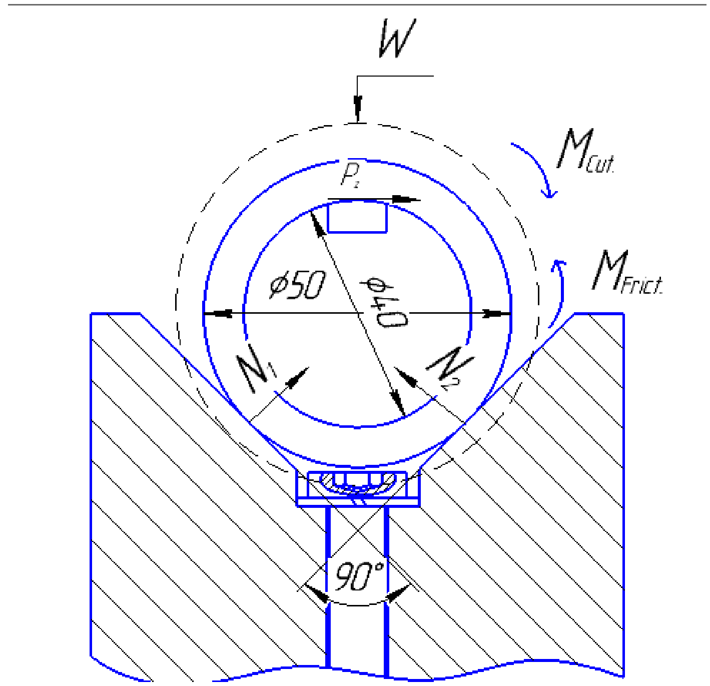


Fig. 2. Scheme of cutting and clamping torgues

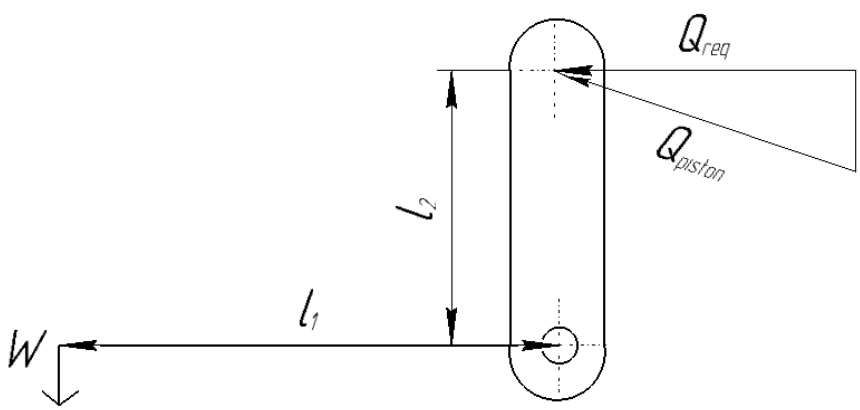


Fig. 3. Scheme of clamping force

Torque equation:

$$W * l_1 = Q_{req} * l_2$$

$$Q_{req} = \frac{W * l_1}{l_2} = \frac{5250 * 0.14}{0.045} = 16333.3\ \text{N}.$$

$$Q_{piston} = 19352\ \text{N} > Q_{req} = 16333\ \text{N}$$

2.3. V-block

V-block is chosen according to GOST standard 12195-66 which is made of steel 20X. It has a very smooth surface finish on the sides where the workpiece is held (Ra=0.4) and these sides (faces) have $\alpha = 90^\circ$. The distance between two faces B_1=70mm, width of the V-block is given by B=85mm.

Two V-blocks are designed with a hole in their centers where the bolt M10 is placed together with a washer, with the help of this setup V-blocks can be adjusted to any required horizontal position on the base plate in between the slot provided for V-block. V-blocks also have a slot and key at their base with the help of which they are attached to the base plate.

Angle plate

There is an angle plate that is fixed to the base plate with the help of T-bolt M10-7H/8g. It has a bolt with ball head that is used to give the 5^{th} locating datum for the work piece. Ball head bolt has the dimensions M10-7H/8g.

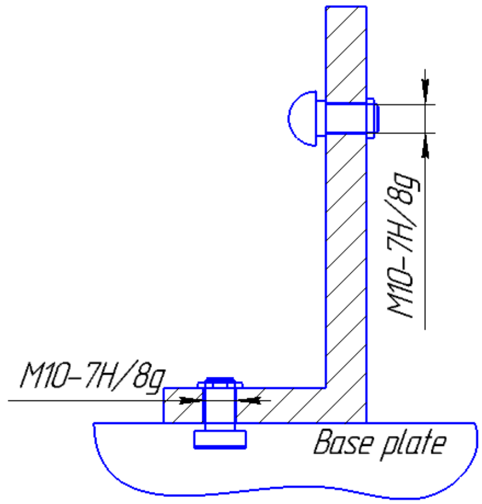


Fig. 4. Angle plate

Base plate

Base plate can be made of cast iron or steel. It is designed to hold the V-block and the pneumatic drive and locate them on the working bed of the machine tool. The base plate has height =25mm with 4 slots in its corners with the help of which it is clamped to the bed of machine tool using four M12 bolts (T-shape).It has a slot and key in the center where the V-blocks are placed and adjusted to their required position. It has four holes where pneumatic drive is place with the help of four M10 bolts.

Conclusion:

We figured out that the force of pistons (Q_{piston}) which we are going to get is much higher than the required force (Q_{req}). Although the piston force is much higher we are not going to change parameters of pneumatic mechanism. The reason is that if there will be some oil the coefficient of friction will dramatically change and required force will be higher.

3. Section "Financial Management, Resource Efficiency and Resource Saving"

ASSIGNMENT FOR THE SECTION ‹‹FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE-SAVING»

Student:

Group	Last, first name
8Л4И	Sabavath Sai Kiran

School	The School of Advanced Manufacturing Technology (ScAMT)
Major	15.03.01 “Mechanical engineering”
Division of School	Division for Materials Science (DMS)

The initial data to the section "Financial management, resource efficiency and resource-saving" :	
1. The cost of resources for the manufacture of parts "Conical shaft"	1. The cost of basic materials determine on the basis of price lists organizations-sellers of materials 2. Hourly tariff rates by categories works: 1st class - 40 rubles per hour. 2ndclass - 51 rubles per hour. 3rd class - 65 rubles per hour. 4th class - 82.96 rubles per hour. 5th class - 105.81 rubles per hour. 6th class - 135 rubles per hour. The work orders should be determined on the basis of the Unified tariff-qualification guide, section "Mechanical treatment of metals and other materials » 3. Tariff for electricity - 5.8 rubles / kWh.
2. Norms of expenditure of resources	To calculate the following limits norms of resource consumption: -cost of transport-procuring expenses - 0.06 -costs on the maintenance of workers maintenance of machinery and equipment, not directly occupied by manufacture products - 40% of the total salary and deductions from its main workers

	costs for materials used for operation of the equipment, it is - 20% of depreciation -costs for repair of equipment -100-120% of basic salary of the main workers. - general workshop costs - 50 - 80%, from the main salaries of basic workers - general business expenses -50% of the main salaries of the main workers. -expenditures for sale - 1% of production cost
3. The used taxation system, rates taxes, deductions, discounting and lending	The rate of deductions for social needs - 30% of wage fund The rate of deductions to the social fund accident insurance for production - 0.7% of wage fund Value Added Tax - 18% from product prices.
List of issues to be investigated, designed and developed:	
1. Calculation of the cost of manufacturing parts "Conical shaft"	1. To carry out calculation of expenses for main and auxiliary materials (after deduction return waste) 2. Take the calculation of costs for the main and additional salaries of basic production workers, deductions for social needs. 3. To carry out the calculation of the cost of maintenance and operation of equipment. 4. Carry out a calculation of the value of general shop, general economic, non-productive costs. 5. To conduct calculation of the cost price.
2. Calculation of the price of the "Conical shaft" part with VAT	Calculation is done using normative method of pricing. The norm profitability should be within 5-20%

The assignment was issued by:

Post	**Last, first , middle name**	**Scientific degree**	**Signature**	**Date**
Senior Lecturer	Potekhina N.V.			

The assignment was executed by the student:

Group	**Last, first name**	**Signature**	**Date**
8Л4И	Sabavath Sai Kiran		

The purpose of this section is to calculate the cost and price of the product, manufactured according to the developed technological process in standard production conditions.

3.1. Calculation of costs under the item "Raw materials"

The article includes the cost of the main materials that are directly included in the composition of manufactured products (parts), as well as auxiliary materials used for technological purposes. Costs for basic materials for each (i-th) type separately are calculated by the formula

$$N_{OTX} = \frac{200}{9000} = 0.022\ Kg$$

Cost of the material: 1 piece (would be):

$$C_{мо} = N \cdot C = (2.7 + 0.022) \cdot 49.89 = 135.8\text{rub.}$$

Where, N is the mass of the workpiece; C - the price of one kg of material.

Auxiliary materials: we will take 15% of the material cost

$$C_{мв} = C_{мо} \cdot 0.15 = 0.15 \cdot 135.8 = 20.37\text{rub.}$$

Transportation and procuring expenses: we will take 15% of the material cost

$$C_{тр.з} = C_{мо} \cdot 0.15 = 0.15 \cdot 135.8 = 20.37\text{rub.}$$

The total costs included in this article are equal to the sum:

$$C_{м} = C_{мо} + C_{мв} + C_{тр.з} = 135.8 + 20.37 + 20.37 = 176.54\text{ rub.}$$

3.2. The calculation of the costs of the item "Reusable products and semi-finished products"

This section includes the cost of waste at the rate of their sale to the side. The present value is excluded from the manufacture cost of production.

$$С_{от} = М_{от} \cdot Ц_{от} = (В_{чр} - В_{чст}) \cdot (1 - \beta) \cdot Ц_{от}$$

where $М_{от}$ - quantity of waste in physical units, obtained in the manufacture of a unit of production;

$Ц_{от}$-price of waste, $Ц_{от} = 7.2\ rub/Kg$;

$В_{чр}$- mass of the workpiece;

$В_{чст}$- net weight of part;

β-share of irreversible losses (accepted 0.02).

$$С_{от} = (3.17-2.72) \cdot (1 - 0.02) \cdot 7.2 = 3.18 rub.$$

3.3. The calculation of costs under the item "The basic payroll of production workers"

This section includes the costs for the labor of workers connected with the manufacturing products.

$$Созп = \sum_{i=1}^{Ko} t_i^{шт.к} / 60 * ЧТС_i * K_{пр}$$

where $t_i^{шт.к}$ is unit time of the i-th operation, min;

K_o - number of operations in the process;

$ЧТС_i$- hourly tariff line for i-th operation;

$K_{пр}$- coefficient taking into account surcharges, payments and bonuses provided for by the labor legislation. When planning, you should take it equal to 1.4.

For the production of a "Conical shaft" part, 7 workers will be required.

1. Stamping - 1 worker of the 4th category
2. Centre drill and milling - 1 worker of the 4thcategory
3. Turning on CNC and general lathe – 2 workers of the 4thcategory
4. Milling a key slot -1 worker of the 4thcategory
5. Grinding- 2 worker of the 4thcategory

$$С_{озп} = \frac{2.24 + 1.95 + 2.52 + 2.54 + 18.14 + 9.0}{60} \cdot 82.96 \cdot 1.4 = 70.44 rub.$$

3.4. The calculation of costs under the item "Additional pay for manufactured products workers"

Calculation of additional wages is carried out according to the formula:

$$С_{дзп} = С_{озп} \cdot k_{д}$$

where $С_{озп}$- basic salary ;

$k_{д}$- coefficient that takes into account the additional salary. When planning, it should be taken equal to 0.1

$$С_{дзп} = 70.44 \cdot 0.1 = 7.04 rub.$$

3.5. Calculation of costs under the item "Taxes, deductions to the budget and off-budget funds"

Here deductions are included according to the norms established by the legislation in-fund of social protection of the population, pension fund, medical insurance and other social needs.

$$С_{н} = (С_{озп} + С_{дзп}) \cdot \frac{(Сс.н. + Сстр)}{100}$$

where $С_{озп}$ – basic salary of workers;

$С_{дзп}$ – additional salary of workers;

$С_{с.н.}$ – social tax rate(accepted 30%);

$C_{стр}$ – rate of insurance premiums (compulsory insurance) (accepted 0,7%).

$$C_н = (70.44 + 7.04) \cdot \frac{(30 + 0.7)}{100} = 23.786 \text{rub.}$$

3.6. Distribution of costs under the item "Consumption and maintenance of machinery and equipment”

This section includes the following types of costs:

1. Amortization of equipment and valuable instruments, designation C_a;
2. Operation of equipment other than costs (for repairs);
3. Operation of equipment other than costs;
4. In-plant movement of goods;
5. Repayment of the cost of general-purpose tools and appliances;
6. Other expenses.

$$A_{год} = \sum_{i=1}^{T} \phi_i \cdot H_{ai} + \sum_{j}^{m} \phi_j \, H_{aj}$$

where $Ф_i$ – the initial book value of the unit-type, type i, i = 1, ..., T;

T – number of types of equipment used;

$Ф_j$ – the same for the j-type j = 1, ..., m;

m – number of types of equipment used;

H_{ai} and H_{aj} – appropriate depreciation rates.

Table 1. Cost of machines

Machine tool	Price, rub.
Hot stamping pressТМПК8045	1 250 000
Milling-center drilling machine МР76-М	1 100 000
Turning machine 16К20Ф3	1 500 000
General lathe 16К20	800 000
Milling machine ФУ251	1 030 000
Circular grinding machine 3М153	900 000

The depreciation rate in general form is determined by the formula:

$$H_a = \frac{1}{T_{Tu}}$$

where $T_{\text{ти}}$ – useful life, years.

Then the depreciation rate for all machines: $H_a = \frac{1}{10} = 0.1$

Let's calculate the cost of depreciation of equipment:

$A_{\text{год}}$= (1250000+1100000+1500000+800000+1030000+900000)* 0.1 = 658 000 rub.

Expected average load used:

$$l_{kp} = \frac{N_B \cdot \sum_{i=1}^{P} t_i^{wt.k}}{\sum_{i=1}^{p} F_i}$$

where $N_{\text{в}}$ – annual output of the product (parts), pieces;

P – number of operations in the technological process;

$t_i^{\text{шт.к.}}$ – piece-calculation time for i-th operation, process, i = 1, .., P;

F_i- the actual annual fund of the operating time of the equipment used in the i-th operation with the account of the accepted number of shifts.

For a two-shift mode of operation, the actual annual fund of equipment operating time F_i = 4029 hours.

$$l_{kp} = \frac{9000 \cdot {(2,24+1,95+2,52+2,54+18,1+8.9)}/{60}}{4029 \cdot 6} = 0.23$$

If $l_{kp} \leq 0,6$, then the amortization of equipment and valuable tools

$$C_a = \left(\frac{A_{\text{г}}}{N_{\text{в}}}\right) \cdot \left(\frac{l_{kp}}{\eta_{\text{з.н.}}}\right)$$

where $\eta_{\text{з.н}}$ - normative coefficient of equipment loading (for small-scale 0.85).

$$C_a = \left(\frac{658000}{9000}\right) \cdot \left(\frac{0.23}{0.85}\right) = 19.78\ rub.$$

$$\text{С}_{\text{экс}} = \left(\text{С}_{\text{озп}} + \text{С}_{\text{дзп}} + \text{С}_{\text{н}}\right) \cdot 0.4 = (70.44 + 7.04 + 23.786) \cdot 0.4 = 40.5\ rub.$$

The cost of materials spent for work equipment is taken to be 20% of the depreciation amount, i.e.

$$\text{С}_{\text{мэкс}} = \text{С}_{\text{а}} \cdot 0.2 = 19.78 \cdot 0.2 = 3.95 \text{rub.}$$

Costs for all types of energy consumed during the operation of equipment. Only electricity costs are calculated by the formula:

$$C_{\text{тэ}} = Ц_{\text{тэ}} \cdot P_{\text{тэ}} \cdot (1 + K_{\text{тэ}})$$

where $Ц_{\text{тэ}}$ – unit rate of the resource, rub;

$P_{\text{тэ}}$ – output energy consumption per unit, kW;

$k_{\text{тз}}$ – coefficient of transport costs ($k_{\text{тз}}$=0)

The energy consumption is equal to the sum of the power expended for all transitions multiplied by unit time.

$$C_{\text{эл.п}} = Ц_{\text{э}} \cdot \text{К}_{\text{п}} \cdot \sum_{i=1}^{P} W_i \cdot K_{Bi} \cdot t_i^{\text{шт.к}}$$

$$P_{\text{тэ}} = \sum_{i=1}^{P} W_i \cdot K_{Bi} \cdot t_i^{\text{шт.к}}$$

$P_{\text{тэ}}$= $9.5 \cdot \frac{2.24}{60} + 2.2 \cdot \frac{1.95}{60} + 2.2 \cdot \frac{2.52}{60} + 0.17 \frac{2.54}{60} + 2.52 \cdot \frac{18.14}{60} + 2.52 \cdot \frac{8.9}{60}$=1.66 kWh;

Tariff for electricity $Ц_{\text{тэ}}$= 5.8 rub/kWh;

then:

$$C_{элп}=5.8*1.05*1.66 = 10.11 \text{ rub.}$$

$$C_{рем} = C_{озп}\cdot(1.0\text{-}1.2) = 70.44 *1 =70.44 \text{ rub.}$$

3.7. The cost of the fixture

Table 2. The cost of fixtures

Fixture	Cost, rub.	Life, years	Cost per year, Rub.	Cost per unit product, rub.
Special fixture	44 000	4	11 000	4.4
Spare parts (3 pieces)	40 000	4	10 000	4.2

$$C_{аоб}= 4.4+4.2=8.6 \text{ rub/piece}$$

$k_{тз}$ is the coefficient of transport procuring expenses $k_{тз}$ =0. 06.

Table 3 - Cost of the instrument

Name of the Instrument	Time of work, min	Tool life, min	Price, Rubles	$\frac{Ц_и \cdot t_{рез}}{T_{ст}}$
Disc mill	0.66	60	2200	24.2
Drills bits	0.05	15	400	1.30
Turning cutter	1.0	30	1500	50.0
Groove cutter	0.031	60	200	0.10
Thread cutter	0.13	70	400	0.75
End mill	0.98	30	1200	39.2
Grinding wheel(circular)	6.0	120	900	45.0

$$C_{инс}= (1+0.06) \cdot (24.2+1.30+50.0+0.10+0.75+39.2+45.0) = 170.18 \text{ rub.}$$

3.8. Calculation of costs under the item "All-purpose costs"

General shop costs are distributed between the products produced in proportion to the basic salary of production workers using the standard coefficient $k_{оц}$, calculated separately for each shop. We accept it equal to 50 - 80%, from the basic salary of industrial workers, i.e.

$$C_{оп} = C_{озп} \cdot k_{оп} = C_{озп} \cdot (0.5 – 0.8) = 70.44 \cdot 0.6 = 42.26 \text{ rub.}$$

Approximately, we can differentiate the values of $k_{оп}$ depending on the type of production: medium-scale – 0.6.

3.9. Calculation of costs under the item "General economic expenses"

This section includes costs for general management of the enterprise, not related to the process of production and including expenses for maintenance of administrative personnel; depreciation charges and expenses on maintenance and repair of the main types of management and general government (office equipment, buildings and structures); expenses for heating, illumination and payment of the enterprise; payment for water and land, etc. The calculation is made with the help of the coefficient $k_{ох}$, which establishes the normative ratio between the amount of these data and the basic salary of the production workers. Recommended value $k_{ох} = 0.5$, i.e.,

$$C_{ох} = C_{озп} \cdot k_{оп} = 70.44 \cdot 0.5 = 35.22 \text{ rub.}$$

3.10. Calculation of expenses under item "Expenses for realization"

The section includes the costs associated with the sale of manufactured products: storage and packaging in warehouses of finished products; delivery of products to the station and to the ports of departure; advertising and distribution network; commission fees of intermediary organizations, etc. These expenses are recommended to be taken equal to 1% of the production cost.

$$C_{рлз} = \sum C_i \cdot 0.01 = (176.54-3.18+70.44+7.04+23.786+19.75+3.95+40.5+$$
$$+10.11+70.44+170.18+8.6+42.26+35.22) \cdot 0.01 = 6.75 \text{ rub.}$$

3.11. Calculation of profit

The profit should be taken in the amount of 5 ÷ 20% of the total cost of the project

$$\boldsymbol{\Pi} = \sum C_i \cdot 0.2 = (176.54-3.18+70.44+7.04+23.786+19.75+3.95+40.5+$$
$$+10.11+70.44+170.18+8.6+42.26+35.22+6.75) \cdot 0.2 = 136.5 \text{rub.}$$

Total cost $C_{поли}$=682.49rub.

3.12. Calculation of VAT (НДС)

VAT is 18% of the total cost of the product and profit.

$$VAT = C_{поли} \cdot 0.18 = (682.49+136.5) \cdot 018 = 147.42 \text{ rub.}$$

3.13. Price of the product

Table 4. Price of the product

	Type of Cost	Expenditure per Unit, ruble
1	Cost of material	176,64
2	Cost of reusable material	3,18
3	Basic salary of workers	70,44
4	Additional salary	7,04
5	Taxes and deductions from the wage fund	23,79
6	Consumption and maintenance cost	323,53
6.1	Depreciation cost	19,75
6.2	Maintenance of equipment	40,5
6.23	Cost of materials spent for work equipment	3,95
6.4	Cost of electricity	10,11
6.5	Cost of repair	70,44
6.6	Cost of fixture and instruments	178,78
7	General economic expenses	35,22
8	All purpose cost	42,26
9	Expenses for realization	6,75
10	**Total cost**	682,49
11	Profit	136,498
12	**Manufacturer whole sale price**	818,988
13	VAT (18%)	147,418
14	**Selling whole sale price**	966,406

Conclusion:

After calculating the expenses for different situations we have the cost price of one piece as 682.49 rub and the selling price would be 966.406 rub which include the profit 20% and VAT of 18%. We can also chose different types of selection of material like rolled stock and follow the same procedure to find the expenditure for the production. According to me this is the most optimal way of production as the initial workpiece is forged to the closest shape of the part which results in less wastage of material.

4. Section "Social responsibility and Safety management"

Assignment for section

Student:

Group	Last, first name
8Л4И	Sabavath Sai Kiran

School	The School of Advanced Manufacturing Technology (ScAMT)
Major	15.03.01 "Mechanical engineering"
Division of School	Division for Materials Science (DMS)

Initial data to the section "Social responsibility":	
1. Characteristics of the object of investigation (substance, material, instrument, algorithm, technique, working area) and the field of its application	*Analyze harmful and dangerous factors in the process of manufacturing a Conical shaft.*
List of issues to be investigated, designed and developed:	
1. Production safety 1.1. Analysis of identified harmful factors in the development and operation of the proposed solution. 1.2. Analysis of identified hazards in the design and operation of the projected solution.	*Analyze harmful and dangerous factors in the workplace:1.1* *1. Deviation of the microclimate indices in the room;* *2. Increased noise level in the workplace;* *3. Insufficient illumination of the working area;* *1. Danger of electric shock;* *2. Fire hazard.*
2. Environmental safety Analysis of the impact of the object on the environment.	*Analyze the negative impact on the environment.*
3. Safety in emergency situations	*Development of measures to prevent the most typical emergency for the educational building (fire).*
4. Legal and organizational issues of security: Organizational arrangements for the layout of the work area.	*Analyze the compliance of the workplace with technical requirements and sanitary standards.*

The assignment was issued by:

Post	Last, First, middle name	Scientific degree, Grade	Signature	Date
Professor of Department of Control and Diagnostic	Nazarenko O.B.	D.Sc.		

The assignment was executed by the student:

Group	Last, First name	Signature	Date
8Л4И	Sabavath Sai Kiran		

This section is devoted to the analysis and development of measures to ensure favorable working conditions used for creative work of an engineer-technologist. It addresses issues of industrial safety, ergonomics, fire safety and environmental protection.

Introduction

Technological progress has made a major change in the conditions of knowledge of workers in industrial activity. Their work has become more intensive, requiring significant investment of mental, emotional and physical energy. This required a complete solution of problems of ergonomics, sanitation and labor organization, regulation of modes of work and rest.

Nowadays computer technology is widely used in all fields of human activity. When working with the computer the person is exposed to a number of dangerous and harmful production factors: electromagnetic fields (frequency range: 5 Hz to 2 kHz, 2 kHz - 400 kHz), ionizing radiation, noise, static electricity, etc. Of great importance for the rational design and layout of the workplace is to maintain an optimal working posture of the human operator.

4.1. Analysis of dangerous and harmful factors

The production conditions in the workplace are characterized by the presence of some dangerous and harmful factors (GOST 12.0.002-80 "SSBT. Basic concepts terms and definitions"), which are classified by groups of elements: physical, chemical, biological and psycho-physiological (GOST 12.0.003-74 "SSBT. Dangerous and harmful factors classification"). On working at the computer engineer can have a depressing affect following dangerous and harmful production factors:

1. Physical: elevated levels of electromagnetic, x-ray, radiation, the lack of natural light, inadequate artificial illumination of the working area, increased brightness, increased contrast, a direct and a reflected best cost, excessive dust, risk of electric shock, noise from equipment operation.

2. Chemical: increased content in the air of working zone of carbon dioxide.

3. Psychophysical: eyestrain and consideration; intellectual, emotional, and prolonged static loads; the monotony of work; a large amount of information processed per unit time; inefficient organization of the workplace.

Industrial noise. The noise worsens the conditions causing a harmful effect on the human body. Working in conditions of prolonged noise exposure, the worker experiences irritation, headaches, dizziness, memory loss, fatigue, loss of appetite, pain in the ears, etc. Such violations in a number of organs and systems of the human body can cause a negative change in emotional state of a person up to stress. Under the influence of the noise reduced concentration, physiological functions are violated; there is fatigue due to increased energy costs and mental stress, deteriorating speech switching. All this reduces the efficiency, productivity, quality and safety. Prolonged exposure to intense noise [above 80 dB] at the hearing of the person leads to its partial or total loss.

The main sources of noise in the office are fans of the power supply units of the computer. The noise level ranges from 35 to 60 dB. By SanPiN 2.2.2.542-96 in carrying out the basic work on the computer is the sound level at the workplace should not exceed 50 dB. To reduce noise walls and ceiling of the room where there is a computer can be lined with sound absorbing materials.

Electromagnetic and ionizing radiation. Most scientists believe that both short and prolonged exposure to all types of radiation from the monitor is not dangerous for the health of the personnel operating the machines. However, comprehensive data on the risk of radiation exposure from the monitors at working with computers does not exist and research in this direction continues.

Valid values for the parameters of non-ionizing electromagnetic radiation from your computer monitor are represented in table. 4.1.

The maximum level of x-ray radiation in the workplace of the operator of the computer usually does not exceed ber/h, and the intensity of ultraviolet and infrared radiation from the screen of the monitor lies within 10…100mWt/m^2.

Table 4.1. Valid values for the parameters of non-ionizing electromagnetic radiation (in accordance with SanPiN2.2.2/2.4.1340-03)

Parameters name electricity		
Magnetic flux density	in the frequency range 5 Hz - 2 kHz	250 nT
	in the frequency range 2 kHz - 400 kHz	25 nT
The electrostatic field		15 kV/m

To reduce the impact of these types of radiation monitors are recommended for use with low level radiation (MPR-II, TCO-92, TCO-99), install protective screens, and comply with regulated regimes of work and rest.

Electric shock. To dangerous factors may include the presence in the premises of the large amount of equipment that uses single-phase electric current voltage of 220 V and frequency 50 Hz. The danger of electrocution study relates to the premises without increased risk, because there is no humidity, high temperature, conductive dust and the possibility of simultaneous contact with the ground bonding metal objects and metal equipment housings.

During normal operation of the equipment danger electrocution small, however, possible modes, called emergency, when there is a random electrical connection of parts under voltage with grounded structures.

Defeat by an electric current or by an electric arc may occur in the following cases:

- when touching live parts during repair;

- single-phase (single pole) touch non-insulated from the ground of the person to uninsulated live parts of electrical installations under tension;

- in contact with the floor and walls, trapped under voltage;

- if possible short circuit in the high voltage units: the power unit, the scanner monitor.

The main measures to ensure electrical safety are:

- isolation (fencing) live parts, eliminating the possibility of accidental contact with them;

- install protective earthing;

- the existence of a common switch;

- timely inspection of technical equipment, insulation.

4.2. Ergonomic analysis of the work process

The microclimate. The parameters of the microclimate can vary within wide limits, while a necessary condition of human life is to maintain constancy of body temperature through thermoregulation, i.e. the body's ability to regulate heat loss to the environment. The principle of normalization of microclimate is creation of optimal conditions for heat exchange of human body with the environment.

Computer science is a source of significant heat, which may result in increase of temperature and decrease of relative humidity in the room. In areas where there are computers, should conform to the defined parameters of the microclimate. Sanitary norms SanPiN 2.2.4.548-96, SanPiN 2.2.2/2.4.1340-03 set the values of parameters of microclimate, creating a comfortable environment. These standards are set depending on the time of year, the nature of the labour process and the nature of the workplace (see tab. 4.2).

The volume of the premises occupied by employees of the data center shall be greater than 19.5 m^3/person. Feed rate of the fresh air into the premises, where the computers are given in table. 4.3.

Table 4.2. The parameters of the microclimate in rooms where computers

The period of the year	The microclimate parameter	Value
Cold	The temperature of the air in the room Relative humidity The speed of air movement	22…24°C 40…60% up to 0,1m/s
Warm	The temperature of the air in the room Relative humidity The speed of air movement	23…25°C 40…60% 0.1…0.3 m/s

Table 4.3. Regulations for supplying fresh air to the rooms where the computers are located

Description of room	Volume flow supplied to the premises of fresh air, m^3 /per person per hour
Volume up to 20m^3 per person 20...40m^3 per person More 40m^3 per person	Not less than 30 Not less than 20 Nature ventilation

To ensure comfortable conditions are used as organizational methods (rational organization of work, depending on time of day and year, the alternation of work and rest) and technical equipment (ventilation, air conditioning, heating system).

Lighting. Properly designed and implemented industrial lighting improves visual work, reduces fatigue, improves productivity, positively affects the production environment, providing a positive psychological impact on employees, increases safety and reduces injuries.

Insufficient lighting results in eye strain, weakens attention and leads to the onset of premature fatigue. Overly bright lighting causes glare, irritation and pain in the eyes.

Wrong direction of light in the workplace can create harsh shadows, glare, confusion working. All these reasons can lead to an accident or occupational diseases, hence the importance of a correct calculation of illumination.

There are three types of lighting - natural, artificial and combined (natural and artificial) .

Natural lighting – daylight uses penetrating through the light apertures in the outer walling of the premises. Natural light is characterized in that it varies widely depending on time of day, time of year, the nature of the field and a number of other factors.

Artificial lighting is used when working in the dark and during the day when you are unable to provide normalized values of the coefficient of natural light (cloudy weather, short daylight hours). Lighting, which is insufficient according to the norms of natural light supplemented with artificial, is called a combined lighting.

Artificial lighting is divided into operating, emergency, evacuation, security. Illumination, in turn, can be shared or combined. Total - lighting in which the lamps are placed in the upper zone of the room evenly or in relation to the location of the equipment. Combo – lighting is that added to the total local lighting.

According to SP 52.13330.2011 "Natural and artificial lighting, actualized edition of SNiP 23-05-95" in the premises of the data center you want to apply a combined lighting system.

When carrying high visual accuracy (the smallest size of an object distinguish between 0.3...0.5 mm) the coefficient of natural lighting (KEO) should not be below 1.5% when visual work average precision (smallest size of an object distinguish between 0,5...1,0 mm) KEO should not be below 1.0%. As sources of artificial light typically use fluorescent lamps type LB or DRL, which are combined in pairs in the lamps, which must be placed above the working surfaces evenly.

Requirements for lighting in rooms with computers, the following: when you run the visual works of high precision General illumination shall be LC, and combined - LC; similar requirements when performing work average precision - 200 and LC respectively.

In addition the entire field of view must be lit evenly is a basic hygiene requirement. In other words, the degree of illumination of the room and the brightness of the computer screen should be approximately equal, because the bright light in the area of peripheral vision significantly increases eye strain and, consequently, leads to fatigue.

4.3. Ergonomic requirements to the workplace

Design of workplaces, equipped with terminals, is among the important problems of ergonomic design in computer science.

Working place and relative location of all of its elements must correspond to the anthropometric, physical and psychological requirements. Of great importance is also the nature of the work, in particular, when workplace design engineer must meet the following basic conditions: optimal placement of equipment that is part of the workplace and sufficient working space that allows you to perform all the necessary movements and displacement.

Ergonomic aspects of design Video terminal jobs, in particular, are: the height of the working surface, the size of legroom, location requirements documents in the workplace (availability and sizes stand for documents, varying placement, the distance from the user's eyes to screen, document, keyboard, etc.), characteristics of the work chair, the requirements to the table surface.

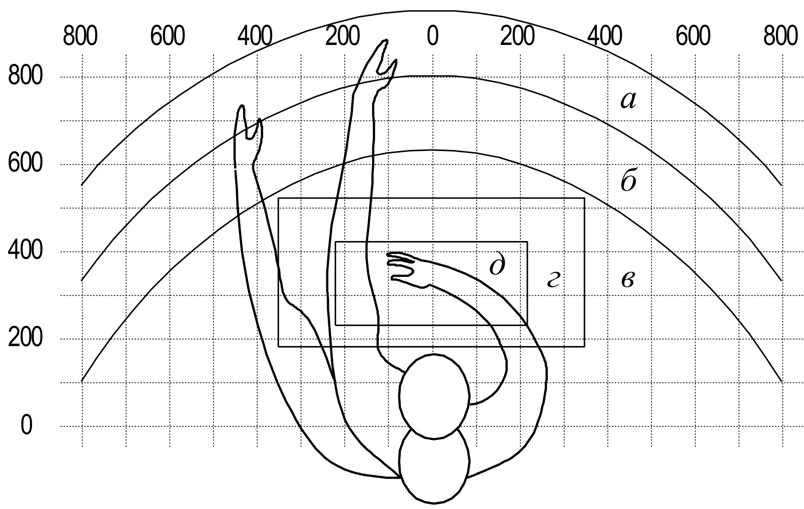
The main elements of the workplace and engineering are the Desk and chair. The main working position is the sitting position.

Working sitting posture causes minimal fatigue engineer. The rational layout of the workplace provides a clear procedure and the permanence of the placement of objects, tools and documentation. It is required to perform work more often located in the zone of easy reach of the workspace.

Motor field is space of the workplace, which can be a physical action of a person.

The maximum range of the hands is a part of the motor field workplace, limited arcs described by the maximally outstretched arms during their movement in the shoulder joint.

The optimal zone is a part of the motor field workplace, limited arcs described by the forearm when moving the elbow with support at the point of the elbow and with relatively immobile shoulder.



а - zone maximum distance;

б - the reach of the fingers at arm's length;

в - in area easy reach of the hand;

г - optimum space for rough manual work;

д - optimal space for fine Handicrafts.

Fig. 1. Zones of arm in horizontal surface

Optimal placement of items of work and documentation in the areas of distance:

The DISPLAY is located in zone а (center);

The SYSTEM UNIT is provided in the recess of the table;

KEYBOARD - in zone г/д;

"MOUSE" - in the right;

The SCANNER in the zone а/б (left);

The PRINTER is in zone а (right);

DOCUMENTATION: required when working in the area easy reach of palms, and in the drawers of table - literature, constantly unused.

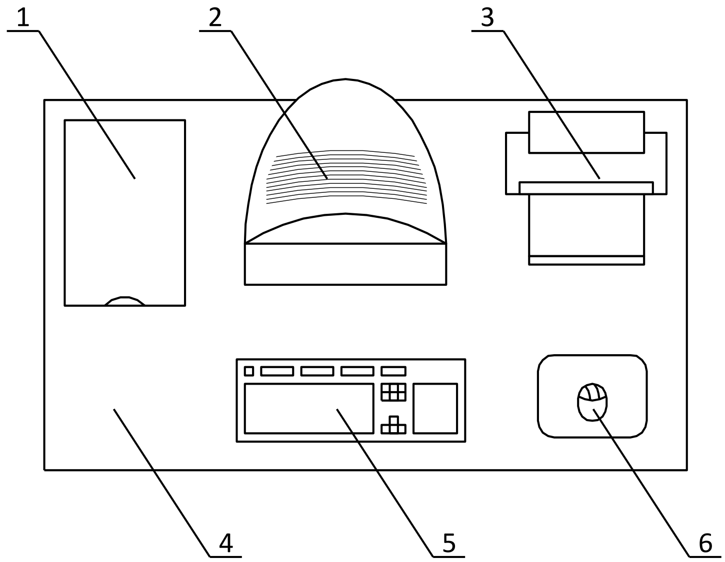


Fig. 2. Personal computer’s components

In Fig. 2 shows an example of placement of the main and peripheral components of a PC on the desktop programmer.

1 scanner, 2 – monitor, 3 – printer 4 – the surface of the desktop,

5 – keyboard 6 – manipulator of type "mouse".

For comfortable work Desk should satisfy the following conditions:

- the height of the table should be selected based on the ability to sit freely in a comfortable pose, if necessary, based on the armrests;

- the lower part of the table needs to be designed to be able to sit comfortably, was not forced to draw in the legs;

- the surface of the table must have the following properties, eliminates glare in the field of view of the programmer;

- the design of the table should have drawers (at least 3 for documentation, listings, stationery).

- the height of the work surface is recommended in the range of 680-760mm. The height of the surface onto which the keyboard is placed should be about 650mm.

Great importance is attached to the characteristics of the Desk chair. So, recommended seat height above floor level is in the range of 420-550mm. The seat surface is soft, the front edge rounded, and the back angle is adjustable.

It is necessary to include in the design the possibility of posting documents: at the side of the terminal, between the monitor and keyboard, etc. in addition, in cases where the video display is of low quality images, such as visible flicker, the distance from the eye to the screen make more (about 700 mm) than the distance from the eye to the document (300-450mm).Generally with a high quality image on the video display the distance from your eyes to screen, document and keyboard to be equal.

The screen position is determined by:

- reading distance of (0.6...0.7 m);

- angle reading, the viewing direction 20° below the horizontal toward the center of the screen, and the screen perpendicular to this direction.

Must also be capable of regulating the screen:

- height +3 cm;

- tilt from -10° to +20° relative to the vertical;

- in left and right directions.

An uncomfortable working position may have pain in the muscles, joints and tendons. The requirements for the operating posture of the user video terminal the following:

- the head should not be tilted more than 20°,

- shoulders should be relaxed,

- elbows - angle of 80°...100°,- forearms and hands in a horizontal position.

The reason for poor posture of users due to the following factors: there is a good stand for documents, the keyboard is too high, and documents - low, no place to put hands and arms, not enough legroom.

In order to overcome these drawbacks provide General advice: better mobile keyboard; must be provided with special devices for adjusting the height of the Desk, keyboard and screen and the palm rest.

Essential for productive and quality work at the computer to have the dimensions of the labels, the density of their placement, contrast ratio and brightness of the characters and background screen. If the distance from the eye of the operator to the display screen is 60...80 cm, the height of the sign shall be not less than 3mm, the optimal ratio of the width and height of the sign is 3:4, and the distance between the marks – 15...20% of their height. The ratio of the brightness of the screen background and characters should be from 1:2 to 1:15.

While using the computer, the physicians are advised to install the monitor at a distance of 50-60 cm from the eye. Experts also believe that the upper part of the video display should be at eye level or slightly below. When a person looks straight ahead, his eyes are opened wider than when he looks down. Due to this, the area is significantly increased, causing dehydration of the eyes. Besides, if the screen is mounted high and eyes wide open, disturbed function of blinking. This means that the eye does not close completely, not washed by the lachrymal fluid, do not receive sufficient moisture, leading to fatigue.

The creation of favorable working conditions and the right aesthetic design jobs in manufacturing is of great importance both to facilitate and to enhance its attractiveness, positive impact on productivity.

4.4. Development of measures of protection from dangerous and harmful factors

As measures to reduce noise it is possible to propose the following:

1. Veneer ceiling and walls with sound-absorbing material (reduces noise by 6-8 dB);
2. Shielding the workplace (raising of walls, diaphragms);
3. Installation in computer rooms equipment, producing minimal noise;
4. The rational layout of the room.

Protection from noise should be performed in accordance with GOST 12.1.003-83 "Noise. General safety requirements and sound insulation of enclosures shall meet the requirements of Chapter SNiP 23-03-2003 "Protection against noise. Design standards".

When protection against external radiation arising from work with display, take the following actions:

According to SanPiN 2.2.2/2.4.1340-03 for optimal health and maintaining health during the work shift must be installed regulated breaks – when 8-hour day duration 15 minutes every hour;

1. The display is set so that from the screen to the operator not less than 60-70 cm;
2. Must be used in displays with built-in protective screens.
3. Electrical safety technical ways and means:

Since all live parts of the computer are isolated, accidental contact with live parts is excluded.

To provide protection from electric shock when touching metal natcoweb parts that may be under stress as a result of damage to the insulation, it is recommended to use protective grounding.

Chassis ground of the computer is provided by summing the grounding conductor to the supply outlets. There must be grounding resistance of 4Ω, according to (PUE) for electrical installations with voltage up to 1000 V.

Organizational measures to ensure electrical safety:

The main organizational activity is instruction and training in safe methods of work, as well as a test of knowledge of safety rules and instructions in accordance with the position in relation to the work performed.

When performing unscheduled and scheduled maintenance of computing the following steps:

- Remove computer from network
- Voltage testing

After performing these steps we proceed to the repair of faulty equipment.

If the repair is carried out on live parts under voltage, execution of work is carried out by at least two individuals with means of electrical safety.

Fire safety. The fire in the study, can lead to very adverse consequences (loss of valuable information, property damage, loss of life, etc.), it is therefore necessary to identify and eliminate all causes of fire; to develop a plan of measures for the elimination of fire in the building; the plan of evacuation of people from buildings.

The causes of fire can be:

– malfunction wiring, sockets and switches which may cause a short circuit or breakdown of insulation;

– damaged (defective) electrical appliances;

– use indoor electric heaters with open heating elements;

– the occurrence of a fire due to a lightning strike to the building;

– fire building due to external influences;

– careless handling of fire or non-observance of fire safety.

Prevention of fire. Fire prevention is a complex of organizational and technical measures aimed at ensuring the safety of people on the prevention of fire, limiting its distribution and also creation of conditions for successful fire extinguishing. For the prevention of fire is extremely important proper fire risk assessment of buildings, identification of hazards and justification of the ways and means of protection.

Modern computers come with a very high density of elements of electronic circuits.

In close proximity to each other are arranged to the connecting cord, patch cords. When flowing over them electric current is allocated a significant amount of heat, which may result in raising the temperature to 80°-100°C, it is possible to melt the insulation of the connecting wires, their exposure, and, as a result, a short circuit.

For removal of excess heat from computers serve as ventilation and air conditioning. However, they can be an additional fire hazard to the building if the fire spread.

The premise computing laboratory for explosion safety concerns to the category (in accordance with the Federal law from July, 22nd, 2008 N 123-FZ "Technical regulations on fire safety requirements").

One of the conditions of fire safety is the elimination of possible ignition sources.

In the office of the ignition sources can be:

– faulty electrical faults in wiring, electrical outlets and switches. To eliminate the risk of fire for these reasons, it is necessary to identify and eliminate defects, carry out routine inspection and eliminate all faults;

– faulty electrical appliances. Necessary measures to prevent fire include the timely repair of electrical appliances, high-quality correction of damage that do not use faulty electrical appliances;

– space heating electric heaters with open heating elements. Open heating surface can cause a fire, as in the room are paper documents and reference materials in the form of books, manuals, and paper – flammable object. In order to prevent fire, do not use outdoor heaters indoors;

– short circuit in the wiring. In order to reduce the probability of fire due to short circuit it is necessary that the wiring was hidden.

– getting into the building from lightning. In summer during a thunderstorm, possibly a lightning strike might result in possible fire. To avoid this, it is recommended to install on the roof of the lightning arrester;

– non-observance of measures of fire safety and Smoking indoors can also lead to fire. To eliminate the ignition as a result of Smoking indoors is recommended to strictly forbid Smoking, and allow only in strictly designated place.

In order to prevent fire hold with engineers working in the room, fire drill, has to be familiarized between employees with fire safety rules, and to teach the use of primary fire extinguishing means.

In the event of a fire you must first disconnect the power, to call the fire Department, evacuate people from the premises in accordance with the evacuation plan and proceed to extinguish the fire with fire extinguishers. If there is a small hearth fire, you can use the means at hand for the purpose of preventing access of air to the object of fire.

In the laboratory are the primary means of fire suppression, a box of dry sand, water, asbestos blankets, manual powder extinguisher OP - 4. To prevent fire and fire prevention systematically conducted inspection of electrical circuits and equipment are detected early and eliminated the fault. The laboratory has developed an evacuation plan, which made available to the laboratory staff.

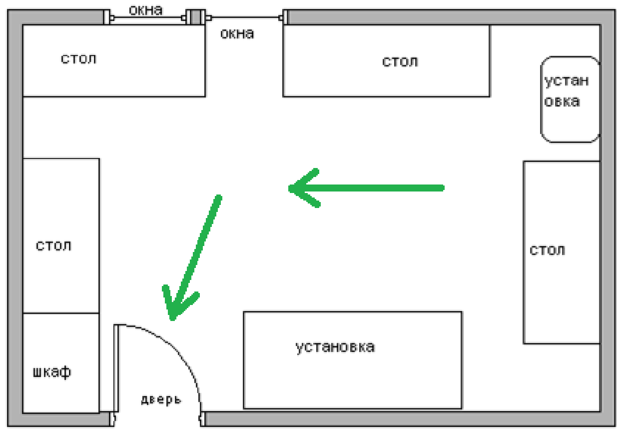


Fig. 3. The evacuation plan

4.5. Environmental Protection

Environmental protection is really important and meaningful process. That is why these issues are devoting a lot of time and attention. Environment is the complex of measures aimed at preventing the negative impact of human activity on nature, providing favorable and safe conditions of human life.

Creation of conditions for improvement of ecological conditions - the process is long, requires coherence and consistency of action. Priority in the environmental policy of the Russian Federation today the following questions:

- ensuring environmentally safe living conditions;
- rational use and protection of natural resources;
- ensuring environmental and radiation safety (MPE);
- the greening of industry;
- increase of ecological culture of society and the formation of ecological consciousness in humans.

Important role in the protection of the environment is given to the procedures for the rational placement of the sources of contaminants. These include:

1) making industrial enterprises of major cities and new construction in sparsely populated areas with unsuitable and unsuitable for agricultural use of land;

2) the optimum location of industrial enterprises taking into account the topography of the terrain and the wind rose;

3) establishment of sanitary protection zones around industrial plants.

4) the rational layout of the urban area, providing optimal environmental conditions for humans and plants.

In the environment play an important role in the quality of the environment designed to conduct systematic monitoring of the condition of the atmosphere, water and soil for the actual levels of pollution. The information obtained about the dirt allows you to quickly identify the causes of increasing concentrations of harmful substances in the environment and actively to fix them.

Environmental protection is a complex problem that requires the efforts of scientists of many specialties. Of particular importance is the quantitative assessment of the impact of environmental pollution and, above all, damage to the national economy of pollution. Protecting the environment from contamination at the present stage in addition to economic objectives are increasing social productivity and also includes socio-economic task of improving the conditions of human life, the preservation of his health.

To minimize the level of pollution emitted by the enterprises, it is necessary to make the following mandatory measures for the environmental protection (EP). Measures for environmental protection are:

1. The identification, assessment, permanent control and limitation of harmful emissions into the environment, creating environmental and resource-saving technologies and equipment.

2. The development of legal laws, legal acts on protection of the natural environment, as well as material incentives for compliance with these laws and environmental measures.

3. The prevention of environmental degradation and the environment from harmful and hazardous factors through the creation of dedicated areas (SPZ).

Non-waste technology is the most active form of protection of the environment from the harmful effects of industrial emissions. Under the concept of "soft technology" is understood as the set of activities in production processes from raw materials to ready-made products, thereby reducing to a minimum the amount of harmful emissions and reduces the impact of waste on the environment to an acceptable level. In this set of activities includes:

1) creation and implementation of new processes for products with the formation of the least amount of waste;

2) development of various types of closed technological systems and water cycles on the basis of methods of wastewater treatment;

3) development of systems for recycling of production waste into secondary materials;

4) creation of territorial-industrial complexes having a loop structure material flows of raw materials and waste inside the complex.

Until full implementation of non-waste technology important areas of greening of industrial production should be considered:

1) improvement of technological processes and development of new equipment with lower emissions of pollutants and waste into the environment;

2) the replacement of toxic waste on non-toxic;

3) replacement of non-recyclable waste recyclable;

4) the use of passive methods of environmental protection.

Passive methods of protection of the environment include a complex of measures to limit emissions from industrial production and subsequent recovery or disposal of waste. These include:

- treatment of wastewater from impurities;

- treatment of gaseous emissions of harmful impurities;
- the dispersion of harmful emissions into the atmosphere;
- suppress noise in its distribution;
- measures to reduce levels of infrasound, ultrasound and vibration in their ways of spreading;

Enterprises, individual buildings and facilities production processes that are sources of negative impact on the environment and human health, should be separated from residential buildings sanitary-protective zones.

References

1. Горбацевич А.Ф., Шкред В.А. Курсовое проектирование по технологии машиностроения. – М.: ООО ИД «Альянс», 2007. – 256 с.
2. Скворцов В.Ф. Основы размерного анализа технологических процес-сов изготовления деталей: Учебное пособие. –Томск: Изд. ТПУ, 2006. -100 с.
3. Справочник технолога машиностроителя. В 2-х томах. Т. 2/ под редакцией А. Г. Косиловой и Р. К. Мещерякова. – 4-е изд., перераб. И доп. – М.: Машиностроение. 1985. 496 с., ил.
4. Справочник технолога машиностроителя. В 2-х томах. Т. 2/ под редакцией А. Г. Косиловой и Р. К. Мещерякова. – 4-е изд., перераб. И доп. – М.: Машиностроение. 1986. 656 с., ил.
5. Анурьев В.И. Справочник конструктора машиностроителя: В 3 т. Т. 1. – М.: Машиностроение, 2001. – 920 с.: ил.
6. Мягков В.Д., Палей М.А., Романов А.Б., Брагинский В.А. Допуски и посадки. Справочник. В 2-х ч. Том 2. – Л.: Машиностроение, 1983. – 448 с.
7. Ансеров, М.А. Приспособление для металлорежущих станков / М.А. Ансеров. – 4-е изд., испр. и доп. – Л. : Машиностроение, 1985. – 656 с.
8. Курсовое проектирование деталей машин: Учеб.пособие для учащихся машиностроительных специальностей техникумов / С. А. Чернавский, К. Н. Боков, И. М. Чернин и др.— 2-е изд., перераб. и доп. — М.: Машиностроение, 1988. — 416 с.: ил.
9. Безопасность жизнедеятельности. Под ред. С.В. Белова. – М.: Высшая школа, 2002. – 357с.
10. Гигиенические требования к ВДТ, ПЭВМ и организации работы. Санитарные правила и нормы 2.2.2.542 – 96. – М., 1996
11. Методические указания по разработке раздела «Социальная ответственность» выпускной квалификационной работы магистра, специалиста и бакалавра всех направлений (специальностей) и форм обучения ТПУ/Сост. Ю.В. Бородин, В.Н. Извеков, А.М. Плахов – Томск: Изд-во Томского политехнического универ-та, 2014. – 11 с.Основы противопожарной защиты предприятий ГОСТ 12.1.004 и ГОСТ 12.1.010 – 76.
12. Охрана окружающей среды. Под ред. С.В. Белова. – М.: Высшая школа, 1991.
13. Правила устройства электроустановок. Минэнерго СССР, 6-е издание – Энергоатомиздат, 1996. – 640с.