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# Develop A Group Processing Parts Of A Body Revolution, Design A Gps And Develop A Group Operation For Processing Part On A CNC Machine

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## Abstract

The goal of any production is the long-term and profitable satisfaction of all requests for its products. Proceeding from this, extensive mechanization and automation of production processes, large-scale introduction of new equipment and progressive technology, Flexible Production Systems (FPS), and training of a new type of personnel, who fully perceived the concepts of flexible automated production and are competent in their subject area, are envisage. Each of the automation tools has its own area of rational use, where they are most effective. The main goal of the creation of the GPS is to ensure an automatic continuous principle of continuous production with serial production of products to quickly and break even stops the production of one product and start producing a new product in a short time. The introduction of the group method of manufacturing and processing parts made it possible to reduce the time required for the technical preparation of the production of new products, to increase labor productivity, to ensure a reduction in the cost of production, to raise the technical culture of production and the level of its organization.

**Keywords:** *NC/CNC Machine, Body Revolution, Design of GPS, Group operation for CNC Machine,*

## 1. INTRODUCTION

A set of symbolically coded instrument arranged sequentially called a part program feed to machine control unit (MCU) is called NC/CNC Machine. CNC is an NC machine with added feature of an onboard computer, which is referred to as the Machine Control Unit or MCU. In addition, CNC carving machine for sculptured surface. Detailed study from basics has been carried out with an idea for building structure was developed. **[1]** Studied effect of preloading of linear guides on dynamics characteristics of vertical column spindle system which is of importance for enhancing the structural performance of a vertical milling machine**. [2]** We observed the primary low productivity is large mass of the moving parts of machine tools which cannot afford high acceleration and deceleration encountered during operation. This composite structure reduced the weight of the vertical and horizontal slides and increased damping by 1.5 to1.7 times without sacrificing the stiffness**. [3]** Analyzed the influence of configuration parameter on dynamics characteristic on machine tools in working space, the configuration parameter have been suggested based on the orthogonal experiment method. **[4]** The production of machining stability is of great importance for the design of a machine tool capable of high precision and high-speed machining, the machining performance is determined by the frequency characteristic of machine tool structure and the dynamics of the cutting process in term of a stability lobe diagram**. [5]** The state of the art in machine tool main spindle unit with focus on motorized spindle units for high speed and high performances cutting. Detailed information is provided about main components of spindle units regarding the historical development recent challenges and future trend. **[6]** observed that ram is a very important component of super heavy duty computer numerical control (CNC) floor type boring-milling machine and deformation of ram is a significant source, causing error in machining process**. [7]** Considered majority of the chatter vibration is high-speed milling which originates due to flexible connection at the tool holder-spindle and tool-holder interface.**[8]** described some interesting result about the tool wear. In a machining process of the North African Aleppo pine the correlation between the tool wear and cutting forces shows that, the running period is about 850m of cutting length**.[9]** observed that chatter stability of machine tool is dependent on the dynamics behavior of spindle systems. The alternative method was presented to predict the chatter stability lobes of high-speed milling with consideration of speed-varying spindle dynamics. **[10]** Highlighted that while designing CNC machine tools it is important to consider the dynamics of the control, the electrical components and the mechanical structure of the machine simultaneously**. [11]** presented an integrated approach for designing large milling machines, taking both mass reduction of mobile structure and the maximum material removal ratio into account**.[12]** described the development of a three-degree of free (DOF) desktop reconfigurable machine tool. **[13]** Discussed the development and performance evaluation of high-speed, 3-axis milling machine using a novel parallel kinematics x-y table. The x-y table is based on an inversion of the Oldham coupling. **[14]** Developed reconfigurable manufacturing system (RMS) paradigm address challenges in the design of manufacturing system and equipment that will meet the demands of modern manufacturing. **[15]** Stated that modularity and configurability of the building blocks of modern manufacturing system have to be considered when evaluating their performances. **[16]** the productivity of these machines is three time higher than in machines of the same type without software control, and the need for production space is three times less.

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## 2. GROUPING OF PRODUCTION OBJECTS

Initial data for design

Part name - **Multiple Type Gears** (Pinion shaft)
Dimensions: $D_{min}$ = 200mm; $D_{max}$ = 220mm; $L_{min}$ = 900mm; $L_{max}$ = 1000mm;
Program – 180; names of parts 100 pieces in the series

### 2.1 Grouping of parts.

The development of the classification of parts is based on the principle of maximizing the technological stability of each group; technological stability predetermines the repetition of an identical or similar complex of transitions. This principle will be used for all groups of parts without exception. Along with this, when grouping, it is necessary to take into account other factors, the most important of which are:

- Grouping based on the dimensional proximity of parts;
- Grouping based on the non-usability of the fixture;
- Grouping based on common stock;
- Grouping according to the method of narrow specialization of machine tools

The following are details that are included in one group for almost all of these factors (Figure 1) we draw a complex part containing all the elements that are on the Parts of the group (Figure 2). All surfaces will be treated.

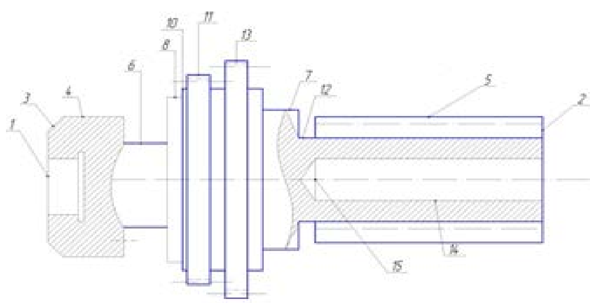

Figure 1 Detail A

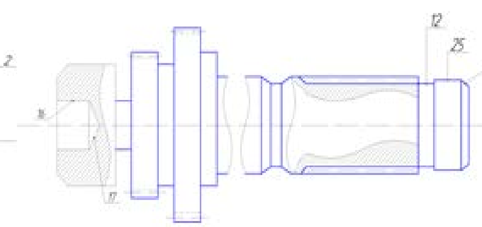

Figure 2 Detail B

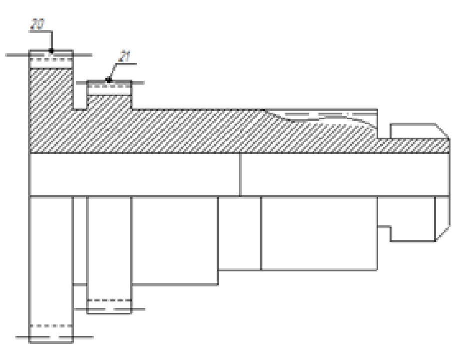

Figure 3 Detail C

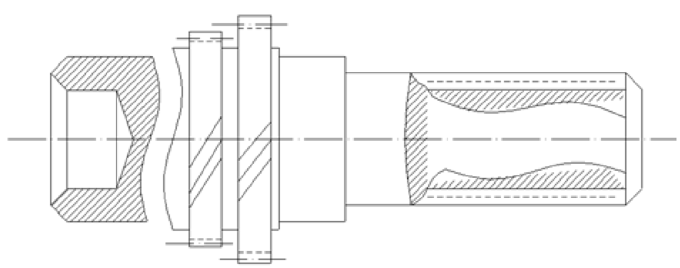

Figure 4 Detail D

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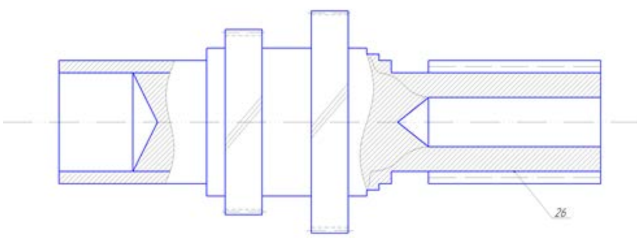


Figure 5 Detail E

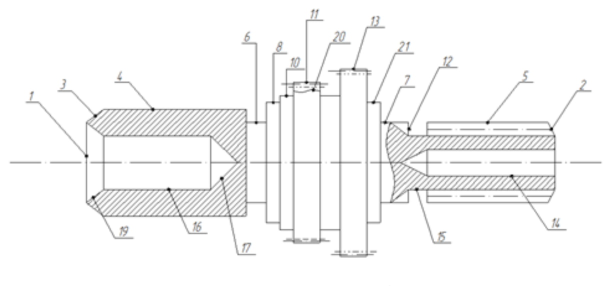


Figure 6 Complex details

## 3. DEVELOPMENT OF PRODUCTION OBJECTS FOR MANUFACTURABILITY

In order to unify the design of parts processed in GPS, which will ultimately lead to a reduction in the range of tools and a decrease in the cost of processing, the part is analyzed for manufacturability. For this purpose, we draw up a correspondence matrix.

Table 1

**Matrix of conformity of structural elements**

| No Element | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | ∑j |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Detail A | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| Detail B | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 14 |
| Detail C | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 10 |
| Detail D | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 13 |
| Detail E | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 8 |
| ∑i | 4 | 5 | 4 | 4 | 4 | 1 | 4 | 1 | 4 | 3 | 5 | 2 | 3 | 3 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| $C_D$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 21 |

Based on the table, we conclude that the adopted details of the group are technological, and the structural elements cannot be changed.

### 3.1 Group Parts Classifier

Part Type: (Shaft-Gear), Type: Multi-End Gears, Part material: (steel 40X), Blank Rental: Sizes: 200-220mm, Length 900-1000mm, highest machining accuracy: IT. 7, the smallest roughness: Ra - .1.25

## 4. FORMATION OF THE STRUCTURAL AND TECHNOLOGICAL SCHEME OF PROCESSING

The development of a technological process should be combine with the development of an appropriate production organization, which includes the principles laid down in the production technology, the structure of workshops and their connections, the procedure for preparing production, the procedure for operational planning and the movement of parts during processing, etc. During the design of technological processes in the conditions of flexible automated production, it is necessary to pay

attention to the maximum use of CNC machines that can be easily integrated into the GPS. In this case, the task of creating a GPS is reduced to the integration of the machine tool control system and the design of a new transport storage system. To form a structural and technological scheme of processing, we represent technological route of processing a complex part.
00 - Procurement operation,
05 - CNC lathe,
10 – Slot milling operation (milling the slot pub 26).
15 - Tooth-cutter milling (milling teeth 27),
20 - Teeth – planer (planning teeth 28),
25 - Crank-grinding (grind the necks of the pob (4 and 7),
30 – Control

Table 2

**Matrix for the presented processing process of a complex part**

| № Operations | 00 | 05 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| Detail A | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| Detail B | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| Detail C | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| Detail D | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Detail E | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| Complex Detail | 1 | 1 | 0 | 0 | 1 | 1 | 1 |

Based on this table, we can conclude that all the details presented are process along the same route.

## 5. DEVELOPMENT OF A GROUP TECHNOLOGICAL OPERATION

The development of an operational technological process for each detail operation provides for the establishment of an optimal sequence of transitions, taking into account the minimum number of tool reinstallations. We draw up an operational technological process for a complex part:

### 5.1 Development of the Structure of the Operation

#### Mill A

**1**. Install the work-piece.
**2.** Sharpen (item 2) roughly and cleanly.
**3**. Sharpen roughly and cleanly the chamfer,
**4.** Sharpen surface five roughly and cleanly.
**5.** Sharpen the groove (item 12) roughly and cleanly.
**6**. Sharpen surface seven roughly and cleanly.
**7.** Sharpen surface nine roughly and cleanly**.**
**8**. Sharpen surface 13 roughly and cleanly.
**9**. Bore the chamfer (item 14).

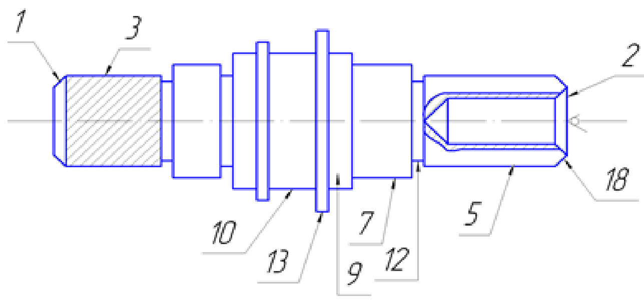


Figure 7 Mill A

**Mill B**

**10**. Reinstall the work-piece.
**11**. Trim the butt end (item 1) roughly and cleanly.
**12**. Sharpen roughly and cleanly the chamfer (item 3).
**13.** Sharpen and finish the surface 4.
**14**. Roughly, cleanly sharpen the groove (item 6).
**15**. Sharpen and rough the surface eight.
**16**. Roughly, cleanly sharpen the groove (item 10).
**17**. Drill a hole (item 16).
**18**. Bore a chamfer (item 19).
**19**. Remove the work-piece.

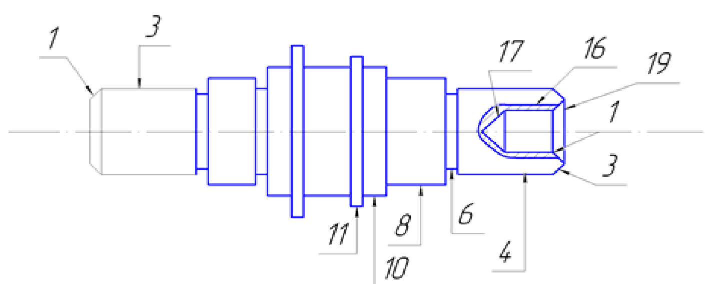


Figure 8 Mill B

## 5.2 Calculation of Cutting Conditions

Initial data

Detail part name – shaft, Material - Steel 40X,
Surface Precision - IT (7...12);
Surface Roughness: 1,2,3,4,5,6,7 - Ra = 1.2,
Blank-Billet - casting (Standard Accuracy IT 14.
Surface Condition - No crust;
Weight - 750kg; Allowance for Surface Finishing 6mm for all surface machines

Figure 9 CNC LATHE: **Model DMTG CAK50**

Table 3

**CNC LATHE: Model DMTG CAK50**

| **Parameter Name** | **Dimension** | **Parameter value** |
|---|---|---|
| Work zone | Work-piece diameter over bed, | 500mm |
| | Maximum processing length, | 2500mm |
| | Max. shaft type product diameter | 650mm |
| | Max. diameter of a disk type product, | 850mm |
| Spindle | Chuck diameter | 15" |
| | Spindle end | ISOA2-11 |
| | Spindle speed range | 20-2000rpm |
| | Main drive motor power | 30KW |
| | Spindle bore | 100mm |
| Moving and feeding | Movement along the X / Z axes | 400/2660mm |
| | Rapid movements of the X and Z axes | 12/16 m/min |
| | Working feed | 0-5000mm/min |
| | Torque on servo motor shaft X / Z | 22/30NM |
| | X / Z Axis Positioning Accuracy | 0.016/0.04 |
| Miscellaneous | CNC system | Fanuc 0i-T |
| | Bed tilt angle | 70° degree |
| Overall dimensions of the machine | Length | 6450mm |
| | Width | 2358mm |
| | Height | 2600mm |
| | Net weight | 14000kg |

### 5.2.1 Selection of processing stages

For surfaces 1, 2, 3, processing is carried out in two stages: - Rough; - Finishing Surfaces 4,5,6,7 are bored.

### 5.2.2 Choice of cutting depth

For rough surface treatment - 3.0mm, for surface finishing - 1.0mm

### 5.2.3 Tool selection

On the CNC DMTG CAK50 machine, cutters with a holder section of 40*50mm are used; the thickness of the carbide insert is 6.4mm. We accept the rhombic shape of the plate from the hard alloy VK6 - for the rough stage of processing, for the finishing stage - VK4 The method of fastening the plate is a wedge with a tack for the roughing stage of processing and a two-arm tack for a notch for the finishing stage of processing We choose the angles: the main angle in the plan φ = 60 °, the auxiliary angle in the plan φ = 32°. For the roughing stage of processing: clearance angle a = 6°, rake angle γ = 8°; the shape of the front surface is flat with a chamfer; f = 0.5mm, p = 0.03mm, $r_o$ = 1.0mm For the finishing stage of processing, the clearance angle is a = 8 °, the rake angle γ = 12 °; the shape of the front surface is flat with a chamfer; f = 0.5mm, p = 0.03mm, $r_o$ = 1.0mm. The standard period of tool durability is T = 45 min

### 5.2.4 Choice of feeds

When turning a part with a diameter of 900mm with a depth of cut up to t = 5 mm, it is recommended to feed $\mathbf{S_{ot}}$ = 1.0mm/rev for roughing, for finishing $S_{ot}$ = 0.6mm/rev. Correction factor for the feed depending on the tool material $\mathbf{K_{Si}}$ = 1.0 for roughing. Correction factors for the feed and for the roughing stage of processing depending on section of the tool holder $\mathbf{K_{Sd}}$ = 1.0; flow rate of the cutting part $\mathbf{K_{Sh}}$ = 1.0; mechanical properties of the processed material $\mathbf{K_{Sm}}$ = 0.9;Work-piece installation diagrams $\mathbf{K_{Sy}}$ = 0.8; the state of the surface of the work-piece $\mathbf{K_{Sn}}$ = 1.0; geometric parameters of the cutter $\mathbf{K_{S\varphi}}$ =1.25; rigidity of the machine $\mathbf{K_{Sj}}$ = 1.1. Feed for roughing: $\mathbf{S_o}$ = ($S_{ot}$* $K_{Si}$* $K_{Sd}$* $K_{Sh}$* $K_{Sm}$* $K_{Sy}$ * $K_{Sn}$ * $K_{S\varphi}$* $K_{Sj}$ * $S_o$) = 1.0 *1.0*1.0* 1.0*0.9 *0.8 *1.0 * 1.2*1.1 = 0.99mm /rev. The calculated feeds for the roughing stage of machining are checked by the axial $P_x$ and radial $P_y$ components of the cutting force, the permissible strength of the machine feed mechanism. Tabular values of the constituent cutting forces. When roughing the surface with a depth of cut up to t = 4mm and feed $S_o$ = 1.0mm /rev; $P_{xt}$ = 2180H; $P_{yT}$ = 420H. Correction factors for cutting forces for changed conditions depending on mechanical properties of the processed material $K_{Rmx}$ = $K_{Rmy}$ = 1.2; the main angle in terms of $K_{R\varphi x}$ = 0.85, $K_{R\varphi y}$ = 1.5; the main rake angle $K_{P\gamma x}$ = 0.9; the angle of inclination of the cutting edge $K_{P\lambda y}$ = 1.0; finally, the components of the cutting force are determined by the formulas: ($P_x$ = $P_{xT}$ * $K_{PMx}$ * $K_{P\varphi x}$ * $K_{P\gamma x}$ * $K_{P\lambda x}$); (Py = $P_{yT}$ * $K_{Pmy}$ * $K_{P\varphi y}$ * $K_{P\gamma y}$ *$K_{P\lambda y}$ ; Px = 2180 * 1.2 * 0.85 * 0.9 * 1.0 = 2001H; Py = 420 * 1.2 * 1.5 * 0.9 * 1.0 = 680H. When finishing the surface with the feed $S_o$ = 0.6 mm /rev, the correction factors for the cutting forces for the changed conditions, depending on mechanical properties of the processed material $K_{Sm}$ = 0.9; work-piece installation diagrams $K_{Sy}$ = 0.8; tool nose radius $K_{Sr}$ = 1.0; quality of the size of the work-piece $K_{Sk}$ = 1.0; Feed for finishing stage: So = Sot • KSm • KSy • KSr • KSk So = 0.6 • 0.9 • 0.8 • 1.0 • 1.0 = 0.43mm /rev

### 5.2.5 Choice of cutting speed

For the roughing stage of processing with a depth of cut up to t = 3mm and feed So = 1.00mm rev, cutting speed $\mathbf{V_t}$ = 168m/min. Correction factor for the roughing stage, depending on the tool material: $\mathbf{K_{Vi}}$ = 0.85. Correction factors for cutting speed at roughing and finishing stages of processing for changed conditions, depending on Group of material machinability $\mathbf{K_{Vc}}$ = 1.0; Type of treatment $\mathbf{K_{Vo}}$ = 1.0; Machine rigidity $\mathbf{K_{Vj}}$ = 1.1; Mechanical properties of the processed material $\mathbf{K_{Vm}}$ = 0.85; Geometric parameters of the cutter $\mathbf{K_{V\varphi}}$ = 1.2; Period of life of the cutting part $\mathbf{K_{V\tau}}$ = 1.0; the presence of cooling $\mathbf{K_{Vzh}}$ = 1.0.The general correction factor for cutting speed is calculated by the formula: $K_V = K_{Vi} * K_{Vc} * K_{Vo} * K_{Vj} * K_{Vm} *K_{V\varphi} * K_{V\tau} * K_{Vzh}$. Correction factor for cutting speed for the roughing stage: $K_V$ = 0.85 *1.0 *1.0 * 1.1 *0.85 * 1.2 *1.0 * 1.0 = 0.95Finally, the cutting speed at the roughing stage of processing is determined by the formula: $V = V_t * K_t$ = 168 *0.95 = 159.5m/min. The cutting speed for the finishing stage of processing is determined at t = 1mm and the feed $S_o$ = 0.60mm / rev cutting speed Vt = 290m /min. Correction factor for the finishing stage of machining, depending on the tool material: $K_{Vi}$ = 0.45 the general correction factor for cutting speed is calculated by the formula: $K_V = K_{Vi} * K_{Vc} * K_{Vo}* K_{Vj} * K_{Vm} * K_{V\varphi} * K_{V\tau} * K_{Vzh}$. Correction factor for cutting speed for finishing stage: $K_V$ = 0.45 * 1.0 * 1.0 * 1.1 *0.85 * 1.2 * 1.0 * 1.0 = 0.51. Finally, the cutting speed at the finishing stage of processing is determined by the formula: $V = V_t$ * Kt = 290 * 0.51 = 147.9m /min.

### 5.2.6. Spindle speed

For the roughing stage: We take the rotational speed of the machine, mph = 60min-1.Then the actual cutting speed. For the finishing stage: We accept the rotational speed of the machine, mph = 50min-1.Then the actual cutting speed to obtain the roughness parameter Ra = 6.3 µm when processing gray cast iron with a cutting speed V = over 100 m / min with a cutter with a tip radius $r_o$ = 1.0 mm, it is recommended to feed $S_{ot}$ = 0.55 mm / rev. Correction factors for the feed depending on the roughness parameter of the machined surface for the changed conditions, depending on Mechanical properties of the processed material $K_{Sm}$ = 1.1; Instrumental material KSi = 1.0; Type of processing $K_{So}$ = 1.0; the presence of cooling $K_{Szh}$ = 1.0.Finally, the maximum allowable feed according to the roughness parameter for the finishing stage of processing is determined by the formula: $So = S_{ot} * K_{Sm} * K_{Si} *K_{So} * K_{Szh}$. $S_o$ = 0.55 * 1.1 * 1.0 *1.0 * 1.0 = 0.61mm / rev. The feed for the finishing stage of processing, calculated earlier $S_{ot}$ = 0.43 mm / rev, does not exceed this value $S_{ot}$ = 0.61 mm / rev.

### 5.2.7 Checking the selected modes according to the power of the drive of the main movement

For the roughing stage of machining with a depth of cut (t) = 4mm and a feed $S_o$ = 0.61mm / rev, the tabular cutting power $N_t$ = 7.8kW. For finishing stages of processing, the power check is not carried out. Correction factor for power depending on the hardness of the processed material KN = 1.05. The tabular cutting power is corrected by the formula: At the rough stage of processing:

### 5.3. Determination of unit time norms.

$T_{pc} = (T_o + T_v) * (1.08 \div 1.22)$. The auxiliary time consists of the components, the choice of which carried out according to [2],$T_V$. Mouth = 5.3 min, $T_V$. op. = 0.15 + 0.03 = 0.18 min, $T_V$ from = 0.1 + 0.05 + (2 * 0.14 + 2 * 0.16) = 0.75 min, $T_v = T_v$. mouth + $T_V$. op. + $T_V$. Out. = 5.3 + 0.18 + 0.75 = 6.23 min;

### 5.4 Determine the processing time of part B at each operation.

**Mill end faces 1:**
S = 0.61 mm/rev,
V = 159.5 m/min,

$$n = \frac{1000 * V}{\pi * D} = \frac{1000 * 159.5}{3.14 * 450} = 112.89\, mm/\min$$

$$S_{min} = S * n = 0.61 * 112.89 = 68.86 mm/min,$$

$$t_1 = \frac{l_{\text{px}} + l_{\text{пер}}}{S_{min}} = \frac{150+5}{68.86} = 2.25 \text{min}.$$

**Turning hemisphere 3:**
S=0.61mm/rev
V=159.5m/min

$$n = \frac{1000 * V}{\pi * D} = \frac{1000 * 159 * 5}{3.14 * 700} = 72.6 \text{ mm/min},$$

$$S_{min} = S * n = 0.61 * 72.6 = 44.29 \text{ mm/min},$$

$$t_2 = \frac{l_{\text{px}} + l_{\text{пер}}}{S_{min}} = \frac{125+5}{44.29} = 2.94 \text{min}.$$

**Boring inner hole 5:**
S=0.61mm/rev,
V=159.5m /min,

$$n = \frac{1000 * V}{\pi * D} = \frac{1000 * 159.5}{3.14 * 150} = 169.3\, rpm,$$

$$S_{min} = S * n = 0.61 * 169.3 = 103.28 \text{ mm/min},$$

$$t_3 = \frac{l_{\text{px}} + l_{\text{пер}}}{S_{min}} = \frac{250+10}{103.28} = 2.52 \text{min}.$$

**Internal groove boring *7:***
S=0.61mm/rev
V=159.5m/min,

$$n = \frac{1000*V}{\pi*D} = \frac{1000*159.5}{3.14*400} = 126.97\text{rev/min},$$

$S_{min}$= S * n=0.61*126.97=77.46 mm/min

$$t_4 = \frac{l_{\text{px}}+l_{\text{пер}}}{S_{min}} = \frac{30}{77.46} = 0.38\text{min}.$$

**Mill end faces 2:**

S=0.61 mm/rev

V=159.5 m/min

$$n = \frac{1000*V}{\pi*D} = \frac{1000*159.5}{3.14*450} = 112.89\text{rev/min},$$

$S_{min}$ = S * n=0.61*112.89= 68.86mm/min

$$t_5 = \frac{l_{\text{px}}+l_{\text{пер}}}{S_{min}} = \frac{150+5}{68.86} = 2.25\text{min}.$$

**Turning hemisphere 3**

S=0.61 mm/rev,

V=159.5 m/min

$$n = \frac{1000*V}{\pi*D} = \frac{1000*159.5}{3.14*700} = 72.6\text{rev}/min,$$

$S_{min}$ = S * n=0.61*72.6=44.29mm/min,

$$t_6 = \frac{l_{\text{px}}+l_{\text{пер}}}{S_{min}} = \frac{125+5}{44.29} = 2.94\text{min}.$$

$T_o=t_1+t_2+t_3+t_4+t_5+t_6$ =2.25+2.94+2.52+0.38+2.25+2.94=13.28min,

$T_{op}$ = $T_o$*1.2=13.28*1.2=15.94min.

$T_{vp.}$=6.23min

$T_{pc}$ =($T_o$+$T_{vp.}$)*1.1= (15.94+6.23)*1.1=24.38min

**Radial drilling 1) drilling hole 8**

S=0.35mm/rev,

V=105.9m/min,

$$n = \frac{1000*V}{\pi*D} = \frac{1000*105.9}{3.14*400} = 79.6\text{rev/min},$$

$S_{min}$ = S * n=0.35*79.6=27.89mm/min,

$$t_2 = \frac{l_{\text{рх}}+l_{\text{пер}}}{S_{min}} = \frac{115+5}{27.89} = 4.31\text{min}.$$

$T_{\text{оп}} = T_o*1.2=4.31*1.2=5.18$

$T_{vp.}$=6.23min

$T_{pc.}=(T_o+T_{vp.})*1.1= (5.18+6.23)*1.1=12.56$min

**Defining a batch run program**

$$n_{pr.zap} = \frac{F_d * K_{gr} * K_{vp}}{K_{30} * \sum T_{pc}} = \frac{10500 * 10 * 1.1}{50 * 36.94} = 69.17 \approx 70\text{pc}$$

**5.5 Determine the pieces-calculation time for each operation**

05 $T_{pc}$.-cal. = Tpc + 1=24.38 + 1 = 25.38min

10 $T_{pc}$.-cal. = Tpc + 1=12.56 + 1 = 13.56min

$$\sum T_{pc-cal}=25.38+13.56=38.94\ min$$

Table 4

**Time of automatic work according to the program**

| Section of the trajectory and № Tools in the previous and working position | Z-axis increment | X-axis increment | Length of the intersection of the trajectory | Minute feed on site | Main time of automatic work | Machine-auxiliary time |
|---|---|---|---|---|---|---|
| | $\Delta Z$, мм | $\Delta X$, мм | $L_i$, мм | $S_м$, мм/min | $T_o$,min | $T_{MB}$, min |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Instrument 1** | | | | | | 0,83 |
| 0-1 | -5 | -130 | 131 | 8000 | | 0,016 |
| 1-2 | 0 | -150 | 150 | 68,86 | 2,17 | |
| 2-3 | 1 | 0 | 1 | 8000 | | 0,0001 |
| 3-4 | 0 | 150 | 150 | 8000 | | 0,019 |
| 4-5 | -1 | 0 | 1 | 44,29 | | 0,023 |
| 5-6 | -125 | 125 | 196,25 | 44,29 | 4,43 | |
| 6-7 | 5 | 0 | 5 | 8000 | | 0,0006 |
| 7-0 | 130 | 5 | 131 | 8000 | | 0,016 |
| **Instrument 2** | | | | | | 0,83 |
| 0-8 | -5 | -205 | 206 | 8000 | | 0,026 |
| 8-9 | -100 | 0 | 100 | 103,28 | 0,97 | |
| 9-10 | 0 | -25 | 25 | 103,28 | 0,24 | |
| 10-11 | -110 | 0 | 110 | 103,28 | 1,07 | |
| 11-12 | 0 | -50 | 50 | 103,28 | 0,49 | |
| 12-13 | -50 | 0 | 50 | 103,28 | 0,49 | |
| 13-14 | 0 | -10 | 10 | 8000 | | 0,0013 |
| 14-15 | 265 | 0 | 265 | 8000 | | 0,33 |
| 15-0 | 5 | -205 | 206 | 8000 | | 0,26 |
| **Instrument 3** | | | | | | 0,83 |
| 0-16 | -5 | -220 | 221 | 8000 | | 0,028 |
| 16-17 | -70 | 0 | 70 | 8000 | | 0,009 |
| 17-18 | 0 | 70 | 70 | 77,46 | 0,91 | |
| 18-19 | -30 | 0 | 30 | 77,46 | 0,39 | |
| 19-20 | 0 | -60 | 60 | 77,46 | 0,77 | |
| 20-21 | 100 | 0 | 100 | 8000 | | 0,013 |
| 21-0 | 5 | 220 | 221 | 8000 | | 0,028 |
| **Instrument 4** | | | | | | 0,83 |
| 0-22 | -5 | -130 | 131 | 8000 | | 0,016 |
| 22-23 | 0 | -150 | 150 | 68,86 | 2,17 | |
| 23-24 | 1 | 0 | 1 | 8000 | | 0,0001 |
| 24-25 | 0 | 150 | 150 | 8000 | | 0,019 |
| 25-26 | -1 | 0 | 1 | 44,29 | | 0,023 |
| 26-27 | -125 | 125 | 196,25 | 44,29 | 4,43 | |
| 27-28 | 5 | 0 | 5 | 8000 | | 0,0006 |
| 28-0 | 130 | 5 | 131 | 8000 | | 0,016 |
| | | | | | **18,53** | **4,3987** |

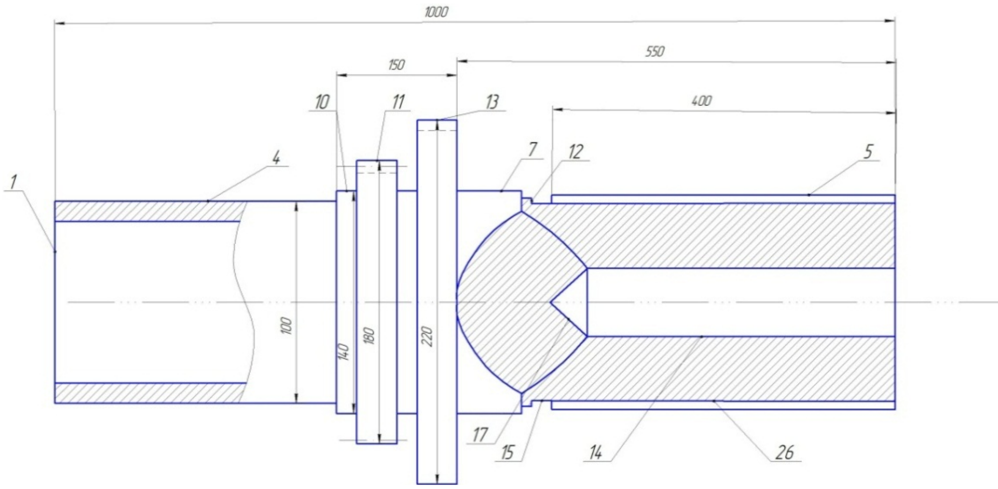


Figure 10 Sketch of the part

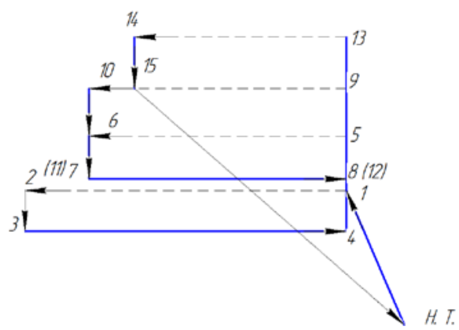


Figure 11 Diagram of tool movement during surface treatment 2.3

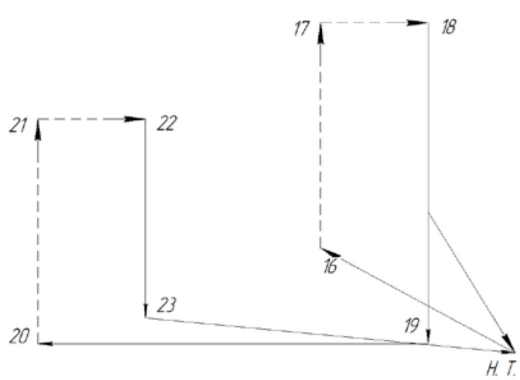


Figure 12 Development of a control program

N001S1287F0, 28T1*
N002X100Z5*
N003Z-400*
N004X105*
N005Z400*
N006X65*
N007Z-220*
N008X50*
N009-195*
N010X55*
N011Z195*
N012X45*
N013Z-5C5*
N014X55Z-190*
N015X40*
N016X110*
N017Z225*
N018S104F0, 48T1*
N019X50Z-5*
N020Z200*
N021X45C5T2*
N022X50*
N023Z-195*
N024X110*
N025Z-205*
N026X65*
N027Z-220*
N029M02*

## 6. CALCULATION OF THE AMOUNT OF EQUIPMENT

The number of machines is calculated using the formula: $C_i = \frac{T_{pc-Cal} * n}{F_d * К_з}$

Where $К_з$ – co-efficient load factor. Raven 0.8...0.85;

*n* - Given program, *n* = 180*100 = 18000 (pieces);

$F_\partial$ - valid annual fund of equipment operation time (4015 hours).

$$C_{05} = \frac{25.38 * 18000}{4015 * 0.8 * 60} = 2.17 \approx 3\, machine$$

$$C_7 = \frac{13.56 * 18000}{4015 * 0.8 * 60} = 1.45 \approx 2\, machine$$

We accept the number of machines - 5 pieces these are only lathes

**6.1 The choice of means of the transport and storage system**

Calculation of the number of cells in the warehouse. The main characteristic of a warehouse is its capacity, i.e. the number of cells or devices of the satellites necessary for the full load of the machines The maximum number of parts for installations of various types of parts is calculated:

$$n_{cell} = \frac{f_d * n * K}{T_N * N} = \frac{305 * 5 * 1.1}{1 * 8.3} = 202.1 \approx 203\, cell$$

$F_d$ - the actual monthly fund of the machine tool (305 hours).
n - The number of machines included in the GPS (6 pieces).
K - Coefficient taking into accounts the stock of cells (1, 1).
$T_N$ is the average monthly labor intensity of processing one work-piece unit (1 hour).N = 100 / 12 = 8,3pcs. - N = 100/12 = 8.3 pcs. - The average monthly program for the manufacture of parts of the same name

## 7. LAYOUT OF THE PRODUCTION UNIT

The initial data for the development of the layout of the GPS are the following values: coordinates of transport routes, the number of warehouses and their overall dimensions, the number and dimensions of the machines to be placed and their orientation relative to the transport line, the number of dimensions and coordinates of unacceptable areas in which equipment must not be placed (for example, hatches, ventilation ducts, columns, walkways). In the process of developing the layout, it is necessary to arrange the equipment in such a way as to minimize transport costs, which are characterized by the total mileage vehicles (km / year). The task of creating an optimal layout is solved by enumerating several options and evaluating them by the length of the vehicle run. To do this, it is recommended to draw areas on a sheet of paper at a certain scale, shade the unacceptable areas and move layouts of equipment cut from thick paper on the same scale. Machines requiring high transport intensity should be located closer to the warehouses. When developing the layout, the requirements of labor protection and safety measures should be taken into account.

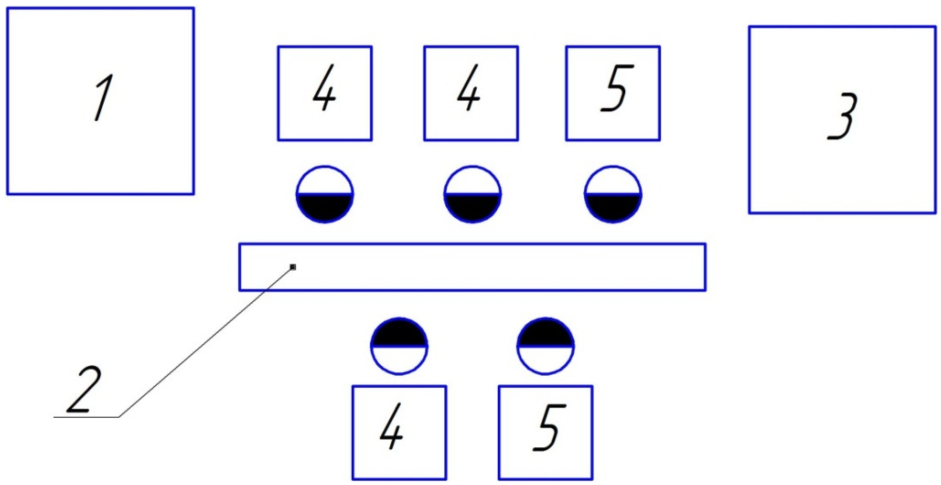


Figure 13 - Layout of the production unit

**1** - Stock warehouse;
**2** - Conveyor;
**3** - Warehouse for finished parts;
**4** - CNC turning and boring machine;
**5** - Radial drilling machine

## CONCLUSION

The technological preparation of the GPS for mechanical processing of 180 types of parts of the type - discs with a central through-hole, having curved ledges, 100 pieces of parts of each name, was carried out. A complex part was developed that includes all surfaces of the group's parts. The routing and operational technological processes of machining a complex part have been compiled. Control programs for processing a complex part have been compiled. The means of the transport and storage system were selected; a plan of the production unit was drawn up.

## CONFLICTS OF INTEREST

On behalf of all authors, the corresponding Author states that there is no conflict of interest in the paper

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