NATIONAL TECHNICAL UNIVERSITY OF UKRAINE

"IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE"

Institute of Mechanical Engineering

Department of Manufacturing Engineering

Head of the Department

________ Olga KHOLYAVIK

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Bachelor Thesis

according to educational-professional program

" Manufacturing Engineering "

" Specialty 131 "Applied Mechanics"

" Manufacturing of the part "Housing" "

Completed by:

Student: Hemant Kumar

Group: MT-93

Supervisor: Ass. Prof. Oleksandr Okhrimenko

Reviewer:

____

I testify that in this thesis project there are no borrowings from the work of other authors without appropriate references.

Student: _________

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Time schedule

Task	Deadline
Report	
Chapter 1	
1.1 Analysis of the purpose and operating conditions of the part in the assembly unit 1.2 Determining the type of production …	
1.3. Design of the blank	
1.4 Locating the workpiece during the manufacturing process	
1.5 Design of the typical surfaces processing routes (table)	
1.6 Design of the operational manufacturing process plan	
1.7 Short description of a manufacturing equipment	
1.8. Cutting tools and cutting conditions selection	
1.9 Time and cost calculations	
Chapter 2	
2.1. Development of the fixture design 2.2. Clamping force calculation	
Chapter 3	
3.1 Spiral drill design 8.5mm	
Completed project	

Supervisor:

Student:

Summary

The bachelor's diploma project titled "Manufacturing Process Planning for a Part: Housing" by Hemant Kumar consists of three chapters.

Chapter 1 focuses on the analysis of the purpose and operating conditions of the part in the assembly unit. It includes an analysis of the part's working conditions, material analysis, and determining the type of production. Additionally, it covers the selection of the base process, design of the blank, and locating scheme selection. The locating scheme selection is further divided into two parts: rationale for the choice of general manufacturing datum and rationale for the selection of manufacturing datum for the first manufacturing operations. Furthermore, it involves the design of the typical surfaces processing routes and the operational manufacturing process plan. A brief description of manufacturing equipment and cutting tools, along with cutting conditions selection, is also provided. Lastly, the chapter encompasses time and cost calculations.

Chapter 2 focuses on the development of fixture design and clamping force calculation.

Chapter 3 centers around the design of a spiral drill with a diameter of 8.5mm. It includes input data for drill design, the selection of material for the spiral drill, drill design itself, and the construction of a three-dimensional drill model using the CAD system Solidworks. The chapter concludes with the drawing of the drill based on its 3D model.

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Chapter 1

In the bachelor's thesis, the design process of the structure of a workpiece is proposed and implemented.

The thesis aims to design and develop any product from scratch on SolidWorks and AutoCAD. At this stage, it helps entrepreneurs in the context of project development by explaining the formation process of the workpiece in detail.

1.1 Analysis of the purpose and operating conditions of the part in the assembly unit

Based on the arrangement of the component known as the "Housing" (refer to Figure 1.1), it has been determined that this particular part falls under the category of "Body." A three-dimensional representation of the component was created within the SolidWorks computer-aided design (CAD) system.

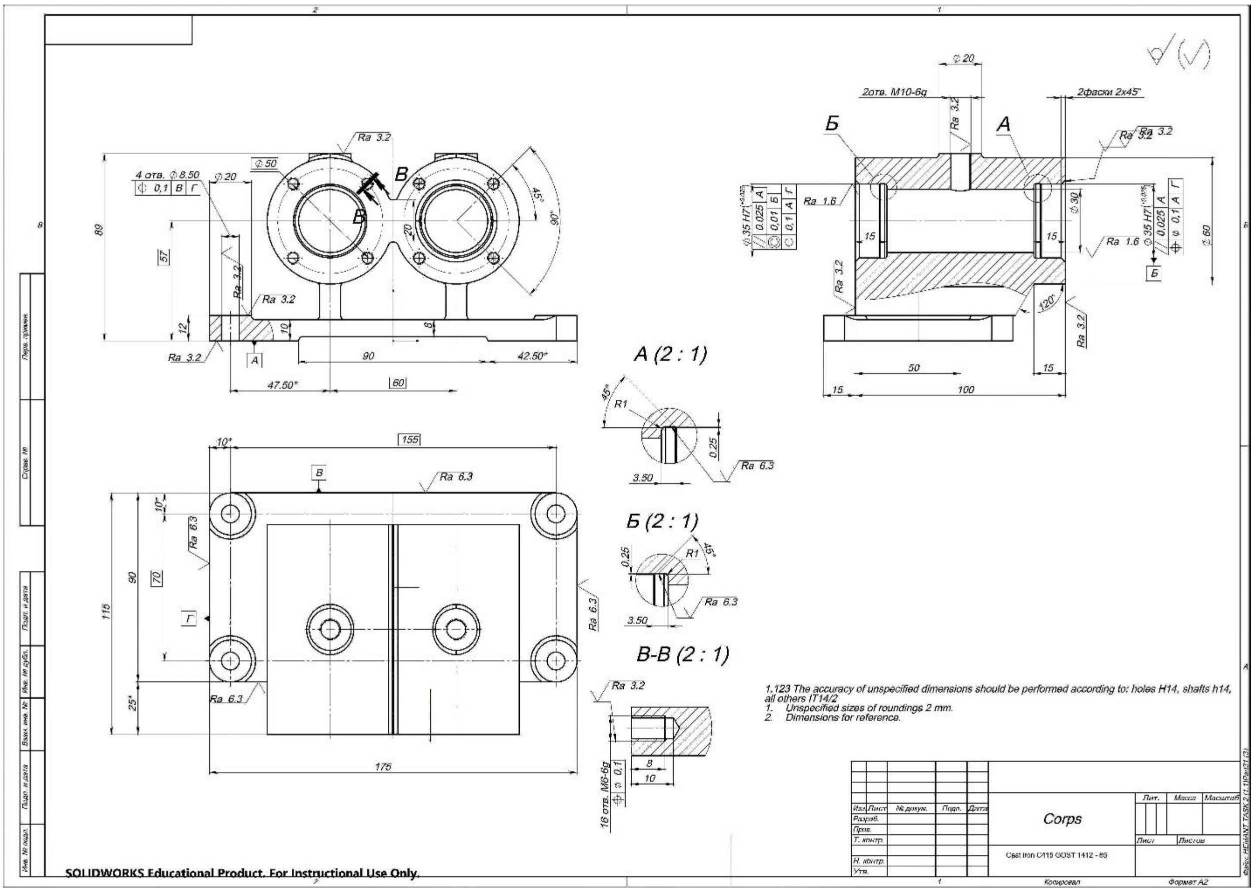


Fig 1.1 – Drawing of a part ‘Housing’

Generally, the part's surface accuracy and quality requirements are not extremely demanding. However, special attention must be given to the central axis of the ø35 holes, as they have stricter criteria. Specifically, the holes' axis should be parallel to the datum surface with a maximum deviation of 0.05mm, and their perpendicularity should also be maintained. The surface of these holes should be finished with an accuracy of H7 and a roughness value (Ra) of 0.8.

Fig 1.2 Three-dimensional model of the "Housing" part has been created.

Additionally, the outer surfaces of the cylinders should be perpendicular to the datum surface with a tolerance of 0.1.

During the manufacturing process, it is crucial to focus on the machining of the hole surfaces, ensuring their parallelism and perpendicularity to the datum surface are achieved.

1.1.1 Analysis of the part's working conditions in the assembly unit

The purpose of the "Housing" is to provide a means of installing and securing shafts that are supported by bearings. It features a variety of holes, both threaded and unthreaded, which serve different purposes. The holes are designed to maintain the positioning of the mounting shaft bearing and also facilitate fastening, as well as provide support for Jig and Fixture systems. Specifically, there are ø8.5 and M6-H7 threaded holes, as well as M10-H7 threaded holes.

During the operational use of the part, it is subjected to significant and prolonged alternating loads and vibrations. To mitigate these effects, the housing is designed with a basement support and holes support, which can be attached to a grip system. This grip system helps to stabilize the part and prevent excessive movement caused by the loads and vibrations it experiences.

1.1.2 Analysis of the material

The "Housing" part is made of Gray Cast Iron, specifically ISO 185 - Class 150. Here is the chemical composition and mechanical characteristics associated with this material:

Chemical Composition (in %):

C	Si	Mn	S	P
3.5 - 3.7	2 - 2.4	0.5 - 0.8	до 0.15	до 0.2

Linear shrinkage: 1.1%

Tensile strength σ_B= 152 MPa; hardness HB=130…241; density ρ= 0.01 g/cm3.

Taking into account the information given above, it can be concluded that the part works with periodic loading and is not under the influence of an aggressive environment and the material proposed by the designer ensures the operability of the part in such conditions. The drawing of the part has a sufficient number of types, sections, which provide a complete understanding of the design features of the part.

1.2 Determining the type of production and analysis of its impact on the manufacturing process plan

For educational purposes we will use analog methods of designation of production type based on weight of a part and production volume.

Part weight m=4.13251 kg (Fig 1.3)

Production volume Np =1500

Let's determine the type of production according to the following table (table. 1.1)

Table 1.1 – Estimation of the production type

Weight of a part, kg	Type of production				
	Single	Small batch	Medium batch	High volume batch	Mass
<1	< 10	10 .. 2000	2000 .. 75000	75000 .. 200000	> 200000
>1 .. 2.5	< 10	10 .. 1000	1000 .. 50000	50000 .. 100000	>100000
> 2.5 .. 5.0	< 10	10 .. 500	500 .. 35000	35000 .. 75000	>75000
> 5.0 .. 10.0	< 10	10 .. 300	300 .. 25000	25000 .. 50000	>50000
> 10.0	< 10	10 .. 200	200 .. 10000	10000 .. 25000	>25000

Fig. 1.3 – Characteristics of the part 'Housing' and its 3-D model

Conclusion: The production type – medium batch, therefore, we will perform all further calculations and make technological decisions for the medium-volume type of production.

1.3 Selection of the base process and design of the blank

Initial data for the process selection (according to the variant):

- drawing of a part
- material of a part – Grey Cast Iron
- Annual output – 1500 pcs

Considering the material (Gray cast iron) and the geometry of the "Housing" part (Figure 1.1), the sand-casting process is a suitable choice as the base manufacturing process.

To determine the required machining allowance (RMA) grade, Table B.1 [2] can be referenced. For medium production and the sand-casting process with Gray Iron, the recommended RMA grade is E, which involves using a sand-casting machine, Mold. According to Table 1 [2], with an RMA grade of E and the longest dimension of the part being 175mm (as shown in the drawing of Figure 1.1), the required machining allowance is estimated to be 1.4mm.

To estimate the casting tolerance (CT) grade, Table A1 (for long series) [2] can be utilized. Considering the sand-casting process with machine Mold and Gray Iron, the CT10 tolerance grade is applicable. The results of the casting tolerance estimation are presented in Table 1.2.

Dimension of a part	RMA	Min limit of size for external features (or max for internal features)	Casting tolerance, mm	Raw casting basic dimension
100	1.4	102.8	3.2	104.4±1.6
35.5	1.4	32.7	2.6	32.7±1.3
35	1.4	32.2	2.6	32.2±1.3
30	1.4	30	2.6	28.7±1.3
8.5	1.4	5.7	2	5.7±1.0
12	1.4	13.4	2.2	13.4±1.1
6	1.4	3.2	2	3.2±1.0
10	1.4	7.2	2	7.2±1.0

Table 1.2. Raw casting basic dimensions estimation

In designing the geometry of the casting for the "Housing" part, the following considerations were taken into account:

- Placing the workpiece to achieve the lowest possible height in the Mold.
- Recommending the placement of the parting line within the plane of symmetry.
- Avoiding sharp corners and incorporating fillets with radii ranging from 2-5 mm.
- Applying a draft angle of 2° to all walls perpendicular to the parting plane to facilitate easy removal of the part from the Mold.
- Adding the required machining allowance (RMA) to the surfaces where secondary processes such as machining are planned.
- Using cores to obtain the two cylindrical holes in the part.
- Employing machining to create small features such as grooves and small holes.

The results of this workpiece design can be seen in Figure 1.4.

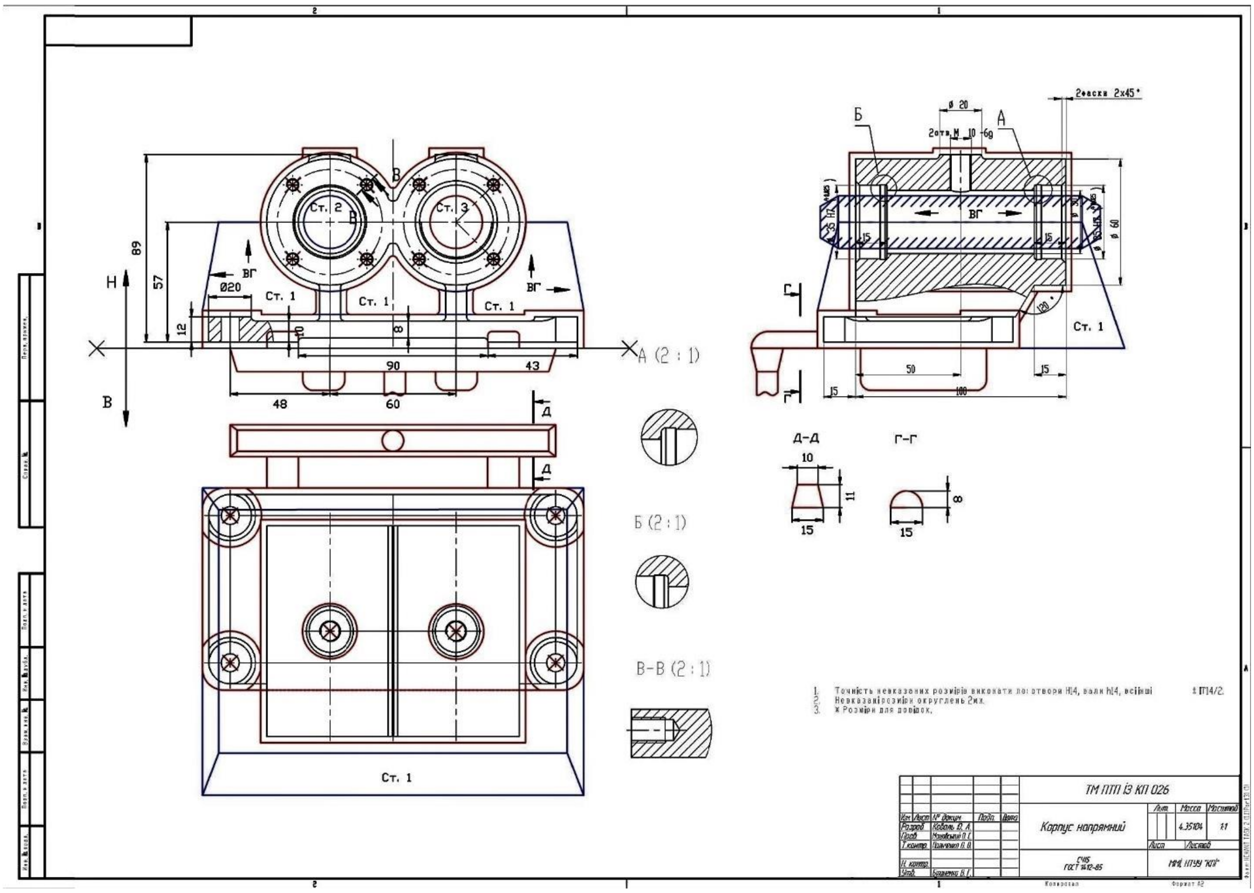


Fig 1.4 Drawing of a Casting

1.4 Locating scheme selection

The general algorithm of substantiation of manufacturing datum (MD) includes two stages:

- Rationale for the choice of general manufacturing datum (GMD)
- Rationale for the choice of manufacturing datum for the first manufacturing operations

1.4.1 Rationale for the choice of general manufacturing datum

General manufacturing datum (GMD) is a set of datum surfaces that can be used to perform all operations of the manufacturing process or most of it.

The initial data to justify the choice of GMD are the working drawing of the part. To solve the problems of the first stage, it is necessary to classify the surfaces of the part for their intended purpose.

The design of any part can be represented as a set of four types of surfaces:

1. Main functional (design) datum
2. Auxiliary functional (design) datum
3. Fastening surfaces
4. Free surface

For further analysis let's classify surfaces of a given part according to their purpose (Fig. 1.5).

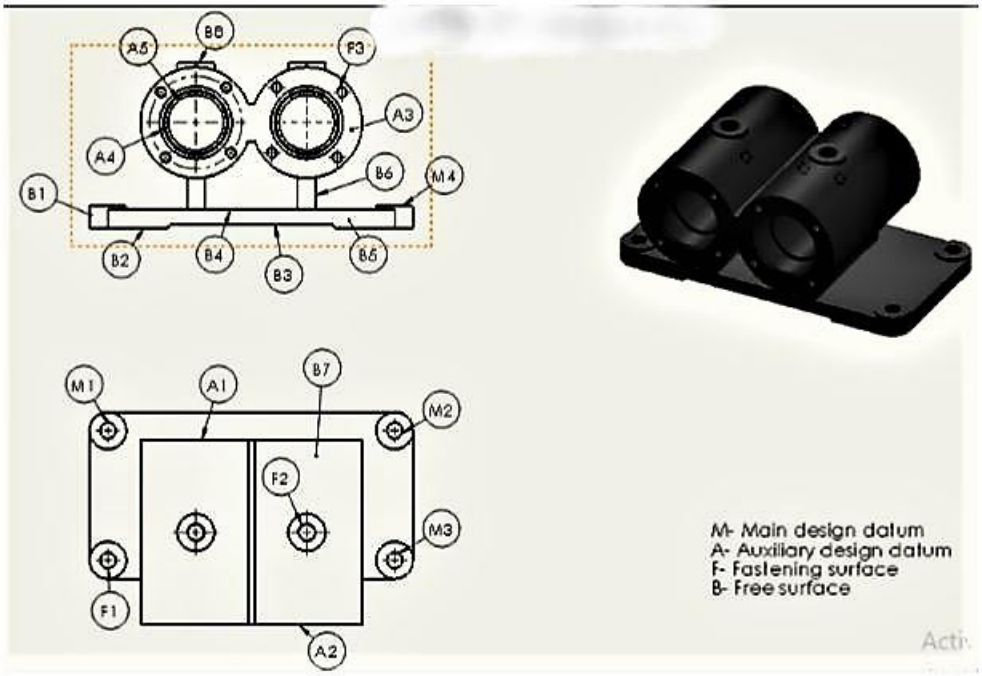


Fig 1.5 Classification of the part according to their intended purpose

Now let's consider the possibility to transform Main Design Datum to GMD.

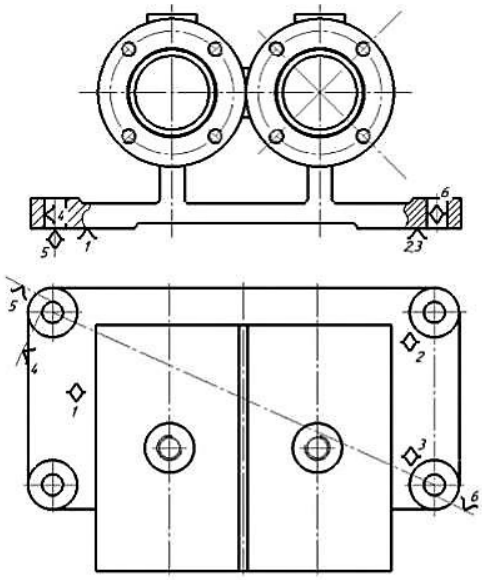


Fig 1.6 Locating scheme for GMD

The formula for the locating scheme presented in Fig 1.6 is as follows:

LS_{GMD} =>S(3)+DS(2)+ O(1), (1.1)

Where S (3) – setting datum, deprives the workpiece 3 degrees of freedom, DS (2) – double support datum, deprives the workpiece 2 degrees of freedom, and O (1) – support datum, deprives the workpiece 1 degree of freedom.

This scheme is implemented using: a plane, round head and diamond head locating pins. In this case, the "Housing" is sufficiently oriented, which allows processing its surfaces with the specified requirements for the spatial position.

1.4.2 Rationale for the selection of manufacturing datum for the first manufacturing operations

When choosing datum surfaces for the first manufacturing operations it is necessary to ensure openness for processing of all surfaces of GMD and to choose machines that can carry out consecutive processing of GMD surfaces for achievement of the set quality characteristics. Otherwise, it is necessary to take into account that the full set of the GMD has to be processed during next first technological operations.

Let’s consider possible locating schemes for the first manufacturing operations as well as their advantages and disadvantages. For this purpose, we will use the following recommendations:

- for MD select surfaces that aren’t supposed to be processed according to the drawing
- if all surfaces of the workpiece have to be processed, then as MD we take the surfaces that have the lowest allowance (this prevents the occurrence of defects on this surface for further processing), if the allowances are uniform, it is necessary to choose surfaces on which defects are not allowed
- choose as MD surfaces for which it is necessary to provide a uniform allowance for the next stages of processing
- if there are several possible schemes of basing, then as MD we accept the option with the shortest dimensional chain

The first variant is presented in Fig. 1.7

Advantages:

- Easy to implement
- Ensures the correct placement of untreated surfaces relative to the treated ones

Disadvantages:

- blocks processing the workpiece from three sides
- forms an uneven allowance for the main holes of the housing for the next stages of processing
- does not ensure the perpendicular of the side planes (adjacent to the main holes) relative to the datum plane

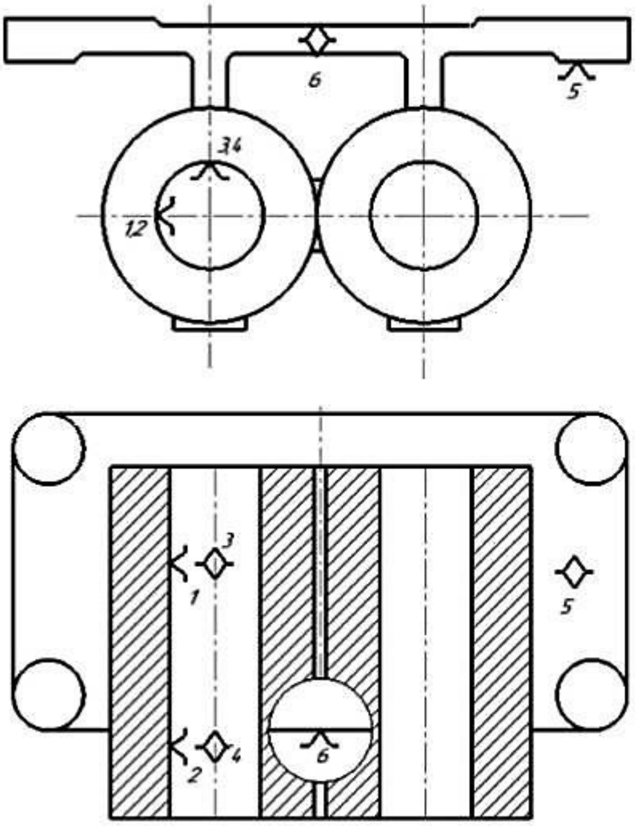


Fig 1.7 – Locating scheme for the first manufacturing operation

The formula for the locating scheme presented in Fig 1.7 is as follows:

$$LS_{MD} \Rightarrow S\ (3) + G\ (2) + O\ (1) \qquad (1.3)$$

1.5 Design of the typical surfaces processing routes

The design of a part can be divided into a set of typical geometric shapes, united by a common service purpose of the part. Typical structural elements are: cylindrical or conical external and internal surfaces, a set of planes, shaped surfaces - screw, involute and others. Depending on the type of surface, different cutting tools can be used to achieve a given surface accuracy and, as a result, there are different sequences of surface treatment.

The development of machining routes for individual surfaces is the first of seven tasks solved in the design of process plan. The manufacturing process thus created, rolled up in time and space, solves the problems of dimensional accuracy, shape and quality of individual surfaces, but does not take into account the accuracy of the relative position at all. This task will be solved later by assigning the locating schemes and dividing the processing stages into modules - rough, finish and final.

When developing a manufacturing process, it is necessary to select one of several possible machining options, which will provide the best economic solution. Therefore, in order to save time, it is necessary to use standard, proven in practice, processes for manufacturing parts and machining their main surfaces.

For a part, presented in fig. 1.5, selected typical machining sequences as well as achieved accuracy and roughness of working surfaces are given in table 1.3. The surfaces classification is given in fig. 1.16.

Surfaces	IT	Ra	Machining sequence	IT	Ra
	According to the drawing			After machining	
1	2	3	4	5	6
M1,M2,M3	14	5	Centering, Drilling, & Reaming	14	5
M4	14	5	Rough Milling, & finish Milling	14	5
A1,A2,A3	14	1.25	Rough Milling & Finish Milling	14	1.25
A4	H7	0.8	Rough turning, finish Turning, Countersinking	H7	0.8
A5	14	2.5	Rough & finish Counterboring	14	2.5
F1	14	5	Centering, Drilling, & Reaming	14	5
F2	7H	-	Centering Drilling, & Threading	7H	-
F3	H7	-	Centering, Drilling, & Threading	14	-

Table 1.3 Machining routes for surfaces of a part “Housing”

1.6 Design of the operational manufacturing process plan

Objective: to develop the manufacturing process plan that will meet all the requirements of manufacturing accuracy, complexity, and cost.

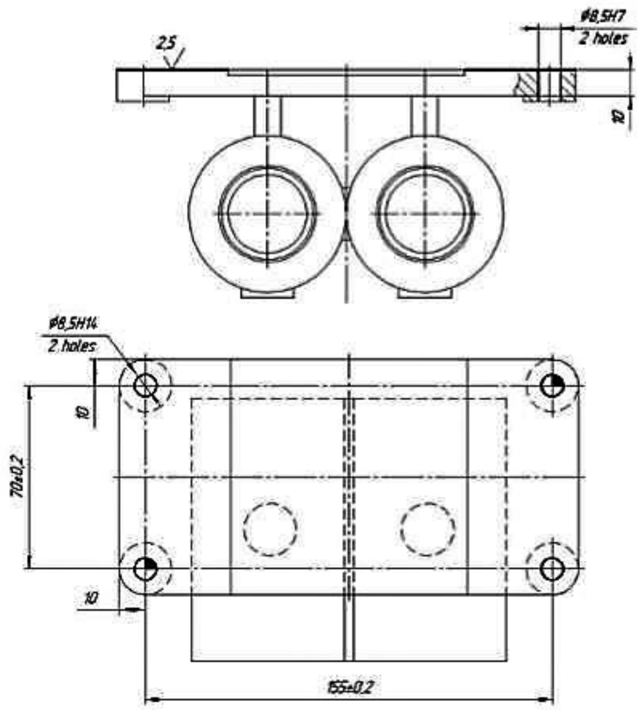
Let’s consider the following recommendations:

1. Surfaces that are the datums for the subsequent stages of processing should be processed first
2. Each subsequent manufacturing step or operation must improve the quality characteristics of the treated surfaces - If this requirement is not met, e.g., when implementing heat treatment, then it is necessary to return to the processing of the workpiece surfaces, which are datum for subsequent processing stages.
3. The roughing must be separated from the next stages of processing by a certain period of time, or aging operations should be provided, especially for critical, large-sized and high-value parts.
4. For timely detection of defects on surfaces where they are not allowed, these surfaces should be processed at the early stages of the manufacturing process.
5. During roughing the first should be processed surfaces that have the highest allowance and the most responsible surfaces.
6. Finishing of the most responsible surfaces must be performed at the latest manufacturing steps.
7. The surfaces which least reduce the overall stiffness of the workpiece should be processed first.
8. Surfaces with a precise relative spatial position should be processed in one installation.
9. Do not change the tool when finishing precise responsible surfaces.
10. Fastening surfaces must be processed at the 3rd stage of the manufacturing process, after finishing the related surface.

1.6.1 005 Multipurpose

Machine: HAAS DT 2

A. Install, secure, remove



Position 1

005.01: Rough and finish mill the plane to a thickness of 10 mm, with a surface roughness (Ra) of 2.5.

005.02: Center the position of 4 holes according to the provided sketch, located at distances of 10 mm, 10 mm, 70 mm, and 155 mm.

005.04: Drill 2 through holes with a diameter of Ø8.5 H14, and a surface roughness (Ra) of 5.

005.05: Drill 2 through holes with a diameter of Ø8.3 mm.

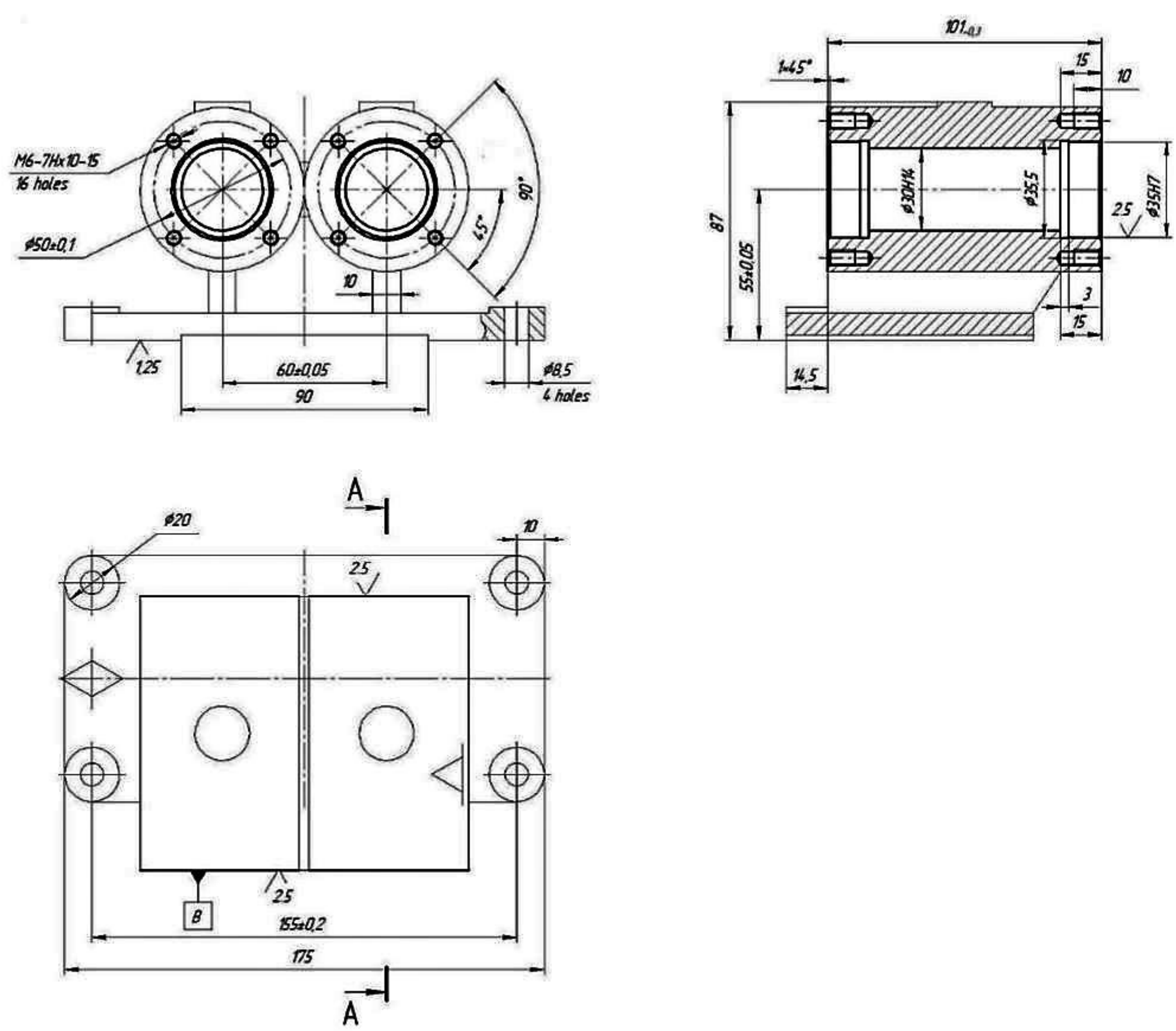
005.06: Ream 2 holes with a diameter of Ø8.5, maintaining a tolerance of H7, and achieving a surface roughness (Ra) of 1.25.

These machining operations will ensure the necessary precision and quality of the specified features on the "Housing" part.

1.6.2 010 Multipurpose

Machine: VF 2TR

A. Install, secure, remove



Position 1:

010.01: Rough and finish mill the datum surface A.

Position 2:

010.02: Turn the table 180°.

010.03: Rough drill 4 bores to a diameter of Ø8.5 mm.

010.04: Semi-finish the 4 bores to a diameter of 12 mm.

010.05: Center the position of 8 holes and simultaneously create chamfers.

010.06: Drill 8 blind holes with a diameter of Ø5 mm and a depth of 15 mm.

010.07: Cut threads in the 8 holes to M6-H7 with a depth of 10 mm.

Position 3:

010.07: Turn the table 180°.

010.08: Center the position of 8 holes and simultaneously create chamfers.

010.09: Drill 8 blind holes with a diameter of Ø5 mm and a depth of 15 mm.

010.10: Cut threads in the 8 holes to M6-H7 with a depth of 10 mm.

010.10: Finish the 4 bores with a diameter of Ø35 H7, achieving a surface roughness (Ra) of 2.5.

1.6.3 015 Multipurpose

015: Vertical milling.

015.01: Center the position of the 2 holes F2.

015.02: Drill the 2 through holes F2 to a diameter of Ø9 mm.

015.03: Cut threads in the 2 holes F2 to M10x1-7H.

020: Washing.

025: Inspection and control.

1.7 Description of a manufacturing equipment

Type and size of machine

The types of machines are specified by the already preselected manufacturing processes. For example, if turning is the selected process then a lathe (or turning center) will be the type of machine to be used.

At the first cut selection the only factor considered is the physical size of the machine in relation to the workpiece. E.g., a lathe whose machine bed is shorter than that of the length of the part cannot be used to turn that part.

Power/Force analysis

After having calculated the power requirements for all operations, those machines that cannot meet the maximum power requirement can be discounted. The exception of this is if there are no other machines available. In this case, reducing feeds and speeds and/or the depth of cut can reduce the power required. On the other hand, those machines with a far greater power output than required can also be discounted. The only exception of this is if such a machine has a higher spindle speed required by one or more operations.

Capability analysis

The factors considered in the capability analysis are the dimensional and geometric accuracy and the surface finish required.

Operational analysis

The operational factor to be considered by the process planner is that of the batch size. Those machines that do not meet the economic batch quantity should be discounted.

Based on the requirements and process plan provided, the preliminary selected machine for the manufacturing of the "Housing" part is the HAAS-DT-2 vertical machining centre. The DT-2 version of this machine (as shown in Figure 1.8) is well-suited for efficient and precise machining of complex parts made from materials such as steel, grey cast iron, and soft metal alloys. It offers the capability to perform milling operations in the X, Y, and Z coordinate axes, as well as in the rotary B axis.

Additionally, the HAAS-DT-2 enables drilling, boring, reaming, and thread cutting operations, making it suitable for the required machining tasks. It also supports the use of screw die heads without aligning bush in the Z axis, providing flexibility in the machining process.

Please refer to the technical data table for detailed specifications and capabilities of the HAAS-DT-2 vertical machining centre.

TRAVELS	S.A.E	METRIC
X Axis	28.0 in	711 mm
Y Axis	16.0 in	406 mm
Z Axis	15.5 in	394 mm
Spindle Nose to Table (~ max)	21.5 in	546 mm
Spindle Nose to Table (~ min)	6.0 in	152 mm

SPINDLE	S.A.E	METRIC
Max Rating	15.0 hp	11.2 kW
Max Speed	10000 rpm	10000 rpm
Max Torque	46.0 ft-lbf @ 1700 rpm	62.0 Nm @ 1700 rpm
Drive System	Inline Direct-Drive	Inline Direct-Drive
Taper	BT30	BT30
Bearing Lubrication	Air / Oil Injection	Air / Oil Injection
Cooling	Air Cooled	Air Cooled

TABLE	S.A.E	METRIC
Length	34.0 in	864 mm
Width	15.0 in	381 mm
T-Slot Width	0.626 in to 0.630 in	15.90 mm to 16.00 mm
T-Slot Center Distance	4.92 in	125 mm
Number of Std T-Slots	3	3
Max Weight on Table (evenly distributed)	250 lb	113 kg

FEEDRATES	S.A.E	METRIC
Max Cutting	1200 ipm	30.5 m/min
Rapids on X	2400 ipm	61.0 m/min
Rapids on Y	2400 ipm	61.0 m/min
Rapids on Z	2400 ipm	61.0 m/min

TOOL CHANGER	S.A.E	METRIC
Type	SMTC	SMTC
Capacity	20+1	20+1
Max Tool Diameter (full)	2.0 in	51 mm
Max Tool Length (from gage line)	7 in	178 mm
Chip-to-Chip (avg)	1.6 s	1.6 s

AXIS MOTORS	S.A.E	METRIC
Max Thrust X	2550 lbf	11343 N
Max Thrust Y	2550 lbf	11343 N
Max Thrust Z	4200 lbf	18683 N

TAPPING	S.A.E	METRIC
Max Tapping Speed	5000 rpm	5000 rpm

GENERAL	S.A.E	METRIC
Coolant Capacity	55 gal	208 L

AIR REQUIREMENTS	S.A.E	METRIC
Air Required	4 scfm @ 100 psi	113 L/min @ 6.9 bar

Table 1.4 Technical Data of Selected Machine

Fig 1.8 HAAS DT 2 Machine

1.8 Cutting tools and cutting conditions selection

Evaluation of process and machine selections – Provided the selection of processes and machines is satisfactory, the range of tools that can be used should be limited to those suitable for the processes and machines selected. Therefore, this limits the initial list of possible suitable tooling.

Analysis of machining operations – A specific machine will carry out every operation required. Each machine tool to be used will have specific tool types to carry our certain operations. This analysis should enable the identification of specific tool types for specific operations.

Analysis of workpiece characteristics – At this step the following should be considered: workpiece material and geometry, dimensional and geometric accuracy, and surface finish. This enables to identify suitable tool materials and geometry.

Tooling analysis – Using the tooling data available, the general tooling specifications generated ant the 3rd stage can be translated into a statement of tooling requirements for the job, that is, a tooling list. This will obviously reflect whatever tooling is actually available for the operations required.

Selection of tooling – If single-piece tooling is being used, then a suitable toolholder should be selected before fully defining the tool geometry and material. If insert-type tooling is being used then the following steps should be followed:

- Select clamping system;
- Select toolholder type and size;
- Select insert shape;
- Select insert size;
- Determine tool edge radius;
- Select insert type;
- Select tool material.

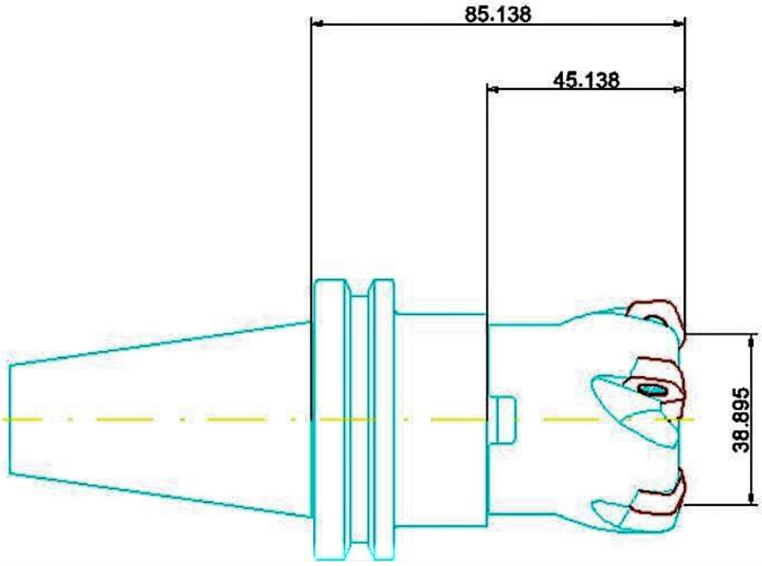
Tool selection for the manufacturing step:

“005.09 Mill surface M1 to dimension 82*61”

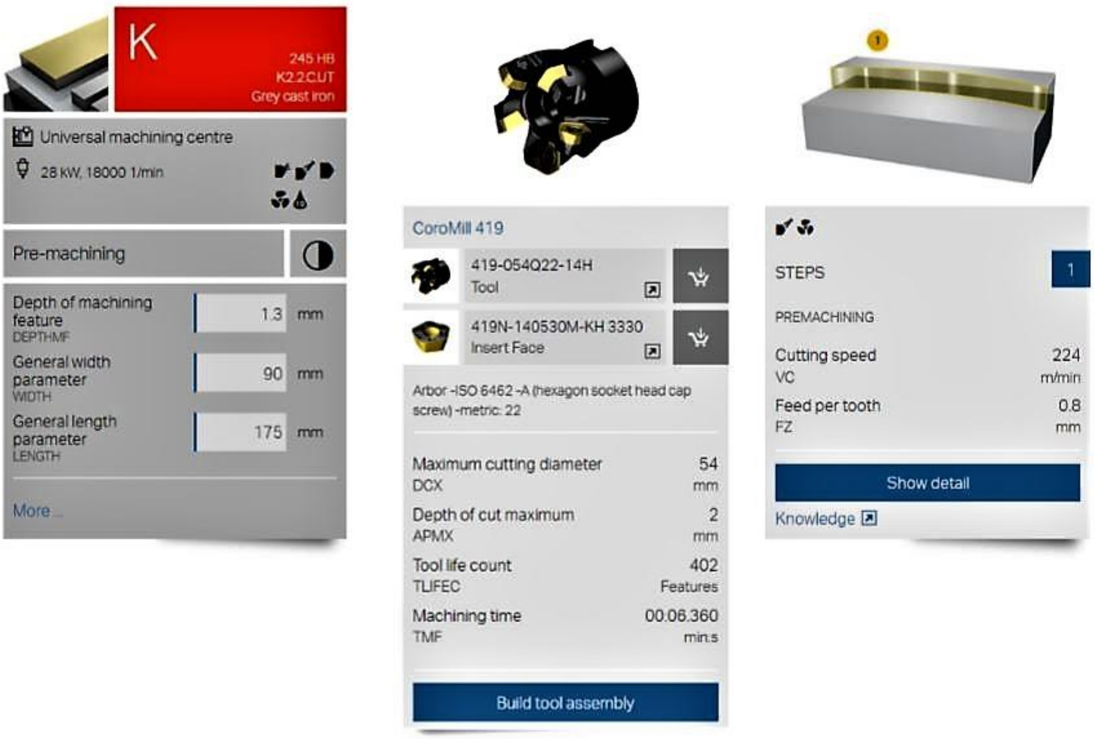
Allowance = 2.5mm

Radial cutting width = 10mm

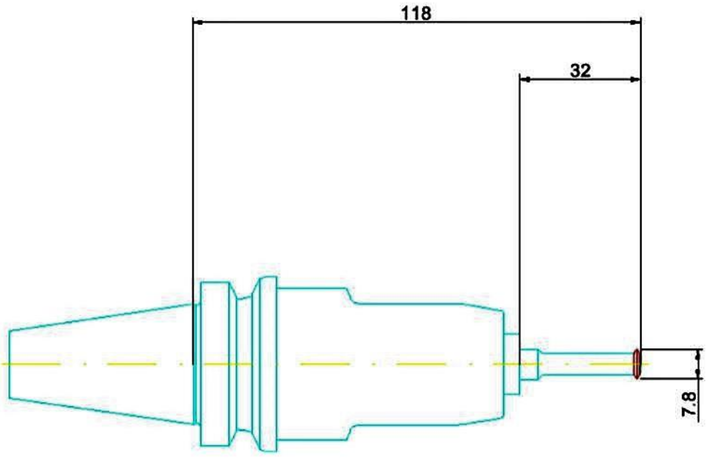
To select the appropriate cutting tool and cutting conditions we will use CoroPlus® ToolGuide [1] Firstly, enter the initial data, incl. type of surface, depth of cut, radial cutting width and workpiece material.


85.138
45.138
38.895

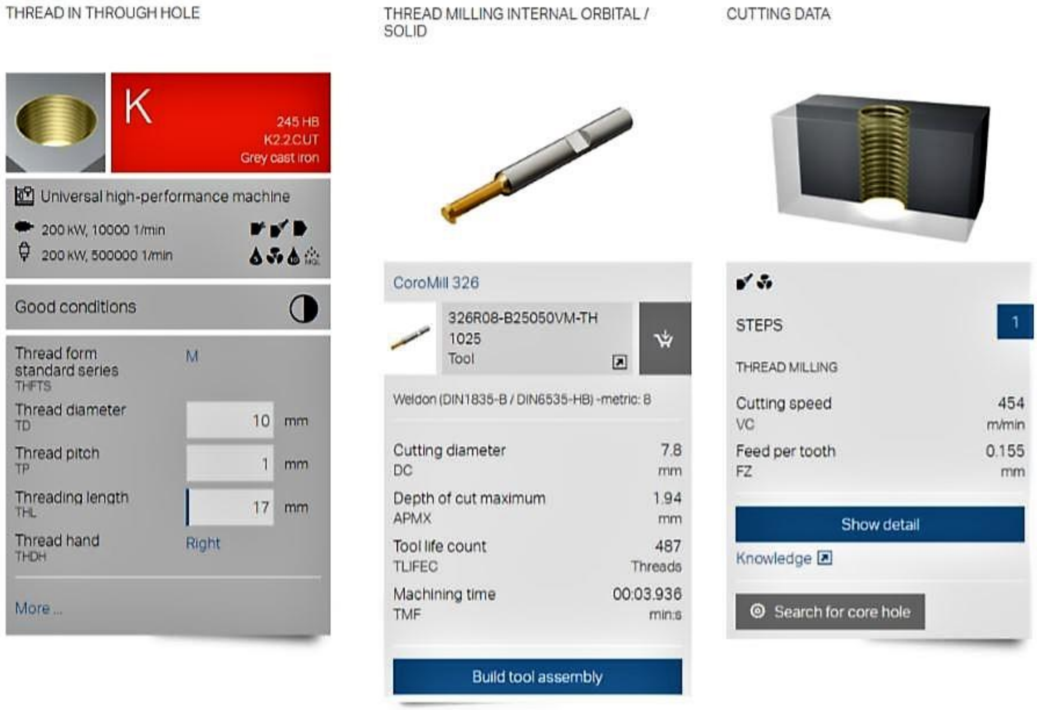
T001


K
245 HB
K2.2.C.UT
Grey cast iron
Universal machining centre
28 kW, 18000 1/min
Pre-machining
Depth of machining feature
DEPTHMF
1.3 mm
General width parameter
WIDTH
90 mm
General length parameter
LENGTH
175 mm
More...
CoroMill 419
419-054Q22-14H
Tool
419N-140530M-KH 3330
Insert Face
Arbor -ISO 6462 -A (hexagon socket head cap screw) -metric: 22
Maximum cutting diameter
DCX
54
mm
Depth of cut maximum
APMX
2
mm
Tool life count
TLIFEC
402
Features
Machining time
TMF
00.06.360
min:s
Build tool assembly
STEPS
1
PREMACHINING
Cutting speed
VC
224
m/min
Feed per tooth
FZ
0.8
mm
Show detail
Knowledge

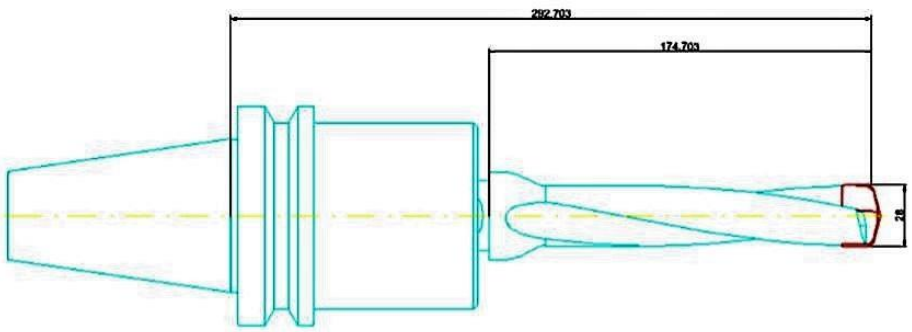
T001



T002

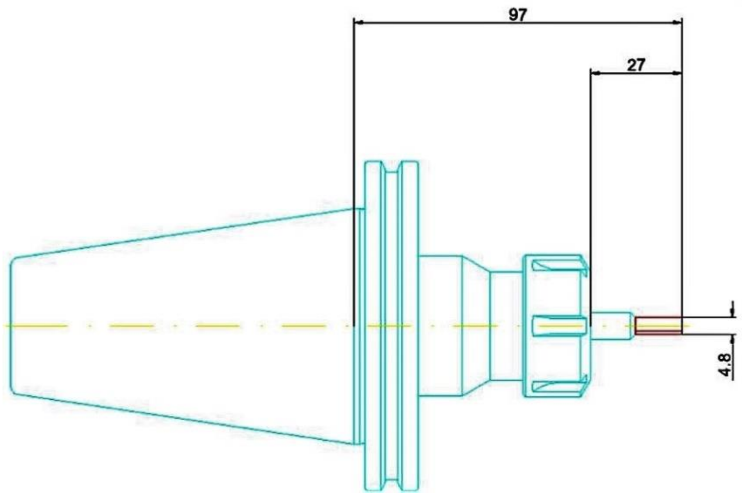


T002



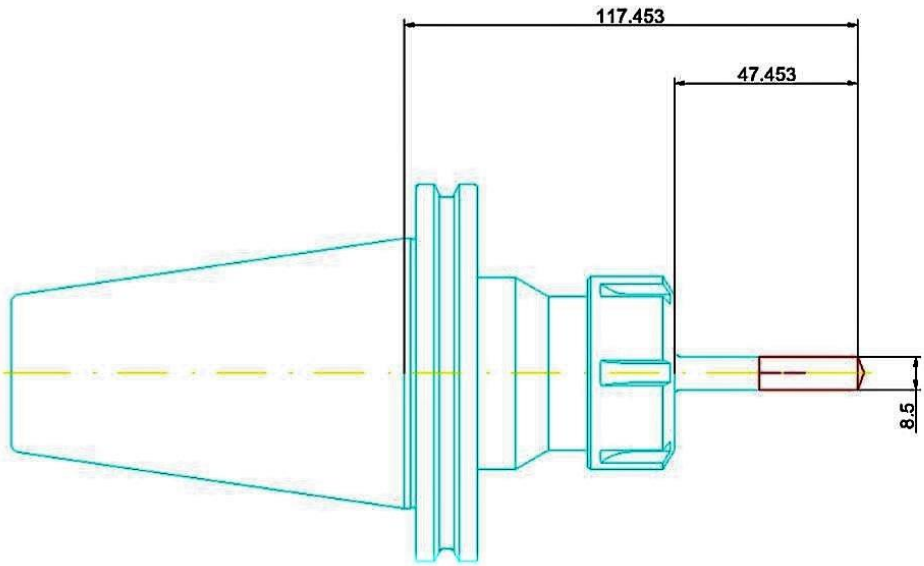
T003

T003

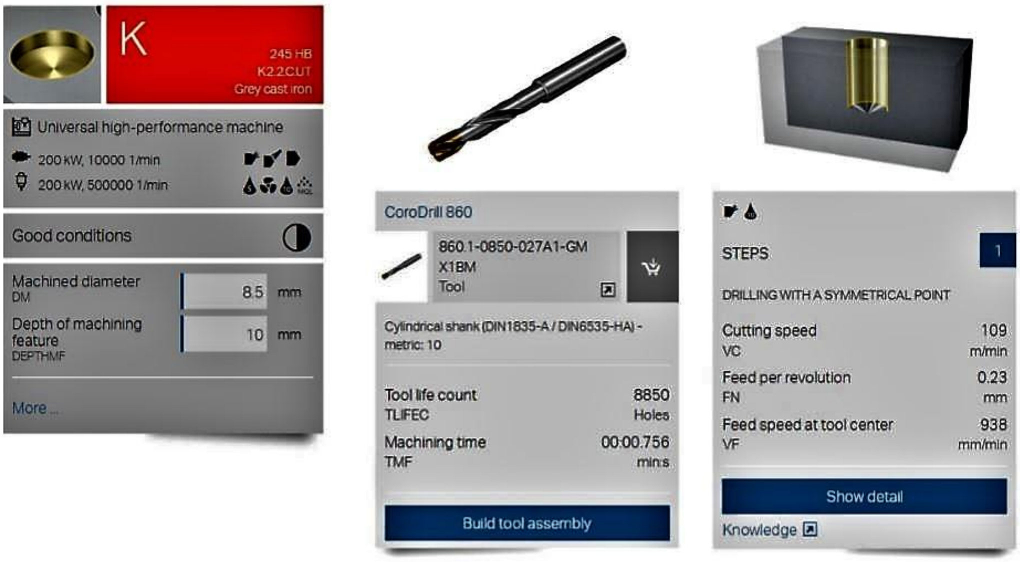


T004

T004



T005



T005

1.9 Time and Cost Calculation

For the calculations performed in this chapter, the online Cost Estimator tool from custompartnet.com was utilized. The first step involved specifying the part quantity, which is determined by the number of parts required to fulfil an annual order or to be used in subsequent processes, taking into account the defect rates inherent in manufacturing processes. In this case, the annual order quantity is 1500 parts.

Considering a defect rate of 1.1%, which represents the predicted percentage of defective parts in the production quantity, a larger production quantity must be manufactured to meet the desired order quantity. The resulting run quantity will be 1517 parts, which includes both the desired parts and any defective or incomplete parts.

The part shown in Figure 1 is made of ductile iron, and it is a prefabricated part (as depicted in Figure 1.1). The dimensions of the workpiece are 175 mm x 115 mm x 89 mm (6.89 in x 4.53 in x 3.50 in), with a weight of 3.404 lb.

These specifications and calculations were taken into account using the custompartnet.com Cost Estimator tool for accurate cost estimation and production planning.

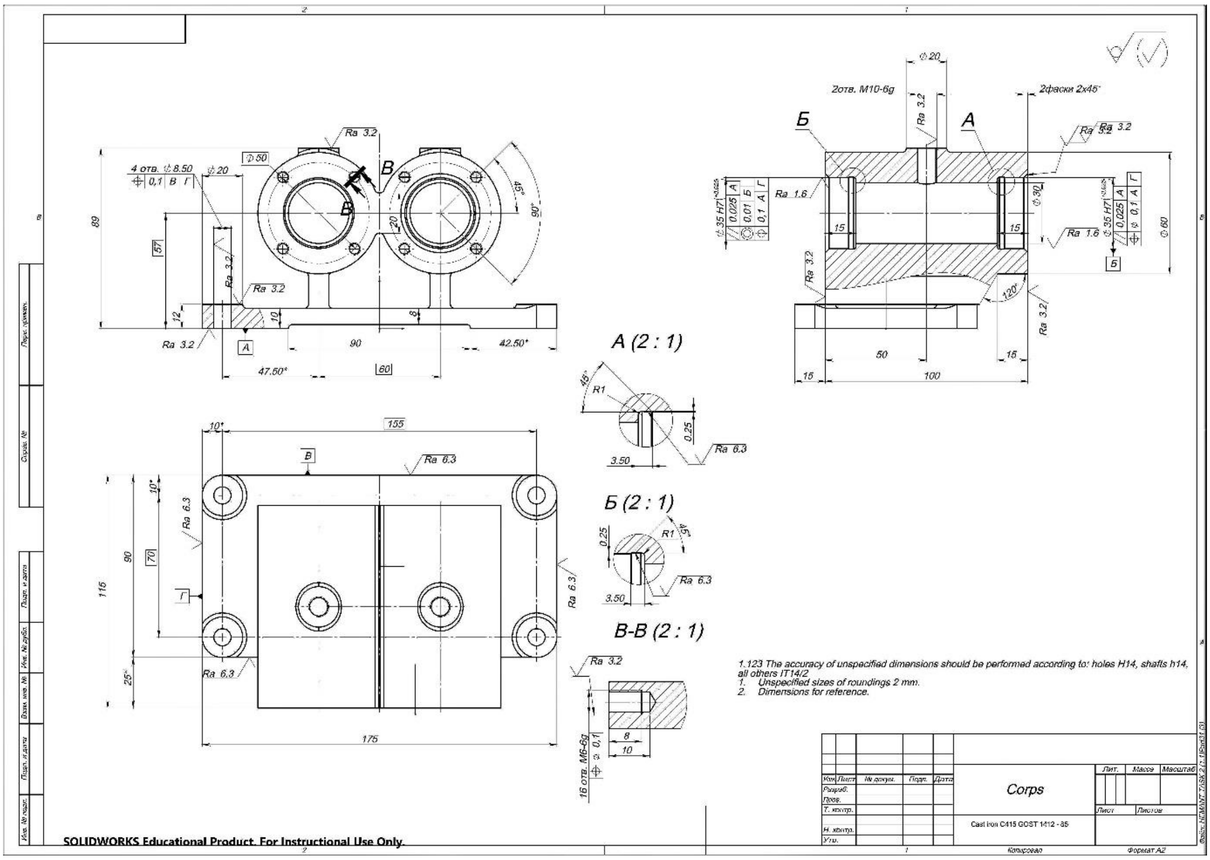


Fig 1.1 Drawing of a Part

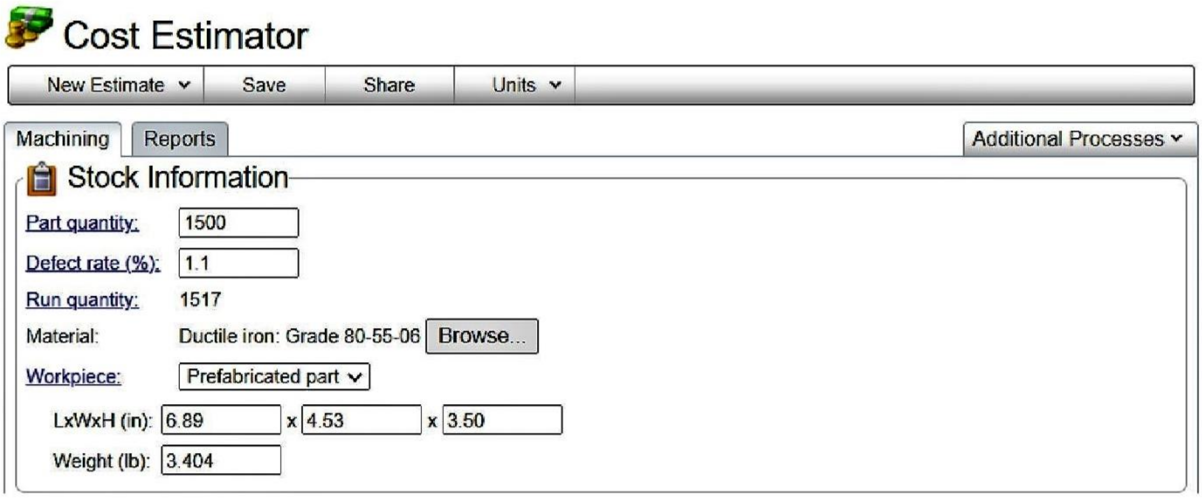


Fig 1.9 Stock Information

Now, consider the first operation 005 Milling.

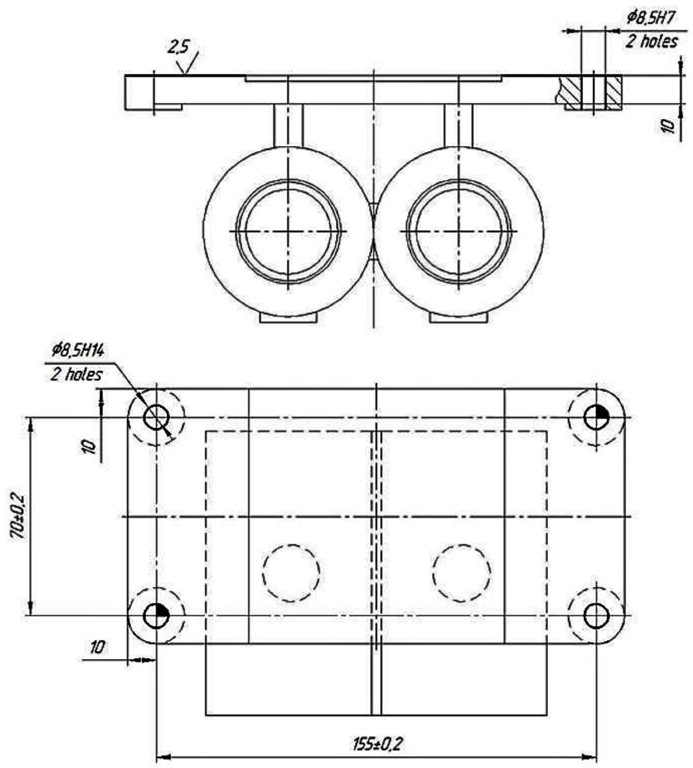


Fig 1.10 Sketch for the Milling Operation

In the first process of the process plan, which will be performed on a vertical milling machine, the operations involve rough milling of two plane surfaces. Here are the details of the rough milling operation:

1. Rough milling of the first plane surface:

- Dimensions of the surface: 154 mm (6.1 in) x 89 mm (3.54 in)
- Depth of cut: 5.08 mm (0.20 in)
- Average spacing between machined surfaces: 120 mm (4.72 in)
- Cutting tool: Face mill with a diameter of Ø54 mm (2.13 in)
- Number of teeth on the face mill: 5

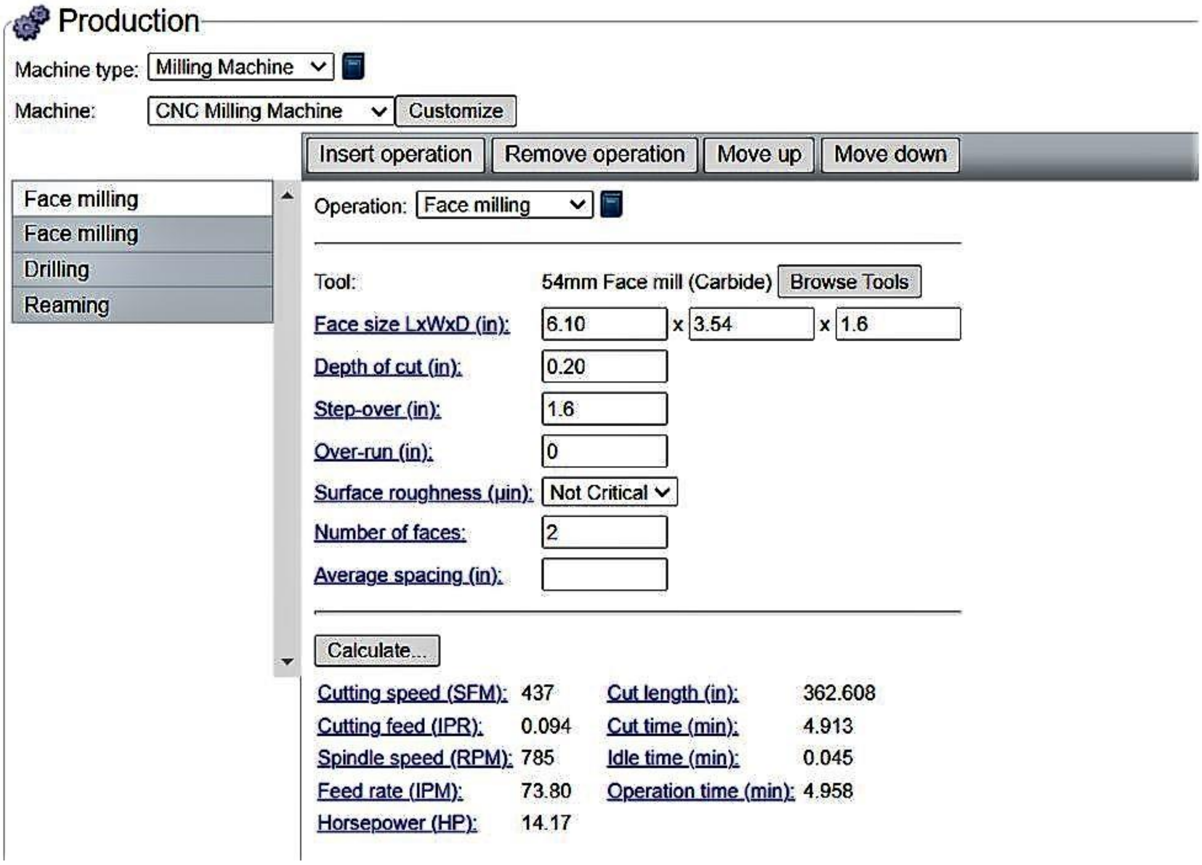


Fig 1.11 Time estimation for rough milling

2. Finish milling of the first plane surface:

- Dimensions of the surface: 65 mm (2.56 in) x 120 mm (4.72 in)
- Depth of cut: 0.762 mm (0.03 in)
- Roughness of the surface: 2.5 µm (98.4 µin)
- Average spacing between machined surfaces: 120 mm (4.72 in)
- Cutting tool: Face mill with a diameter of Ø100 mm (3.94 in)
- Number of teeth on the face mill: 6

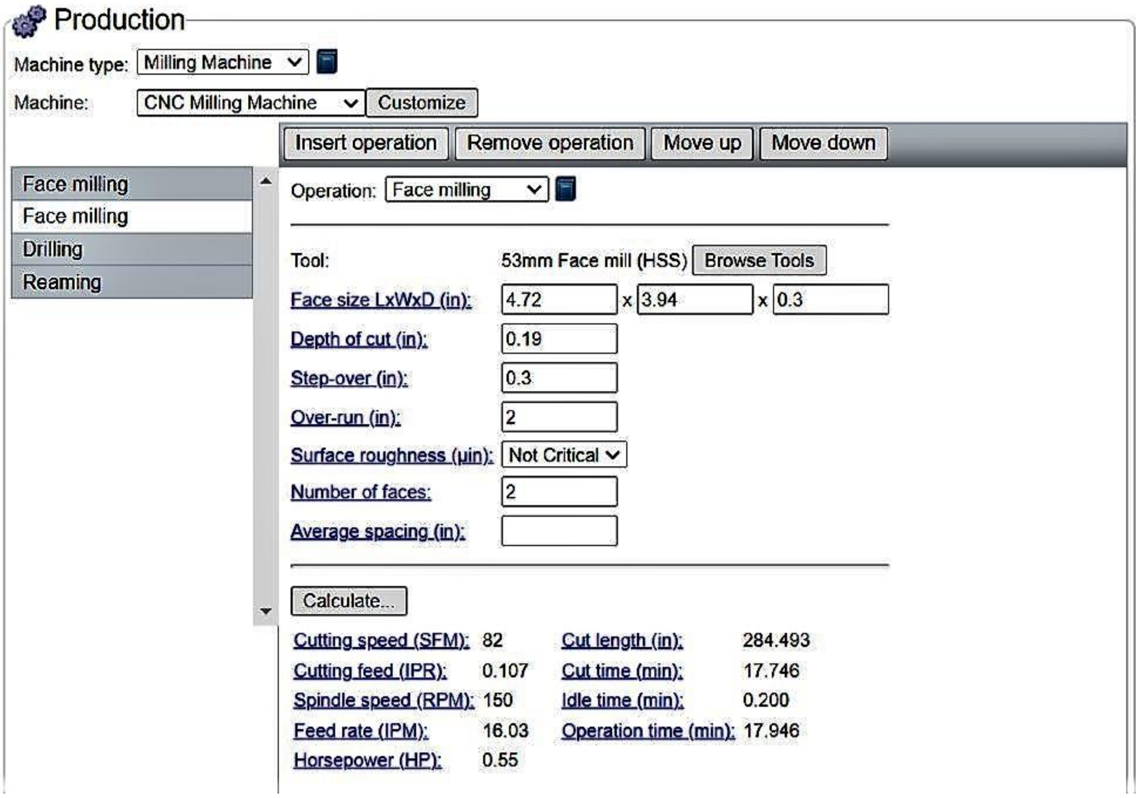


Fig 1.12 Time estimation for finish milling

3. Drilling of two through holes:

- Hole diameter: Ø8.5 mm (0.33 in)
- Hole depth: 15 mm (0.59 in)
- Average spacing between the two holes: 250 mm (9.8 in)

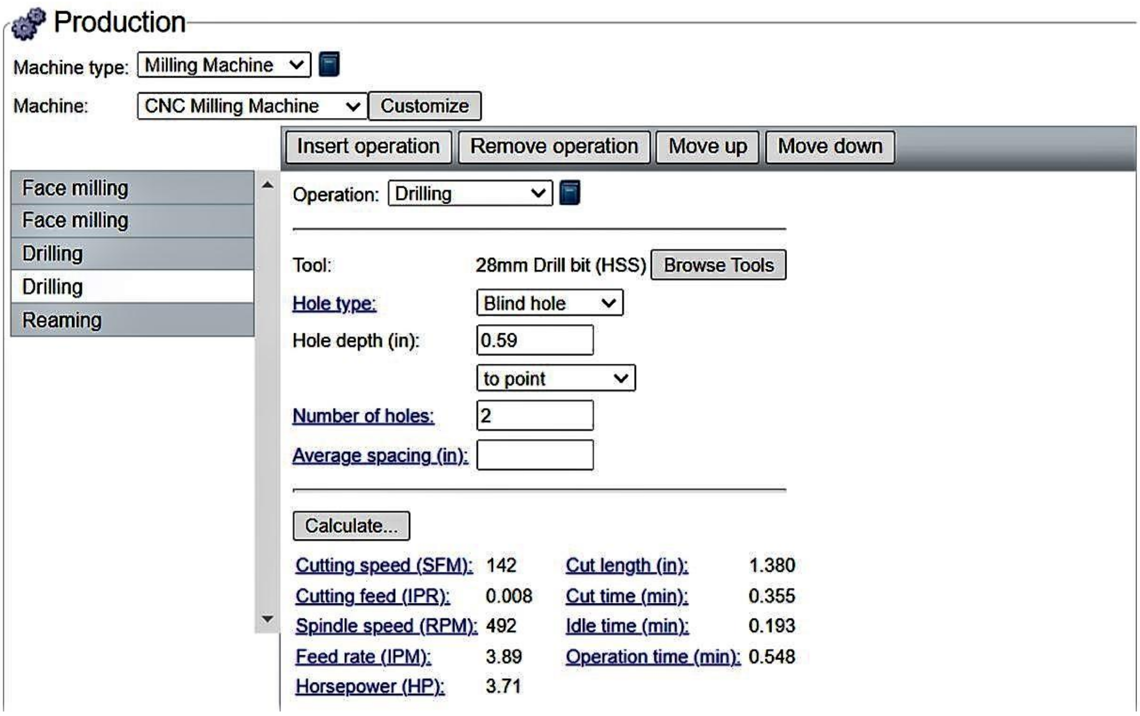


Fig 1.13 Time estimation for drilling

4. Drilling of two through holes:

- Hole diameter: Ø8.3 mm (0.33 in)
- Hole depth: 15 mm (0.59 in)
- Average spacing between the two holes: 250 mm (9.84 in)

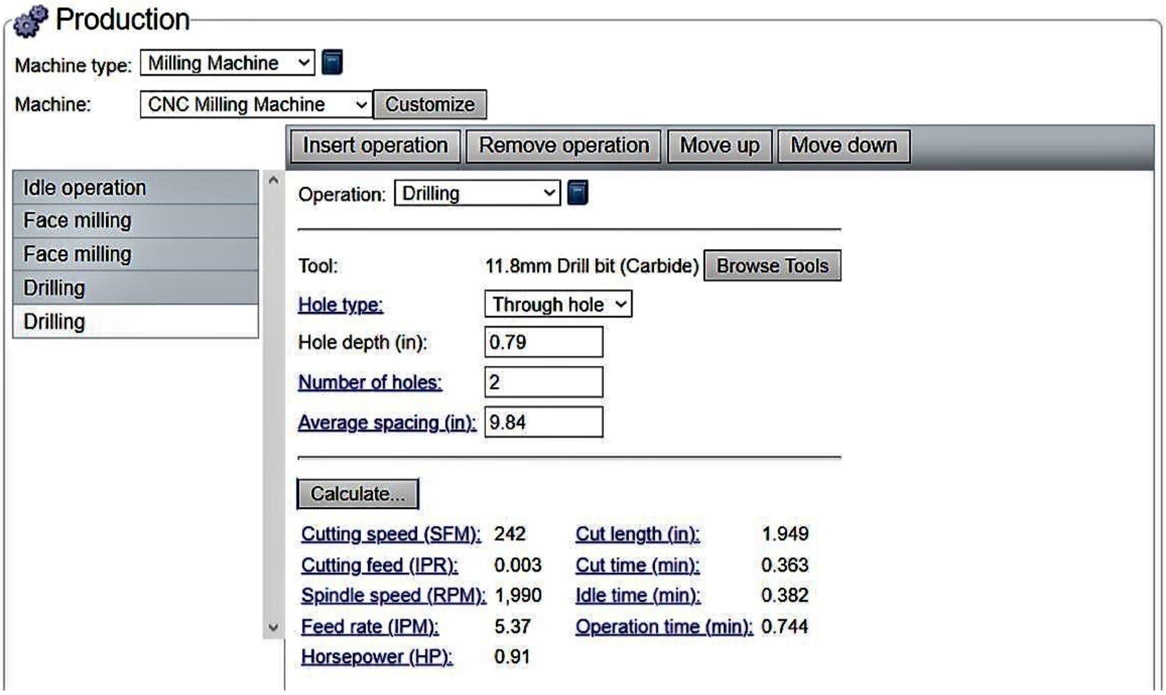


Fig 1.14 Time estimation for drilling

5. Reaming of two through holes:

- Hole diameter: Ø8.5 mm (0.33 in)
- Hole depth: 20 mm (0.79 in)

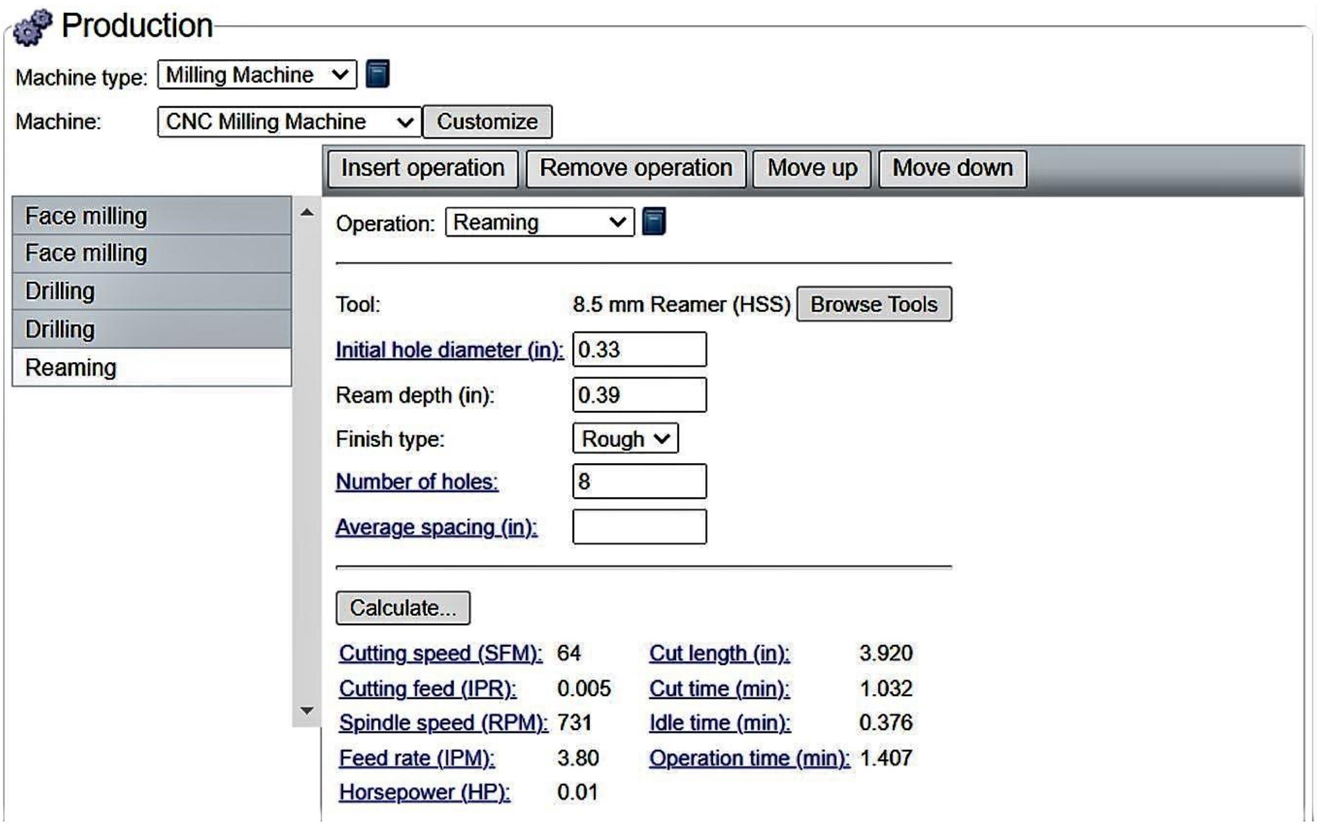


Fig 1.15 Time estimation for reaming

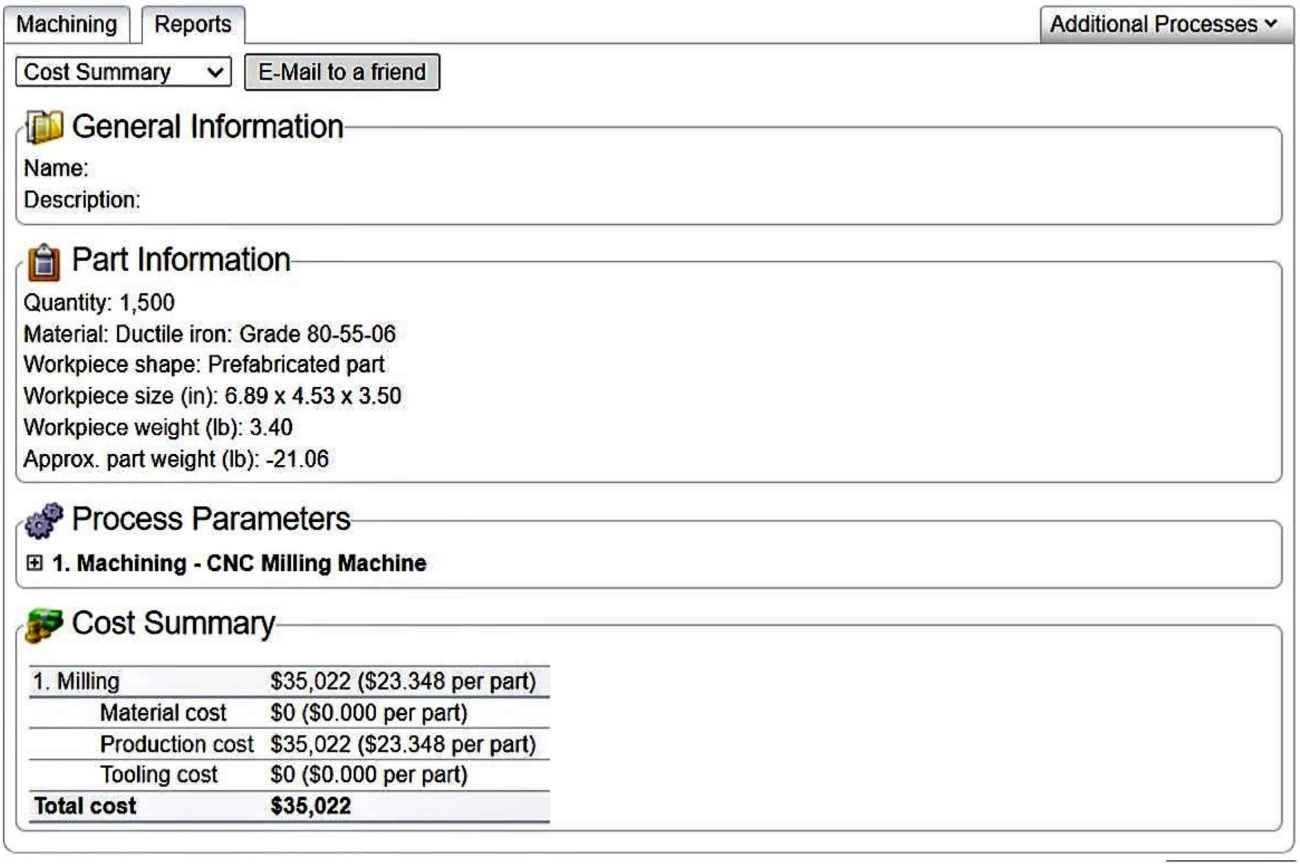


Fig 1.16 Machining Details

Fig 1.17 Cost Summary

Chapter 2

2.1 Development of the Fixture Design

Fixture drawing for the 1st Manufacturing Operation

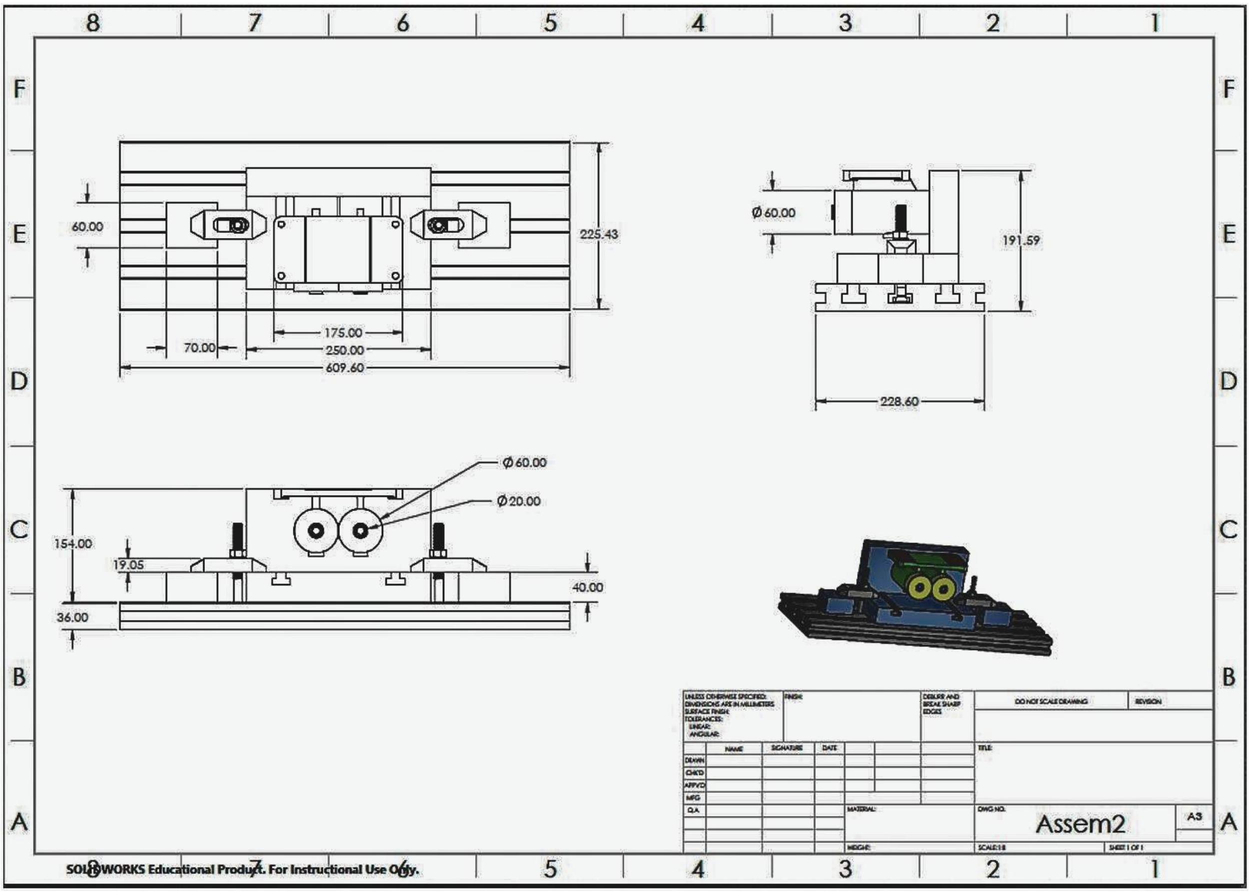


Fig 2.1 Assembly drawing of a fixture for 1st operation

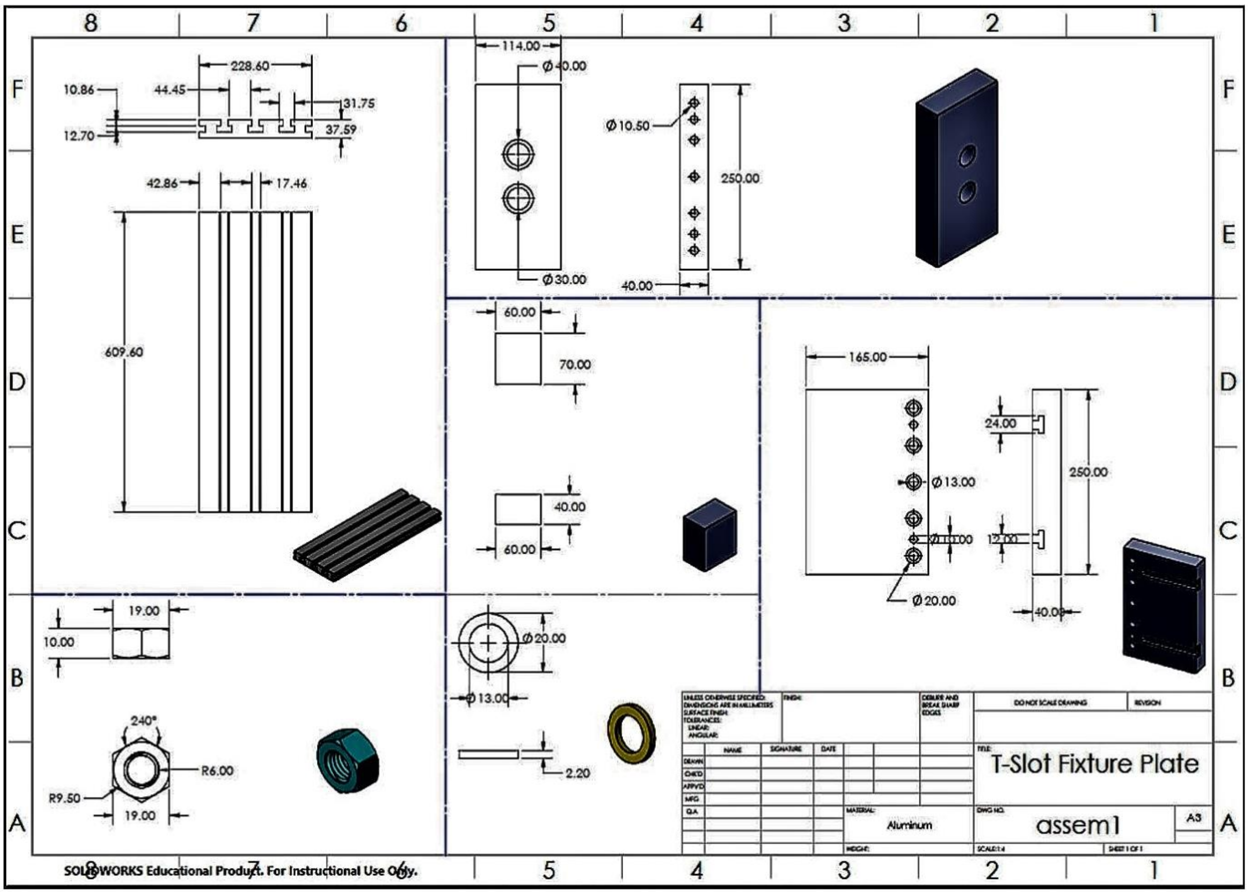

T-Slot Fixture Plate
assem1
Aluminum
SOLIDWORKS Educational Product. For Instructional Use Only.

Fig 2.2

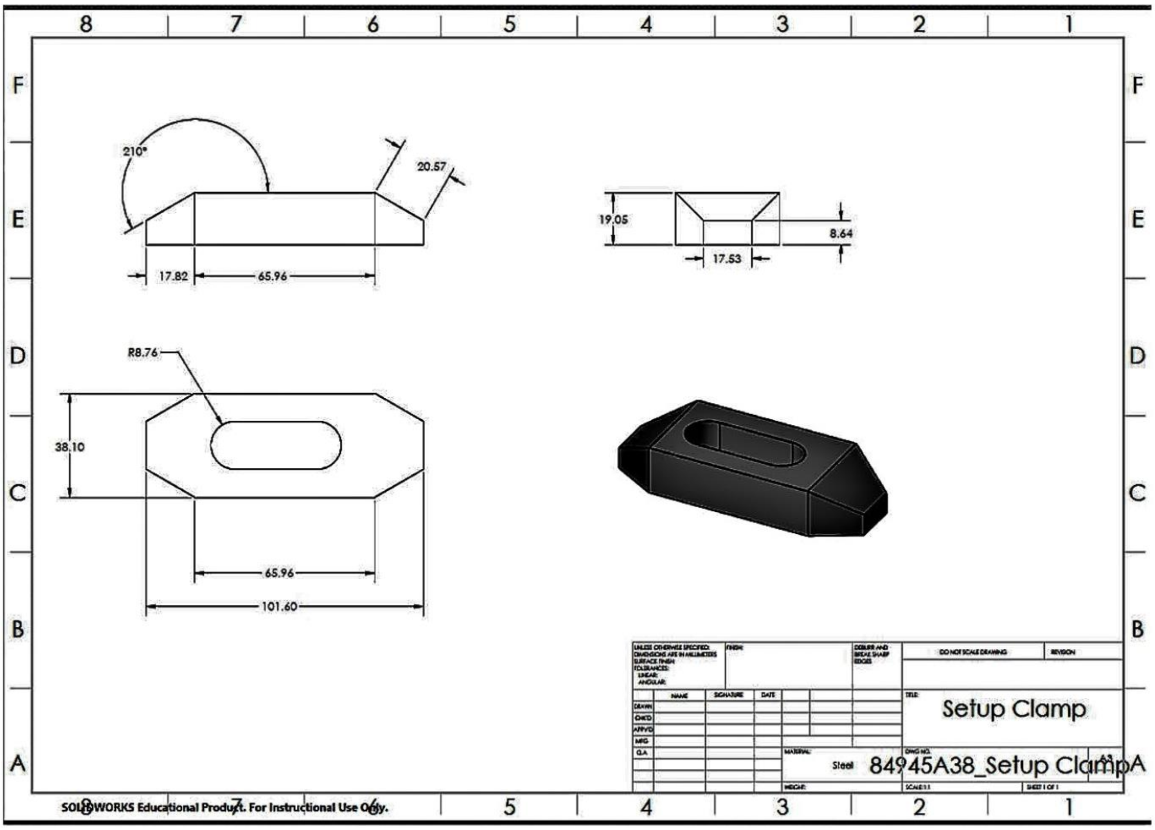

Setup Clamp
84945A38_Setup Clamp
Steel
SOLIDWORKS Educational Product. For Instructional Use Only.

Fig 2.3

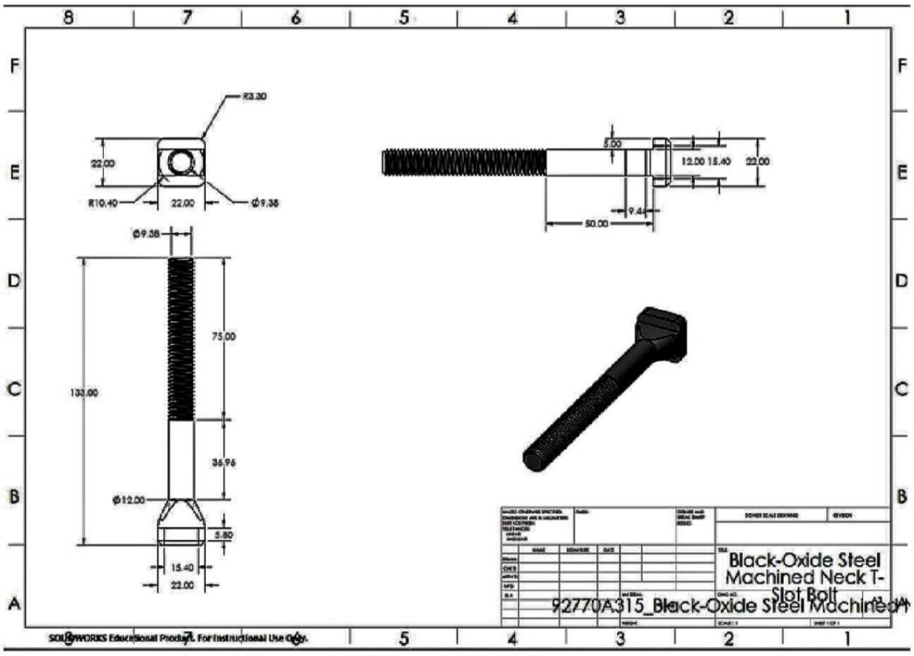

Black-Oxide Steel Machined Neck T-Slot Bolt
92770A315_Black-Oxide Steel Machined
SOLIDWORKS Educational Product. For Instructional Use Only.

Fig 2.4

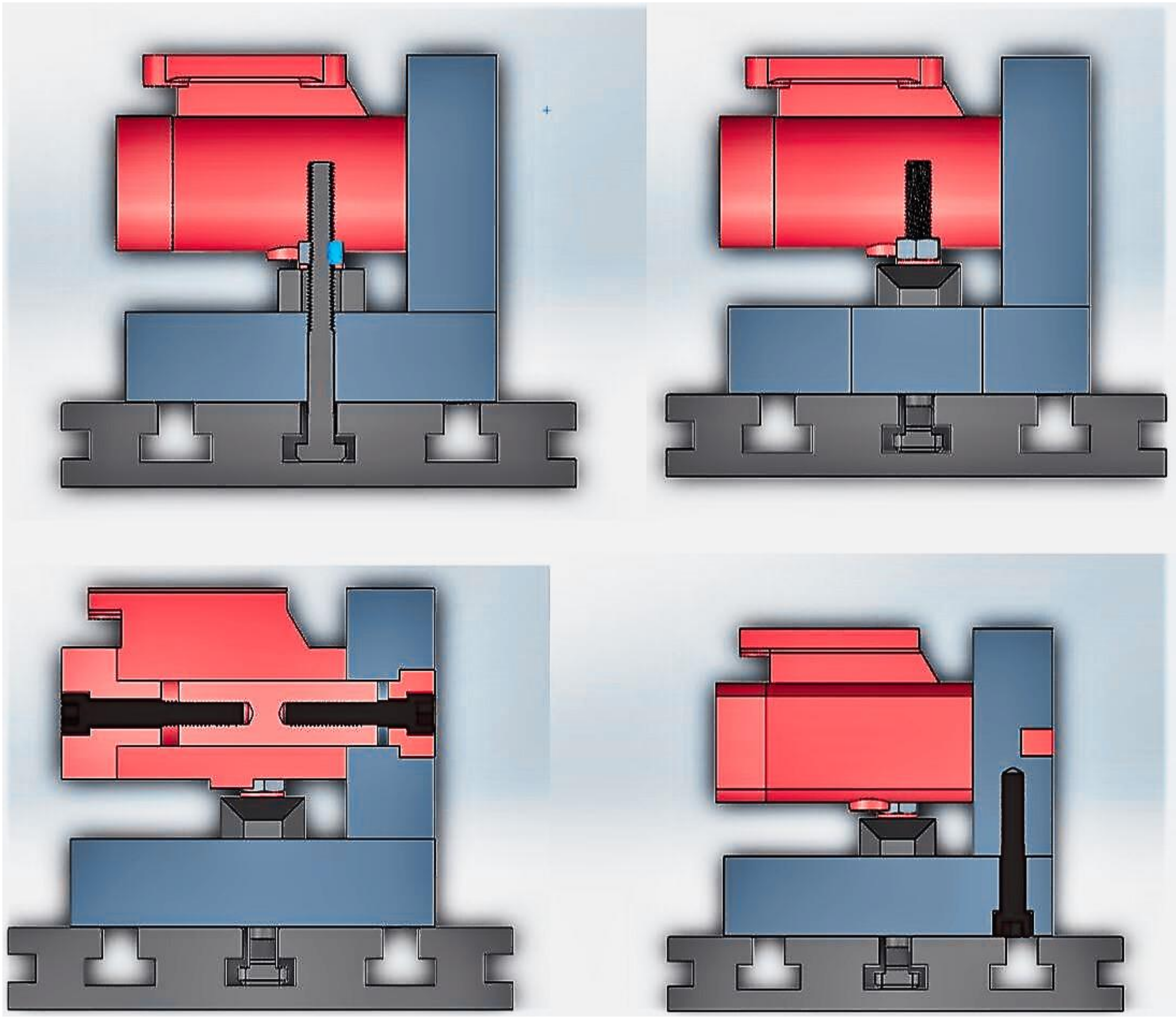


Fig 2.5

Fixture drawing for the 2nd Manufacturing Operation

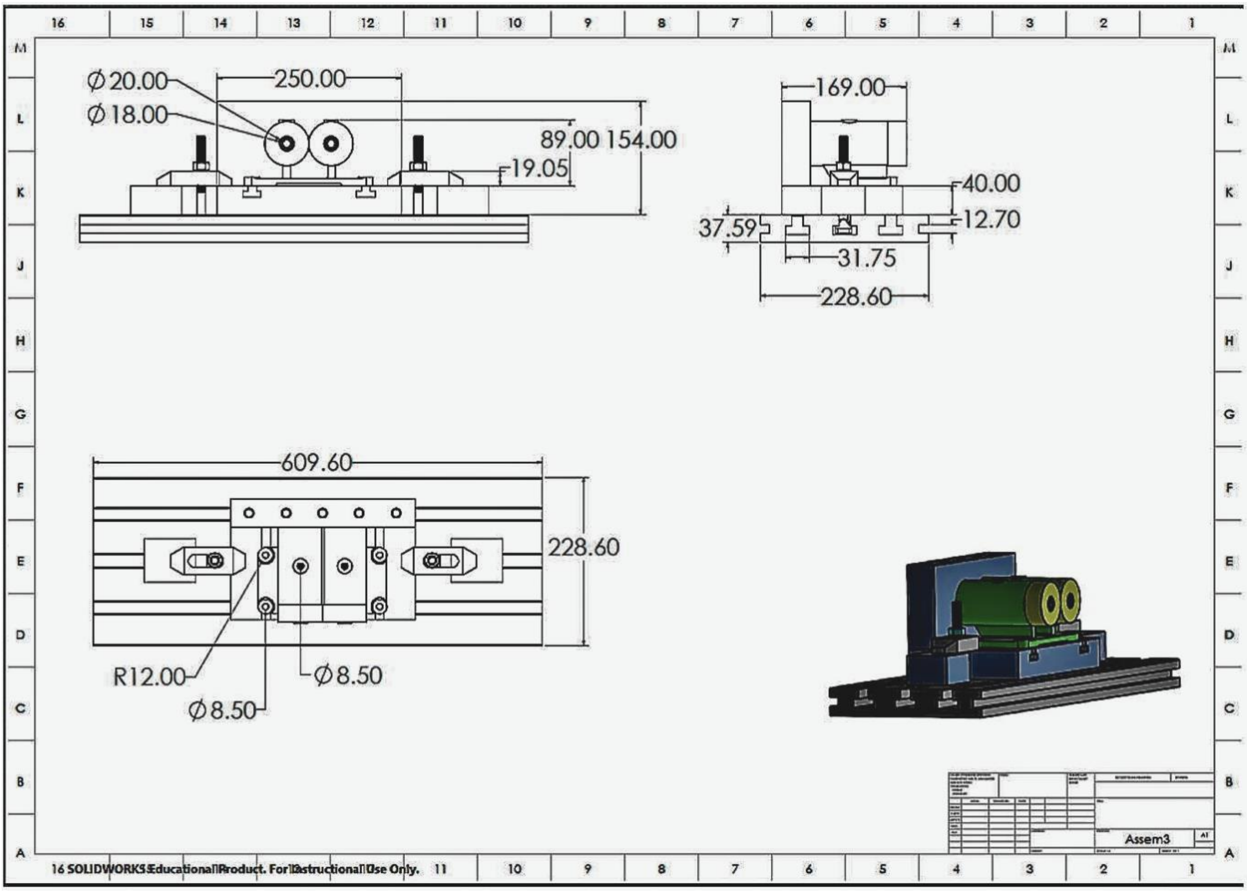


Fig 2.6 Assembly drawing of a fixture for 2nd operation

2.2 Clamping Force Calculation

To secure a component, various types of devices can be utilized, such as specialized tools, modular fixture systems, and versatile devices. Considering the medium-scale production nature, it is most efficient to employ the modular fixture system. This device is uncomplicated, featuring manual clamping, and designed for use with multipurpose machines.

With a total weight not surpassing 25 kg, it weighs 19 kg, allowing for manual loading onto the machine's work area. The chosen positioning method for the current operation involves placing the workpiece on the designated surface and hole, effectively eliminating five degrees of freedom.

To execute the complete positioning approach, a dedicated grip is additionally introduced, ensuring accurate placement of the part prior to fastening and processing.

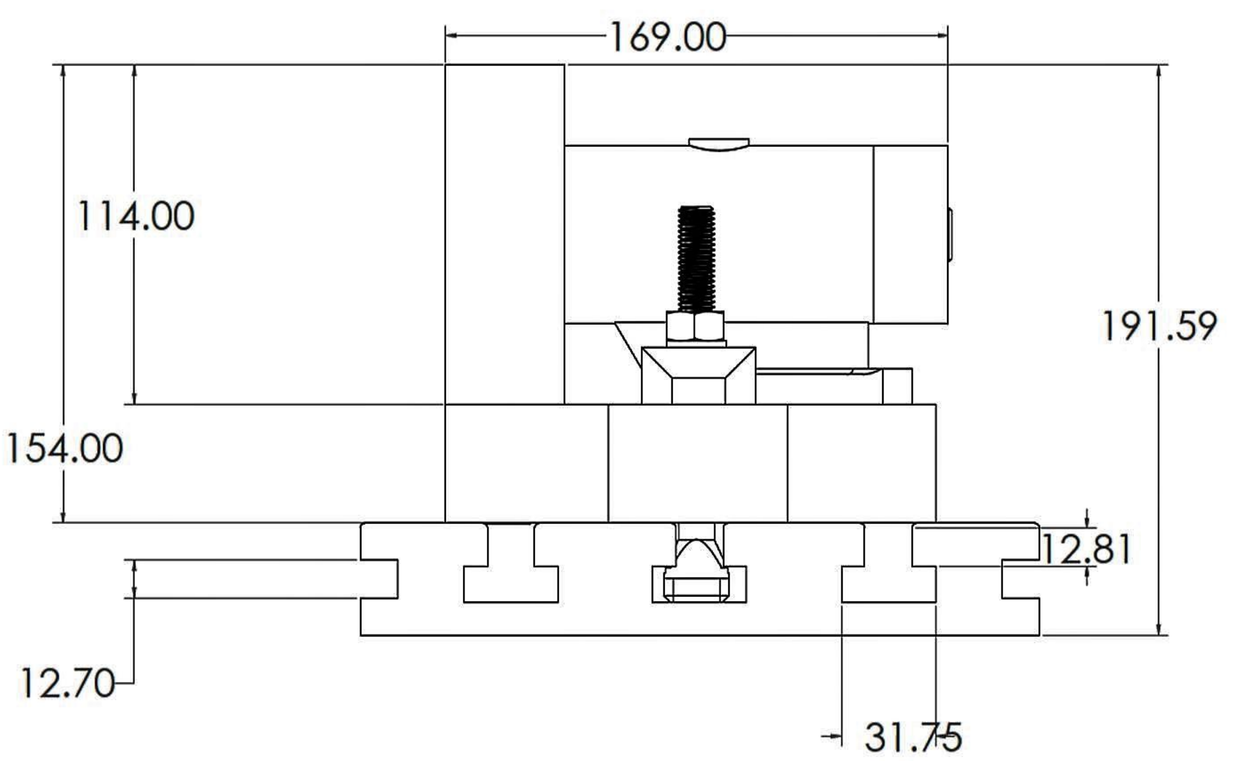


Fig 2.7 Fixture Sketch

Under the given conditions, we need to calculate the clamping force Q required to securely fix the workpiece. To perform the calculation, we make the following simplifying assumptions:

- The weight of the workpiece is disregarded.
- Supports and clamping components are rigid.
- The positioning fingers do not experience cutting forces.

Based on the equilibrium condition, we determine the permissible force Q:

$X = 0$, $kP = 2Q * (f1 + f2)$, $Q = kP / (2 * (f1 + f2))$

Where:

$P = \sqrt{(Pay^2 + Pz^2)} = \sqrt{(0.16Pz^2 + Pz^2)} = 1.07Pz$

Pz - tangential component of cutting during processing

Pz = 7090N

K is the coefficient of clamping reliability

f_1 is the coefficient of friction for the untreated surface at the contact point of the clamping mechanism with the part,

$f_1 = 0.25$

f_2 is the coefficient of friction for the treated surface at the contact point of the part with the supports,

$f_2 = 0.10...0.16 = 0.10$

Therefore, $kP = 2Q * (f_1 + f_2)$, $Q = (1.0)$

Then,

$kP = 2Q * (f_1 + f_2)$, $Q = (1.07 * k * P_z) / (2 * (f_1 + f_2))$

Since there may be deviations from the calculated conditions in actual practice regarding the forces and cutting moments, it is important to consider their potential increase by introducing a reliability coefficient (safety factor) for clamping, denoted as k. The value of the reliability factor k should be selected separately based on the specific operational conditions and the method of workpiece fixation. Its value can be expressed as the product of coefficients, each reflecting the influence of a specific factor:

$k = k_0 * k_1 * k_2 * k_3 * k_4 * k_5 * k_6$

k_0 - guaranteed safety margin coefficient,

$k_0 = 1.5$;

k_1 - coefficient accounting for the increase in cutting force due to random irregularities on the workpiece;

k_2 - coefficient considering the effect of temperature variations during the operation;

k_3 - coefficient accounting for the dynamic loads acting on the workpiece;

k_4 - coefficient considering the uncertainty in the applied forces and moments;

k_5 - coefficient accounting for potential wear and tear on the clamping mechanism;

k_6 - coefficient considering the uncertainty in the friction coefficients.

Each of these coefficients should be determined based on the specific circumstances and characteristics of the process.

Chapter 3

3.1 Spiral drill design 8.5mm

3.1.1 Input data for drill design

It is necessary to design a spiral drill for machining a hole with a diameter of 6 H12 and a depth of up to 60 mm, about fermented material structural steels of the type Steel 15 – Steel 50, their main characteristics in accordance with [1] HB from 131 to 241, σ_{in} 324 MPa to 530 M Pa., machinability set from 1.6 to 0.8 for high-speed steels and 1.5 and 1.0 for hard alloy.

3.1.2 Vybir material spiral drill

Nowadays, tool steels (carbon, alloy, high-speed), hard alloys, mineral ceramic materials, super hard materials are used for the manufacture of cutting tools.

High-speed steels are the main materials for the manufacture of spiral drills. The volume of production of steel tools among cutting tools is 50 – 70%. This situation is typical for most developed countries.

Over the past 15 - 20 years, new grades of high-speed steels have been developed and mastered, in many countries the production of high-quality tool steels by powder metallurgy has been mastered. The use of cutting part coatings has increased significantly.

For the manufacture of drill bits in accordance with the processed material and recommendations [1], we choose a high-speed cuter steel R6M5F3-MP, which contains 6% tungsten, 5% molybdenum and 3% vanadium.

It is used to manufacture all types of cutting tools designed for machining structural steels. After heat treatment, steel R6M5F3-MP has a hardness of HRCe6.4 – 6.6.

Steel R6M5, F3-MP was adopted as a tool material for the manufacture of a spiral drill. The chemical composition in % of material P6M5, F3-MP is shown in Table 1. 1.

C	Co	Cr	Cu	Mn	Mo	Ni	O_2	P	S	Si	V	W	N_2	Fe
1,25-1,35	before 0,50	3,8-4,3	before 0,25	before 0,50	5,5-6,0	before 0,40	before 0,02	before 0,03	before 0,03	before 0,60	3,1-3,7	5,7-6,7	0,02-0,06	basis

Table 3.1 The chemical composition of the material: R6M5, F3-MP

3.1.3 Drill design

The main geometric dimensions of the drill are chosen according to GOST 885-77, and GOST 886-77, namely the diameter of 6 mm, the length of the drill 1 = 139 mm, the length of the working part l_1 = 92mm.

To improve the performance of such a tool, it is recommended to perform two-plane sharpening of the tool and for the material being processed the following geometric parameters of the cutting part of the drill are recommended in accordance with the recommendations for choosing their numerical values [1, 2, 3, 4, 5], select the following values, as shown in Table 3.2 (Fig 3.1)

№	Parameter name	Meaning
1	Drill diameter	D = 8.5 mm
2	Drill length	l = 139 mm
3	The length of the working part of the drill	l_1 = 92 mm
4	Core diameter	d=0.15D=0.15*8.5=1.275mm
5	The angle of inclination of the helical groove	$\omega=30^0$
6	Rear tool angle	$\alpha_{in}=12^0$
7	Angle in plan	$\varphi=60^0$
8	The angle of inclination of the transverse cutting edge	$\psi=55^0$
9	The angle of inclination of the dividing line of the plane R and F	$\varepsilon=5^0$

Table 3.2 The main parameters of spiral drill and geometry of the cutting part

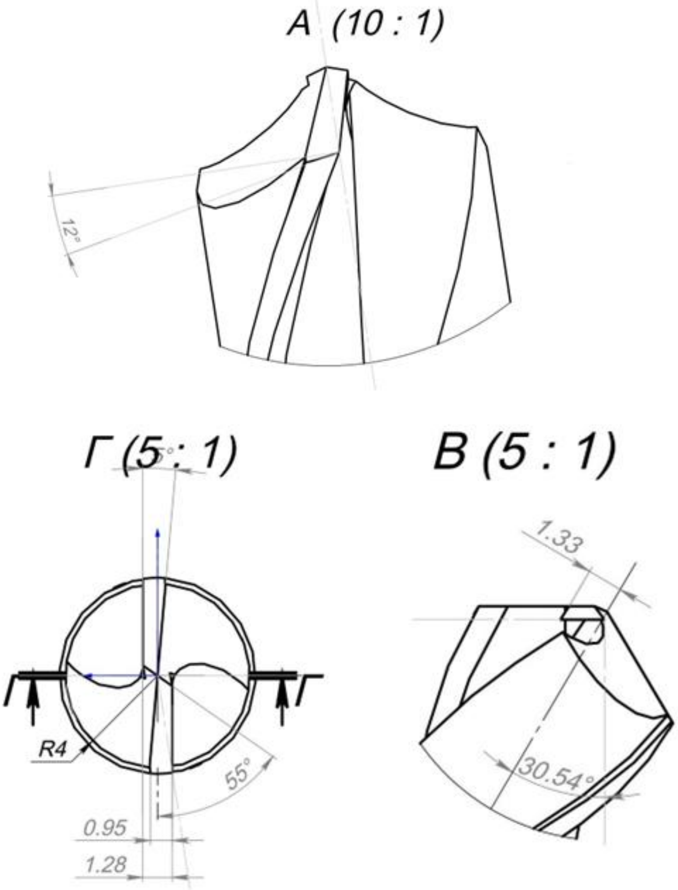


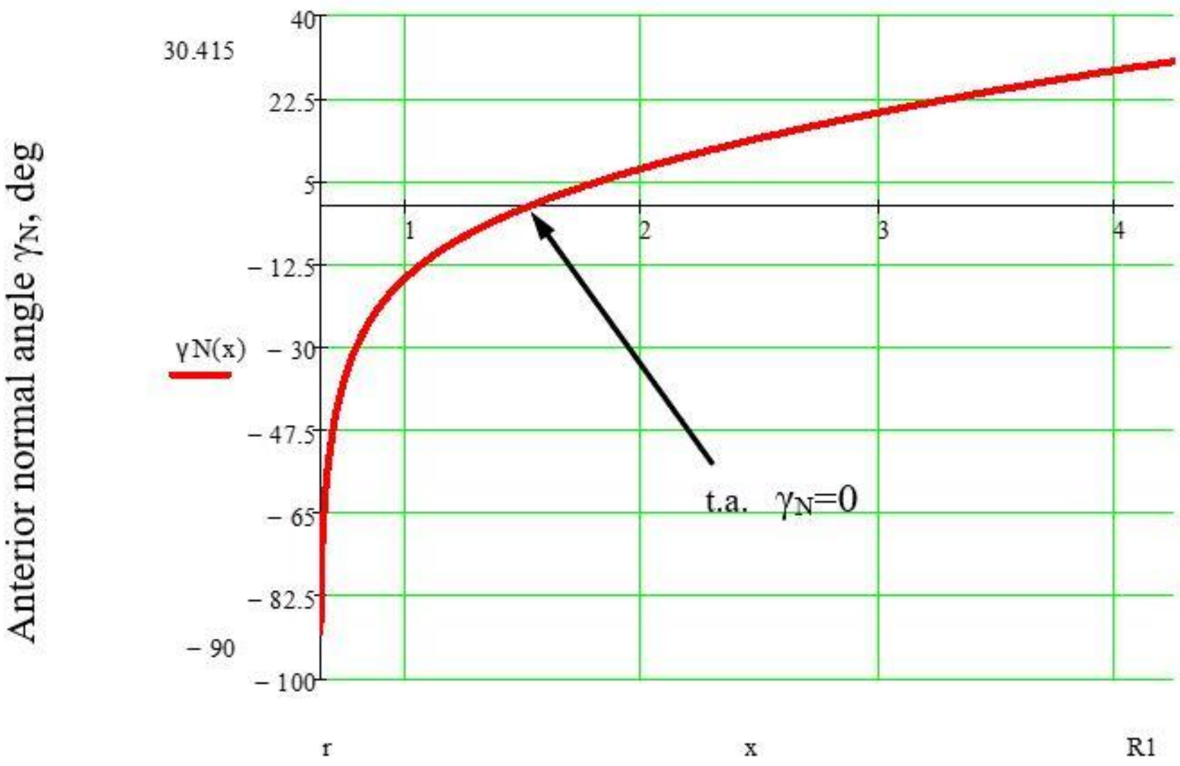
Fig 3.1 The main parameters of the geometry of the cutting part of the drill

To improve the geometry of the front surface of the cutting part of the spiral drill, it is recommended to make a point of the transverse cutting edge of the drill, since the change in the values of the front normal angle of the cutting γ_N according to [2]:

$$\operatorname{tg}\gamma_N = \frac{R_x}{R}\operatorname{tg}\omega\,\frac{(1-\sin^2\mu\,\sin^2\varphi)}{\sin\varphi\cos\mu} - \cos\varphi\operatorname{tg}\mu,$$

$$\sin\mu = \frac{d}{R_x}. \qquad , (1.1)$$

In accordance with the values of the parameters of the drill from table 3.2. the graph of changing the angle γ_N will be as follows (Fig 3. 2)

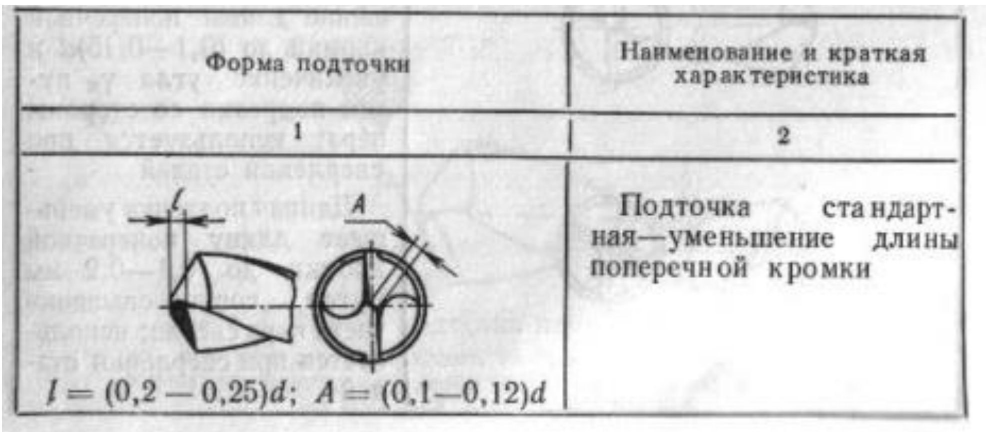


Drill edge cutting point radius, mm

Fig 3.2. Graph of change of the front normal angle γ_N for the drill with the parameters of Table 3.2

The point allows you to eliminate the section of the cutting edge with a negative front angle and create a more rational geometry of the cutting part there.

The main types of subpoints and their joint characters are shown in Fig 3.3



Форма подточки	Наименование и краткая характеристика
1	2
$l = (0,2 - 0,25)d$; $A = (0,1 - 0,12)d$	Подточка стандартная—уменьшение длины поперечной кромки

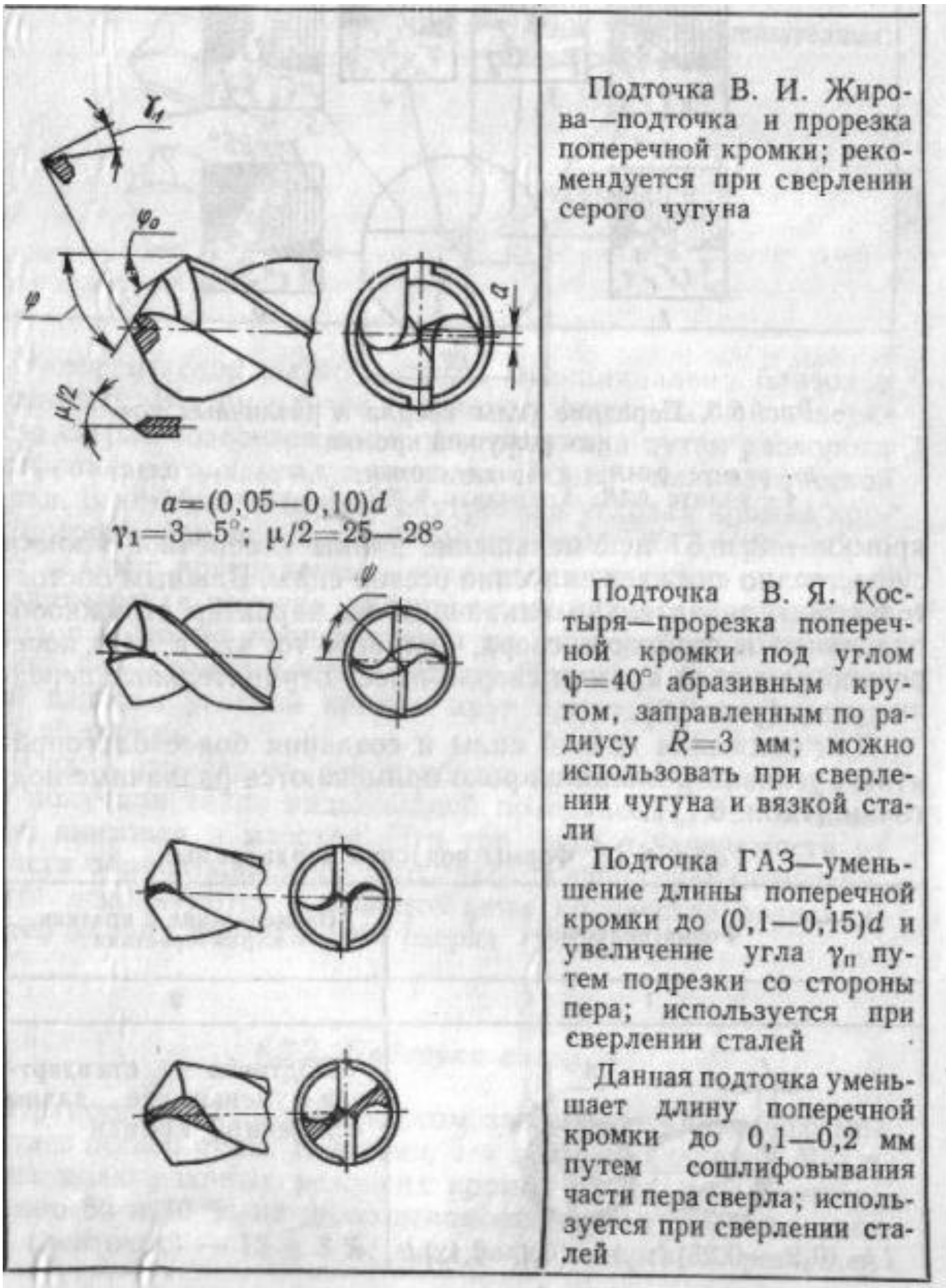


Fig 3.3 The main forms of subpoints of the transverse cutting edge

The main feature of these subpoints is the use of semicircular circles and a convex profile. Therefore, to improve manufacturability, it is proposed to use flat-shaped circles and place them so that the subpoint is formed by the peripheral part of the circle. Pidochka to carry out so that it starts from the cutting-edge point for some angle γ_N=0, for this it is necessary to determine this diameter, from the dependence (1,1), which is equal to zero, determine the value of the radius Rx for which this p will be executed. (Fig 3.4):

$$D := 8.5 \qquad d := 0.15 \cdot D =$$

$$\omega := 30 \cdot deg \qquad \varphi := 60 \cdot deg$$

$$R1 := 0.5 \cdot D = \qquad r := 0.5 \cdot d =$$

$$Rx := \sqrt{\frac{r \cdot \sin(\varphi) \cdot (R1 \cdot \cos(\varphi) + r \cdot \sin(\varphi) \cdot \tan(\omega))}{\tan(\omega)}} =$$

$$Dx := 2 \cdot \frac{r \cdot \sin(\varphi) \cdot (R1 \cdot \cos(\varphi) + r \cdot \sin(\varphi) \cdot \tan(\omega))}{\tan(\omega)} =$$

$$\frac{Rx}{R1} \cdot \tan(\omega) \cdot \frac{\left(1 - \sin\left(\mathrm{asin}\left(\frac{r}{Rx}\right)\right)^2 \cdot \sin(\varphi)^2\right)}{\sin(\varphi) \cdot \cos\left(\mathrm{asin}\left(\frac{r}{Rx}\right)\right)} - \cos(\varphi) \cdot \tan\left(\mathrm{asin}\left(\frac{r}{Rx}\right)\right) =$$

$$\gamma N(x) := \frac{\mathrm{atan}\left[\frac{x}{R1} \cdot \tan(\omega) \cdot \frac{\left(1 - \sin\left(\mathrm{asin}\left(\frac{r}{x}\right)\right)^2 \cdot \sin(\varphi)^2\right)}{\sin(\varphi) \cdot \cos\left(\mathrm{asin}\left(\frac{r}{x}\right)\right)} - \cos(\varphi) \cdot \tan\left(\mathrm{asin}\left(\frac{r}{x}\right)\right)\right]}{deg}$$

$$Rx \rightarrow \frac{1}{\sqrt{2}}\left(\sqrt{\left(r^2 \sin^2(fi) - \cot(w)\sqrt{\left(r^2\left(-\sin^2(fi)\right)\tan(w) - r\,Rd\sin(fi)\cos(fi) - r^2\tan(w)\right)^2 - 4r^4\sin^2(fi)\tan^2(w)} + r\,Rd\sin(fi)\cos(fi)\cot(w) + r^2\right)}\right)$$

(Fig 3.4)

Substituting the values from Table into this dependence. 1.2. we obtain the following value of this radius R x 0=1.529 mm (diameter D_x 0=4.67 mm).

Next, according to the data obtained, we build a parametric model of the drill in the CAD System SOLIDWORKS

3.1.4 Construction of a three-dimensional drill model in the CAD System Solidworks

The main parameters for constructing a parametrical drill mode are taken from table 3.2. The construction of a parametric model of the drill will consist of the following steps.

1. Construction of the drill blank Ǿ8 (fig 3.5).

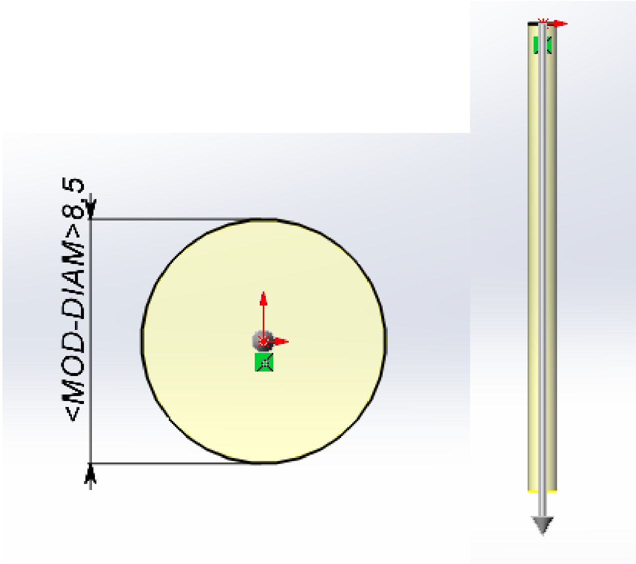


Fig 3.5 Construction of the drill blank

2. At the end of the cylinder, we build an auxiliary sketch of the projection of the cutting edge. Size v42 =0.15*0.5*D – drill core; The angle of inclination of the transverse edge $\psi=55^0$(Fig 3.6).

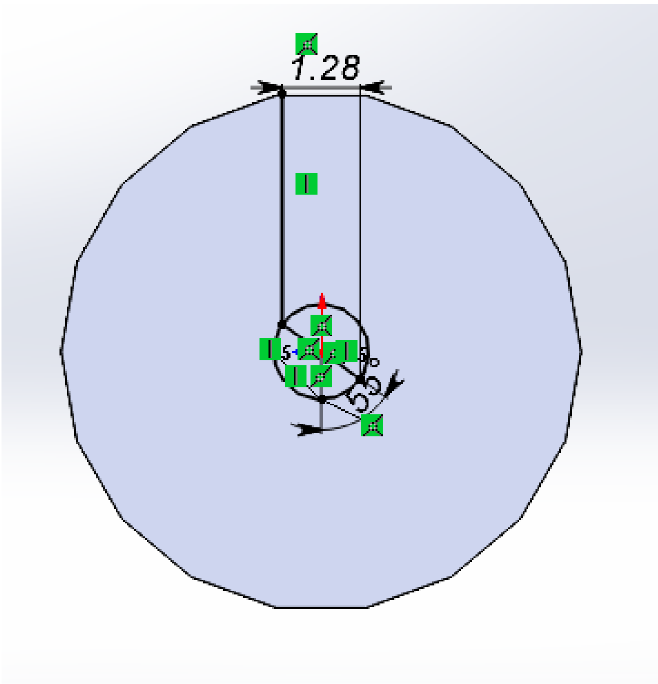


Fig 3.6 Sketch of the projection of the cutting edge.

3. In the plane that is perpendicular to the end of the drill and passing through its axis, we build a sketch of the cutting edge with an angle of $\varphi=60^0$. We project part of the previous sketch to this one using the command "Project object" and change its type to "Thin" (Fig 3.7).

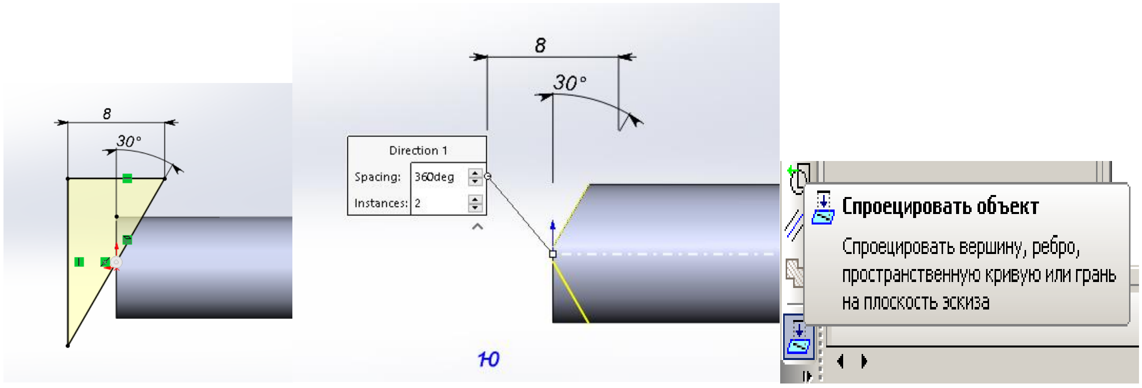
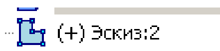


Fig 3.7 E cut edge cutting

Infusing the binding "Point in the middle of the curve", we connect the sketch of the cutting edge with a point from the designed straight line and put down all dimensions (Fig 3.8)

Fig 3.8 Sketch of cutting edge with dimensions

It is advisable to affix all dimensions on the sketch in order to fix it in the construction tree, a fully fixed sketch is indicated by a sign (+) 

4. Extrude the resulting sketch according to the help of the command "Surface Squeezing" and pull it out in two directions so that the workpiece completely overlaps (fig 3.9).

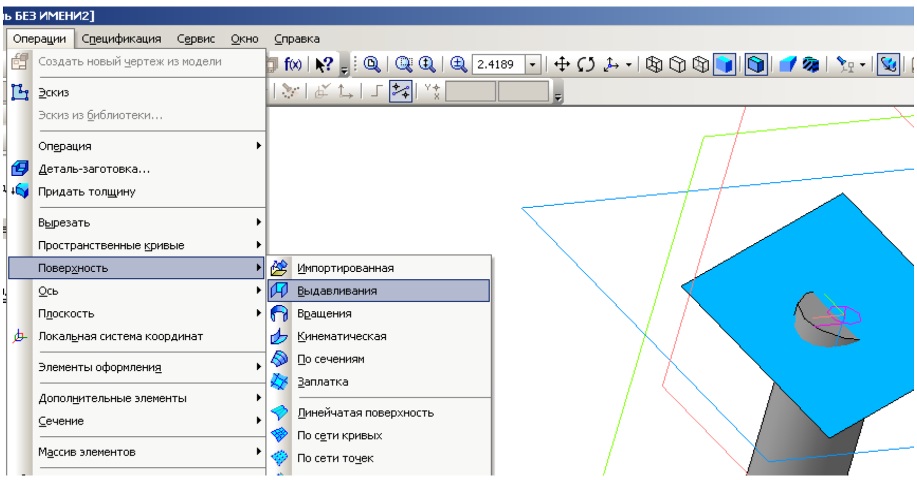


Fig 3.9 Building a sketch of the cutting edge

5. Build the axis of the workpiece using the command "Here is the conical surface" and multiply the surface "Massed along the concentric grid" in a circle (fig 3.10).

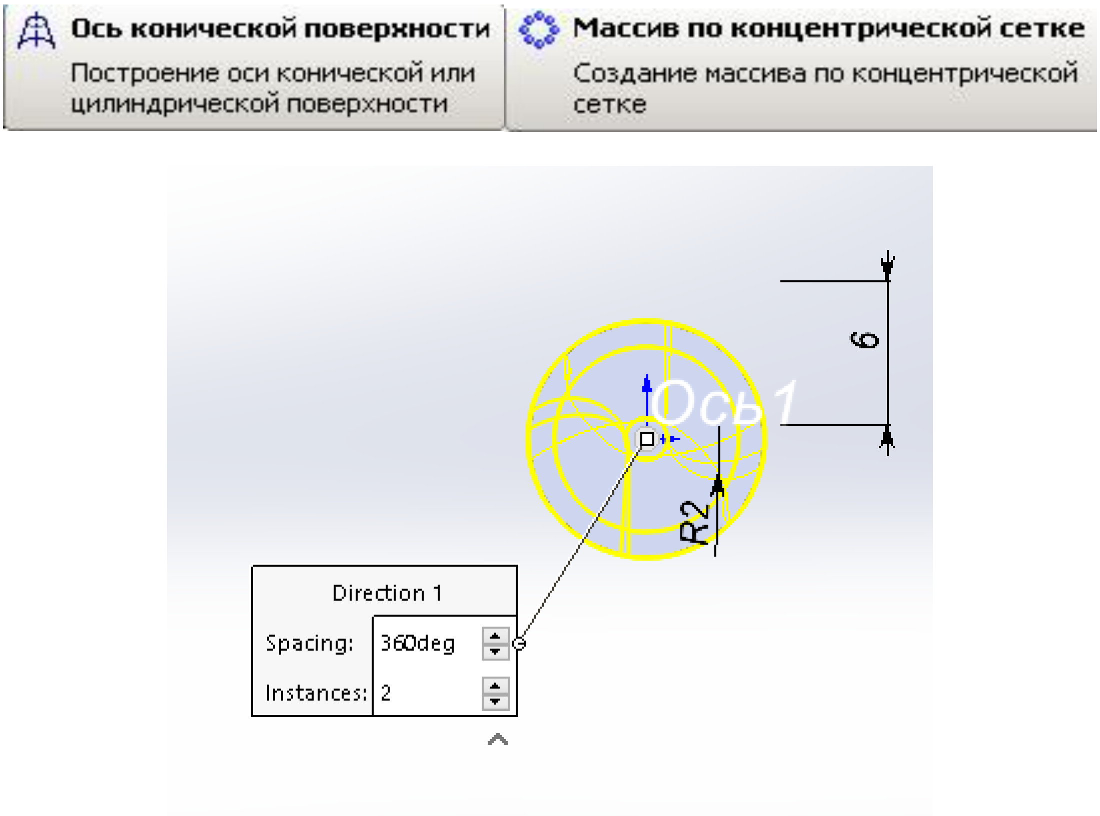


Fig 3.10 Building the workpiece axis

6. Using the "Surface Section" command, cut out a wedge protrusion at the end of the drill blank for each plane and then hide the plane (fig 3.11).

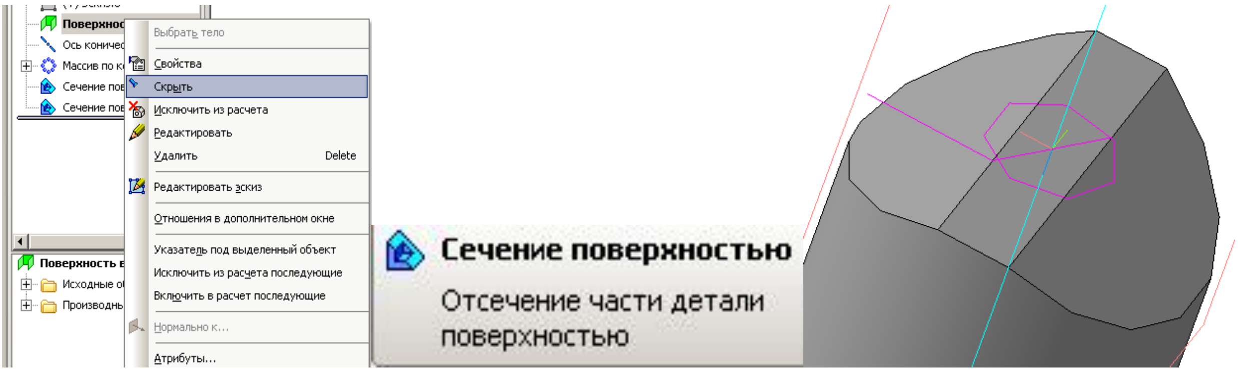


Fig 3.11 Construction of a wedge protrusion at the end of the drill blank

7. On an inclined end plane, we build a sketch of the profile, which we will then cut along the trajectory (fig 3.12)

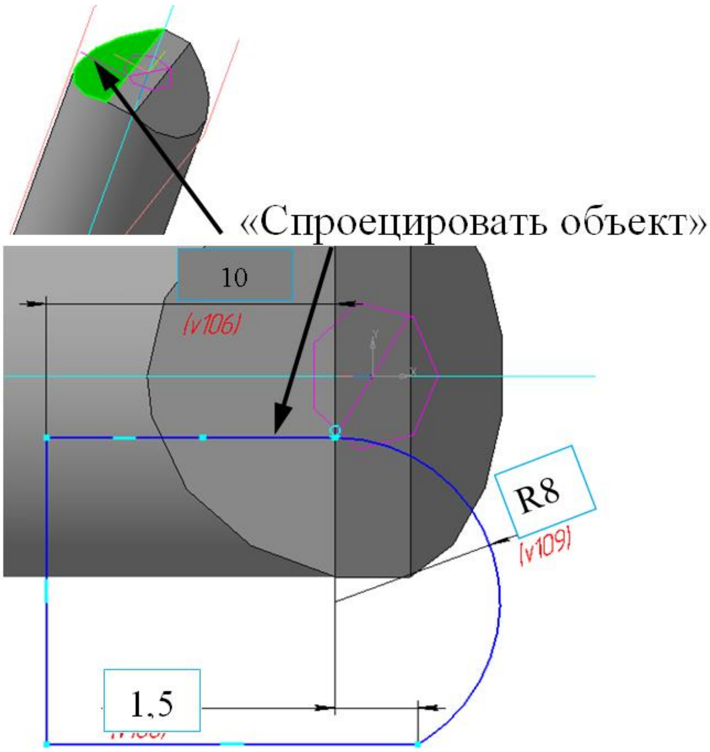


Fig 3.12 Building a profile sketch

8. On the end and plane of the drill we build a spiral with the following parameters: the spiral pitch is calculated by the formula H=(πD)/tg(ω), where dis the diameter of the drill, ω-angle of inclination of the helical drill line on the outer diameter (ω=30^0) H = 46.252 mm, the number of turns 3, the initial angle of the spiral is 360-ψ=360-55=235^0, the diameter tab "by object". To build a spiral, it is first necessary to build a circle by designing a corresponding circle from a sketch of the cutting edge, which we will then use when building a spiral "on the object" (fig 3.13).

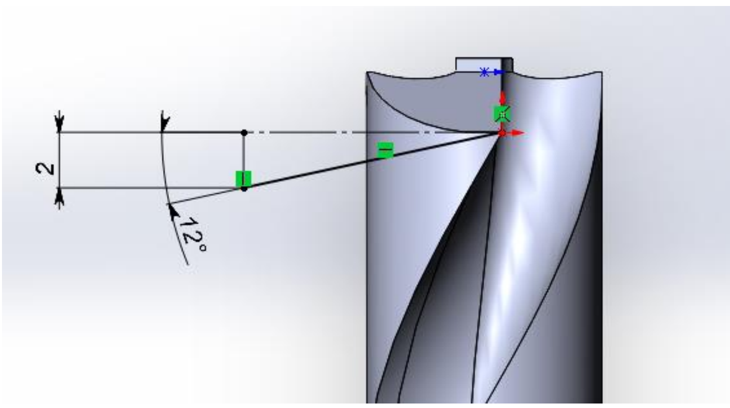


Fig 3.13 Construction of a spiral on the end plane of the drill

9. Using the sketch built in step 7. and the spiral in step 8 we cut along the trajectory and with the help of the surface of the vetch "Massed along the concentric grid" multiplied in a circle, we make a second groove (fig 3.14).

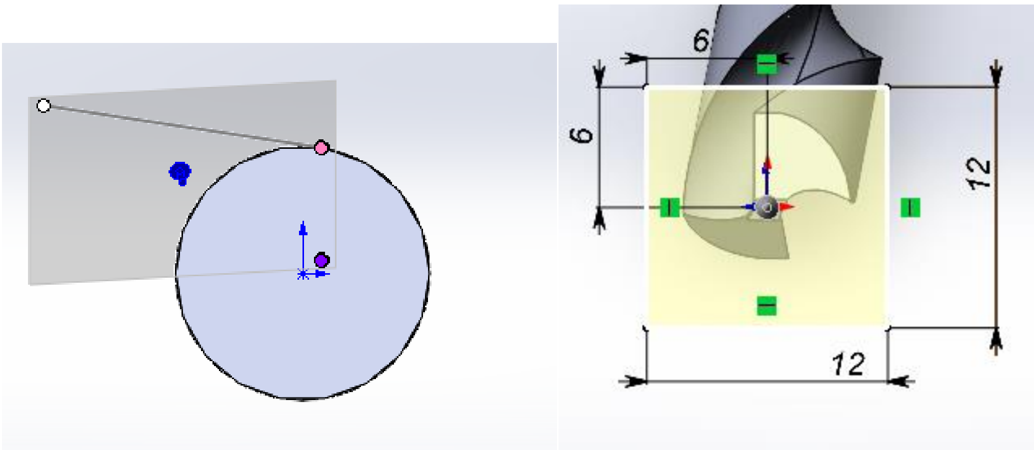


Fig 3.14 Construction of the second groove of the drill

10. Select the jumper plane, create a sketch, select the command "Project an object" and project the boundaries of the sketch plane and pull them out by 1-2 mm (Fig 3.15).

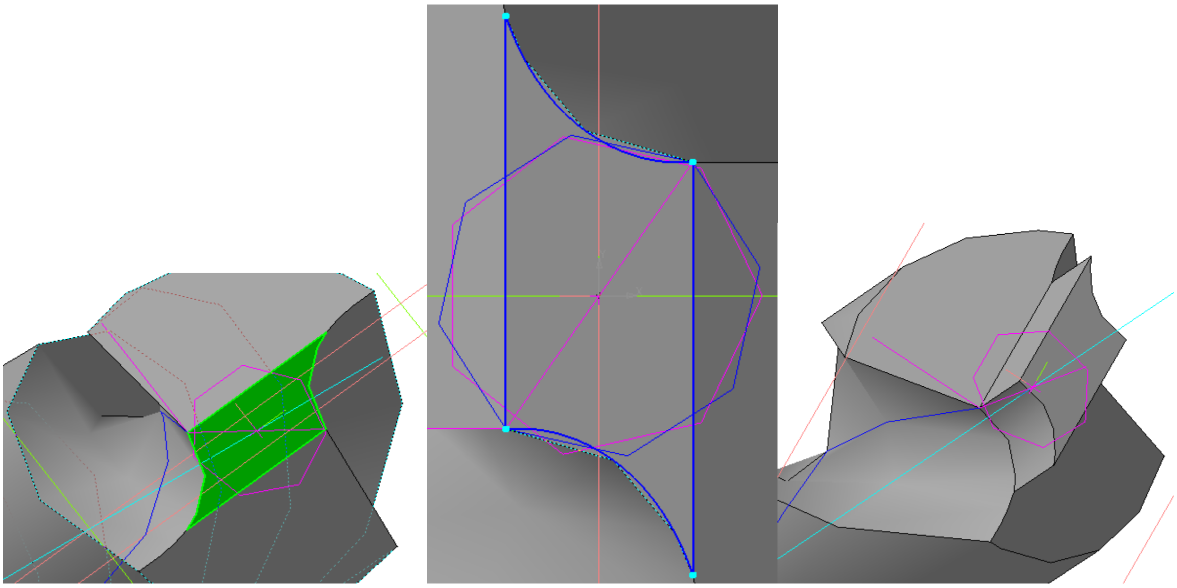
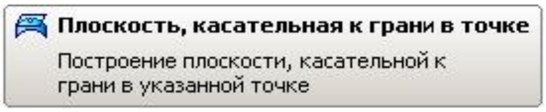


Fig 3.15 Construction of the auxiliary volume of the jumper location

11. To build the back surface of the drill R we create an auxiliary plane at the extreme point of the cutting-edge tangent to the cylindrical surface of the drill (in it we will set the back corner of the drill) (Fig 3.16).



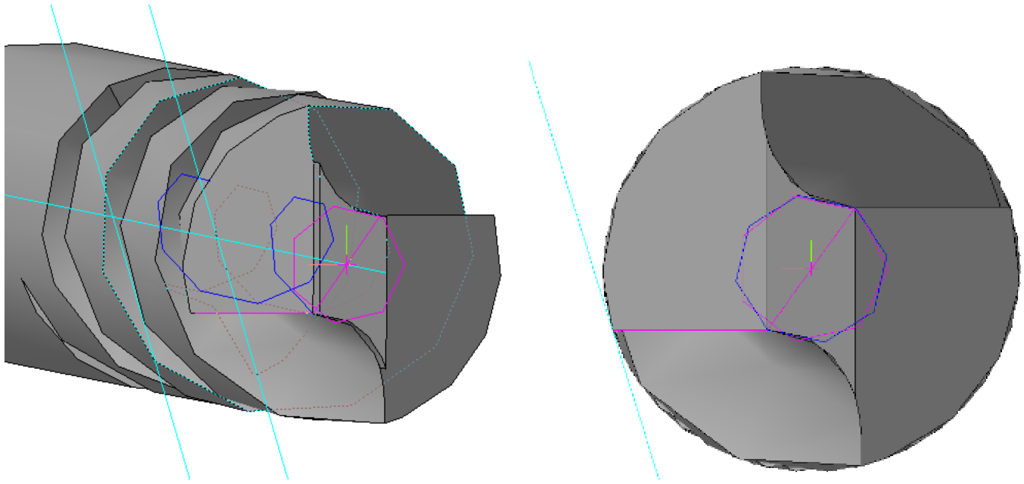


Fig 3.16 Creating an auxiliary plane at the extreme point of the cutting edge

12. In the constructed plane, p.11 sets the product of the back surface at the required angle (as is done in the standard for drills), this line is inclined at a rear angle of $\alpha=12^0$ (Fig 3.17).

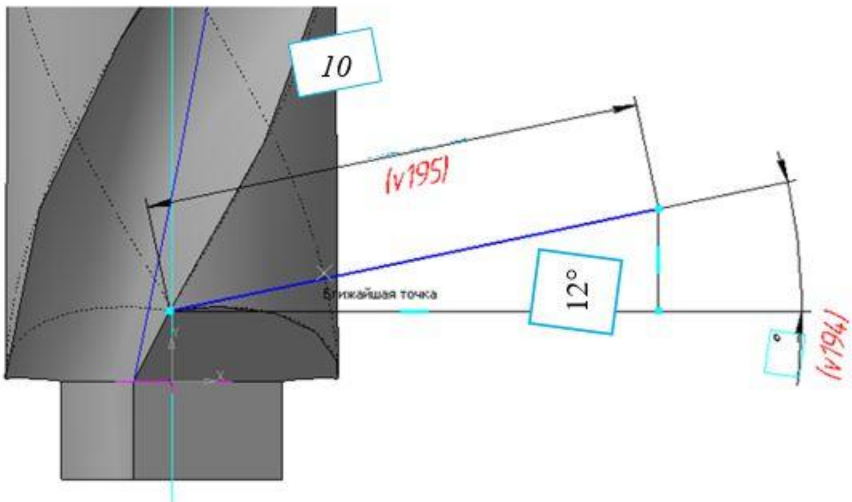


Fig 3.17 Construction of the generating back surface

13. We build an auxiliary plane on three points. As three points, we take 2 points on the cutting edge and construct a point on the sketch from the vowed in paragraph 12 (Fig 3.18).

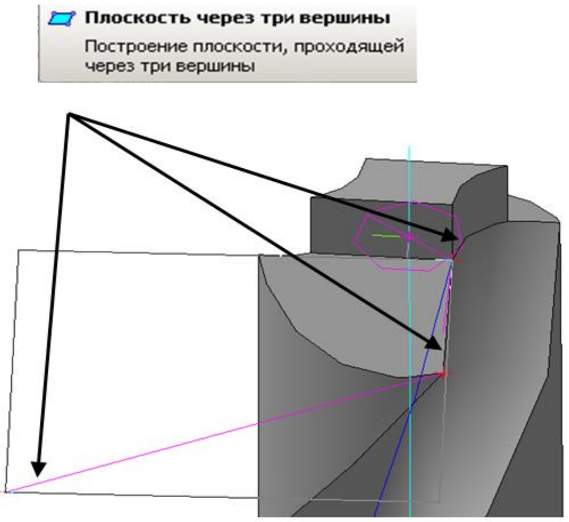


Fig 3.18 Building an auxiliary plane

14. Construction of the rear plane R drill. In the constructed plane p.13, we build a sketch of any shape so that it overlaps the projection of the entire surface of the drill and cut this sketch through and multiply it on the second section of the drill (fig 3.19).

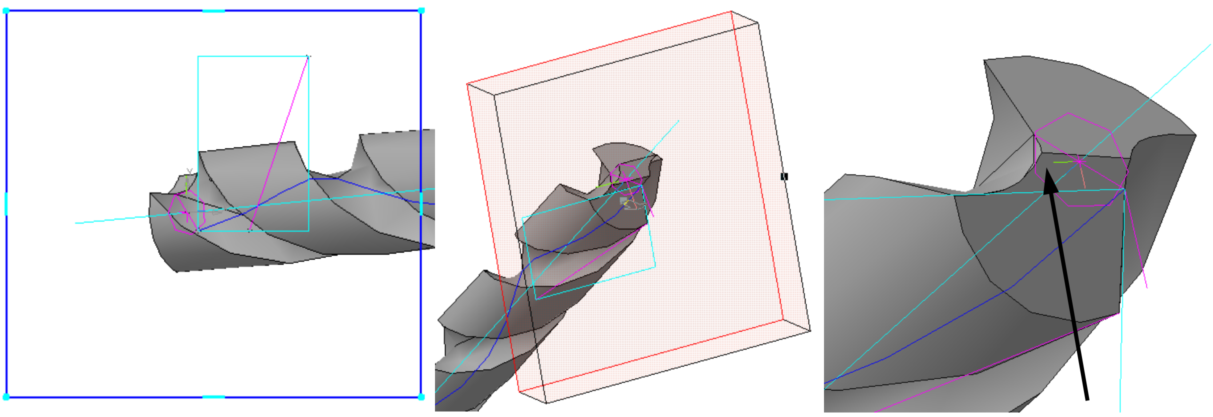


Fig 3.19 Construction of the back plane R drill

15. We build the drill plug, the plane F, it must pass so that its intersection with the plane R is located, the transverse cutting edge takes the position of ψ=55 0 and the dividing line of the planes R and F is located at an angle of ε (see Figure ε>0). We build an auxiliary plane that goes along the axis of the drill and is located at an angle of ε, knock out the axis of the drill and the coordinate plane ZX (for this construction option) (Fig 3.20).

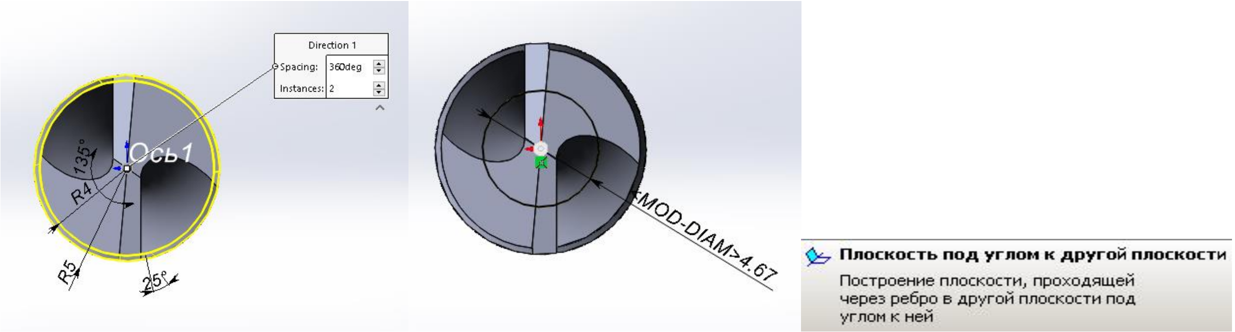


Fig 3.20 Construction of drill plug and auxiliary plane

16. Using the command "Operations", "Spatial curves", "Curved intersection" we build an auxiliary line of intersection of the plane Rof the drill and the plane constructed in paragraphs 1, 5 (Fig 3.21).

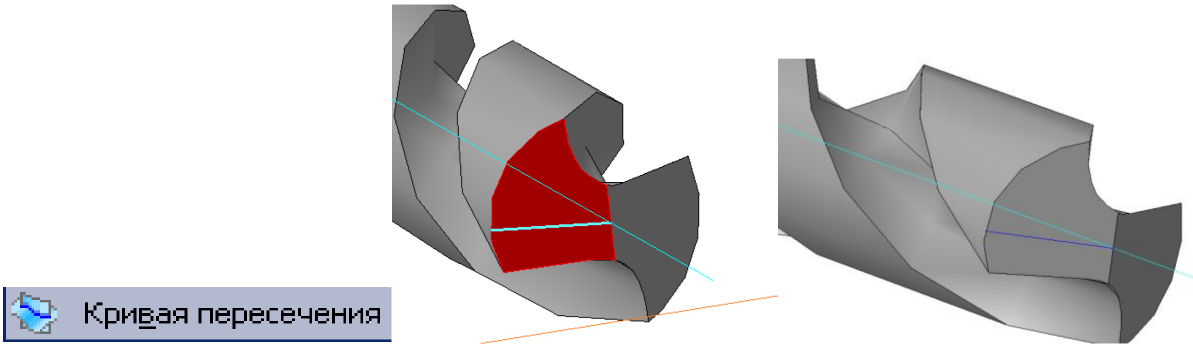


Fig 3.21 Construction of an auxiliary intersection line

17. We build an auxiliary plane on three points. As three points we take 2 points on the constructed curve and the opposite point of the cutting edge on the constructed sketch (fig 3.22).

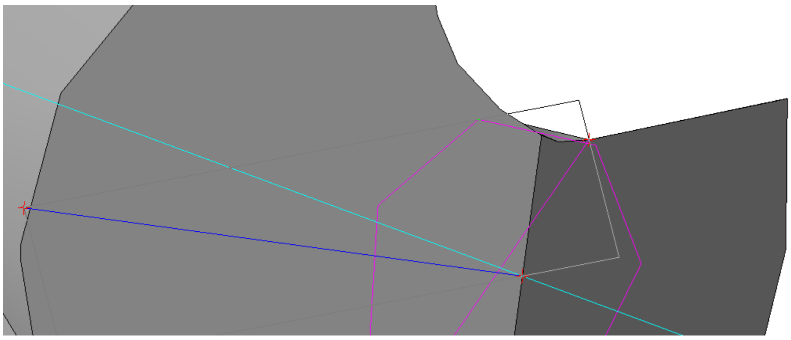


Fig 3.22 Construction of an auxiliary plane

18. In the constructed plane, we build a sketch of any shape so that it overlaps the projection of the entire surface of the drill and cut this sketch through and multiply it on the second section of the drill (fig 3.23).

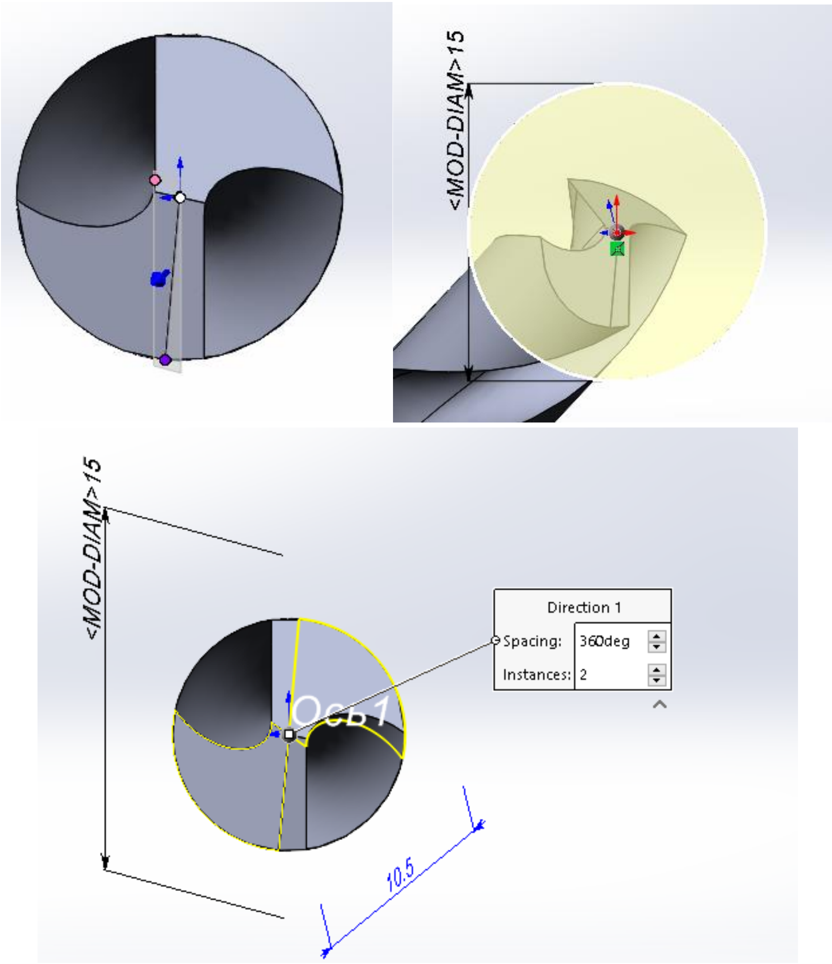


Fig 3.23 Construction of the surface F of the drill

19. We make out the output of the chip groove, rounding command (fig 3.24).

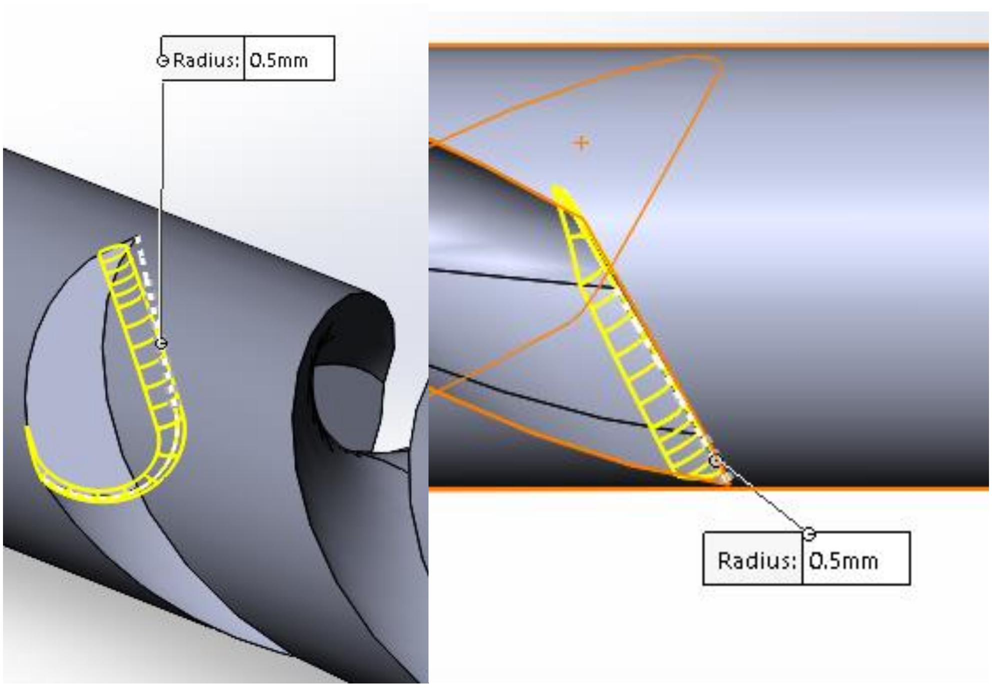


Fig 3.24 Construction of chip groove outlet

20. We make out the screw ribbon of the drill. (Fig 3.25)

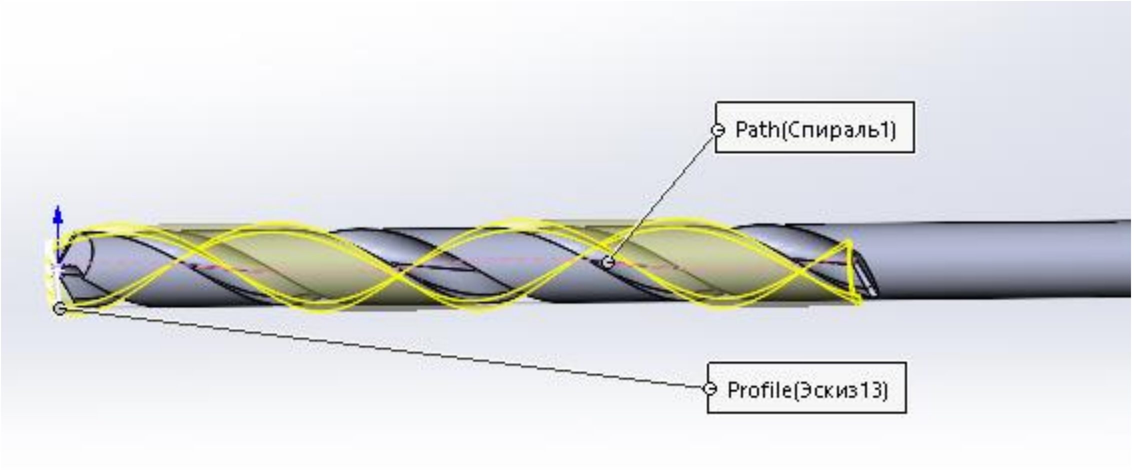


Fig 3.25 Drill model

21. To build a subpoint, it is necessary to check on the 3D drill model to check the correctness of the determined radius from which the negative geometry of the front angle of the cutting edge begins. To do this, we take the resulting model of the drill, its only working cutting part (fig 3.26).

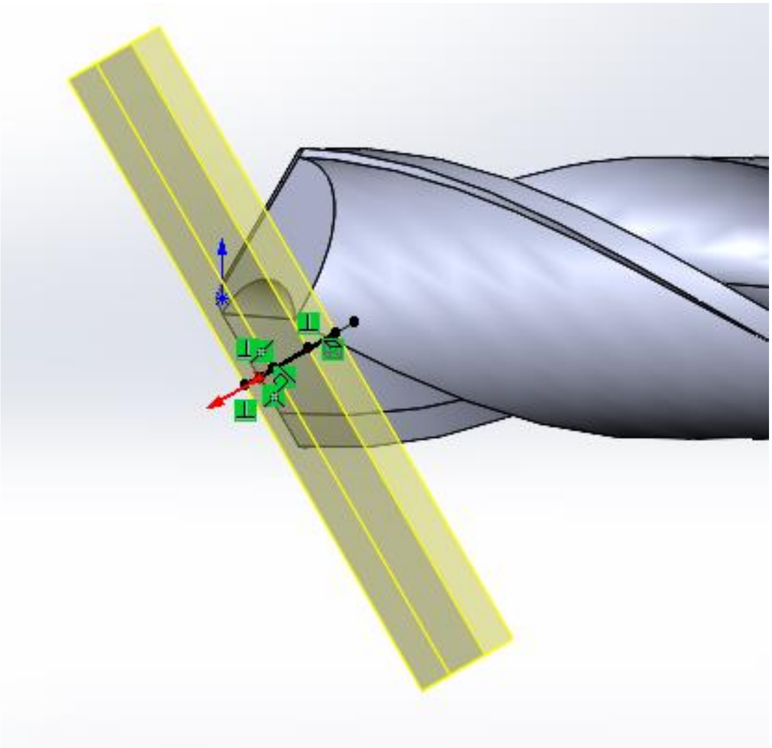


Fig 3.26 Model of the cutting part of the drill

According to the obtained model, we make drawings and making the necessary types and sections we find the front normal angle at the cutting-edge point with a certain radius R x 0=1.529 mm (diameter Dx 0=4.67 mm) Fig 3.27, which confirmed the previously obtained analytical calculations on dependence (1.2)

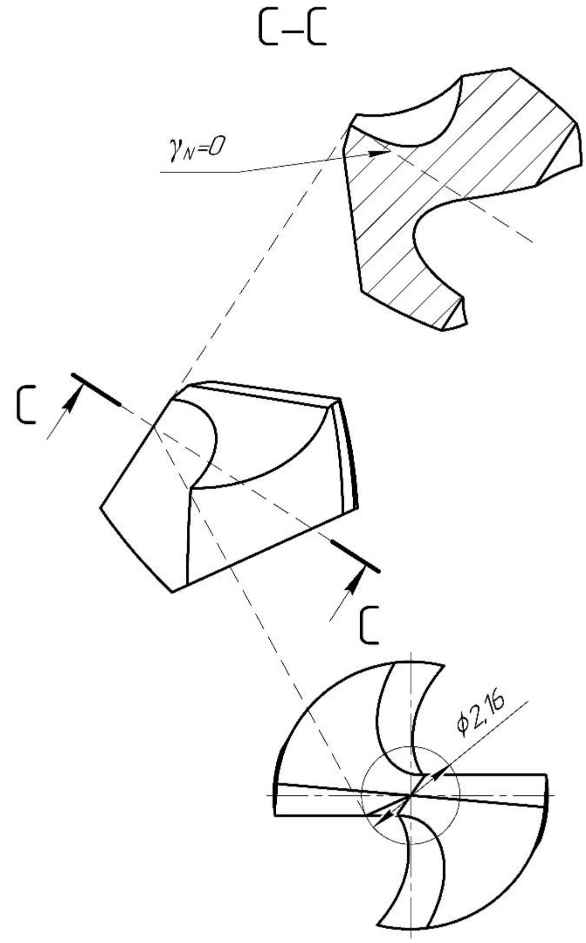


Fig 3.27 Graphical determination of the front normal angle using the 3D model

Accordingly, according to the data obtained, from a point with a diameter of 2.16 mm on the drill model, we form a subpoint so that the front normal angle was 14^0 in its value according to the recommendations [1] (Fig 3.28) the value of the subpoint is formed so that the decrease in the thickness of the transverse edge according to the recommendations [1] is from 1/3 to 2/3 of the initial value (Fig 3.28), and the shape of the subpoint is chosen so that the background is formed by a circle of simple shape (PP) to increase the manufacturability of such drills.

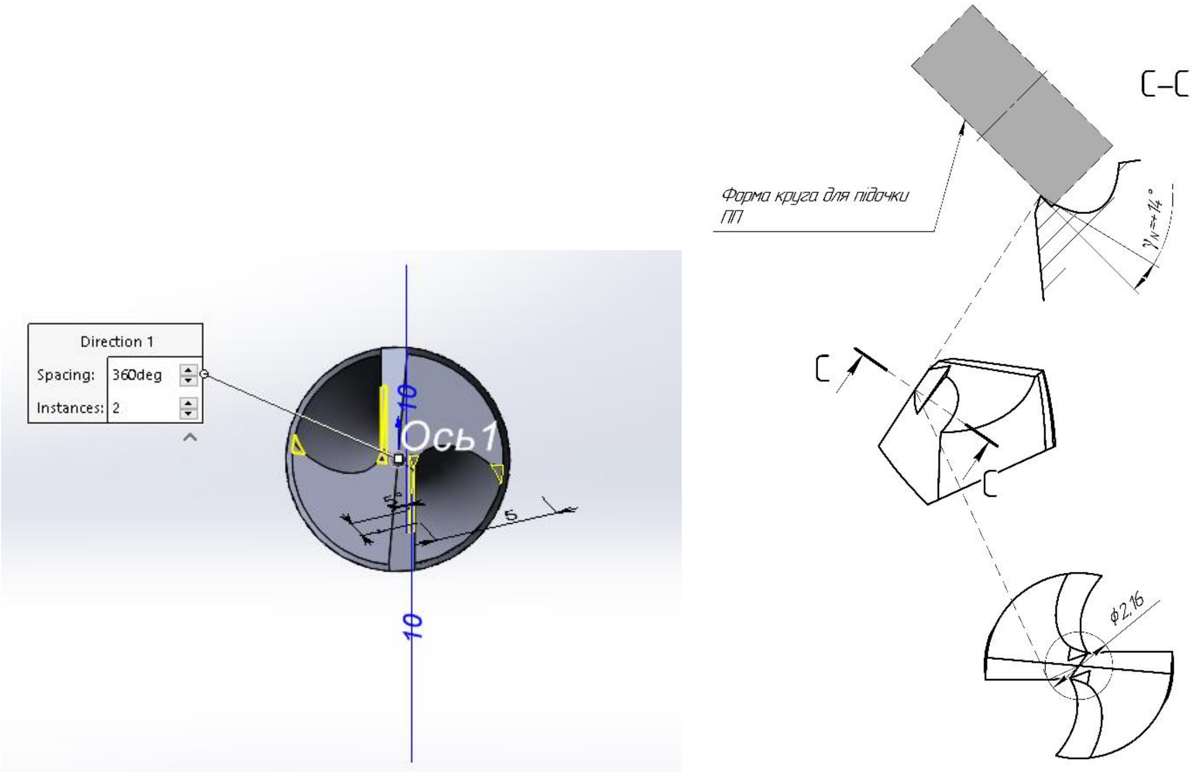


Fig 3.28 Installation of a wheel for forming a cutting-edge point

a) a 3D model of the cutting part of the drill with a subpoint was built,

b) determining the geometry of the front surface of the cutting part of the drill at the point of the diameter of the drill where the cutting-edge point begins.

In accordance with the obtained results of the values of the geometry of the front surface (Fig 3.28), for further construction we take the calculated data and complete the model 3D of the drill, decorating the necessary elements of the point there.

22. According to the obtained model 3D of the drill, we build a working drawing of the drill (Fig 3.29).

We take technical requirements for drill elements according to the Basic technical requirements according to GOST 2034-80E

The initial data of the design of tools, in addition to the drawing, are the technical requirements that are put forward to the developed tool.

Spiral high-speed drills are manufactured in three accuracy classes – A1, B1 and B.

Classes B1, B – normal accuracy.

Normal precision drills are designed to drill holes up to 14 accuracy qualifications. Drills are made of high-speed steel according to GOST 19265-73.

The hardness of the working part of high-speed steel drills with a diameter of more than 65 мм4 – 66 HRCe.

Diameter tolerance fields, measured at the beginning of the working part, for drills B1 – h 8, B – h9.

Drills are manufactured with an inverse taper on the working part with a value of -0.02-0.1100 мм mm.

The core of the working part should evenly increase the thickness in movement towards the shank. The magnitude of the increase in thickness is 1.4- by length.1,8 мм100 мм

The symmetry assumption of the core relative to the drill axis for drill bits with a diameter of 10 is equal to .20 мм0,10 мм

The tolerance of radial runout on the tapes along the length of the working part relative to the axis of the shank for class B1 –, for B – .0,13 мм0,16 мм

The cutting edges should be symmetrically placed relative to the axis of the drill.

The tolerance of the end runout in the middle of the cutting edges for drills B1 –, for B – .0,23 мм0,30 мм

The roughness of the rear surfaces, guide tapes, shanks should not be lower than R a 0.63; groove surfaces not lower than R_a2.5.

The permissible deviation of angles at the top and rear angle should not be greater than ±3°.

3.1.5 Drawing of the drill according to its 3D model

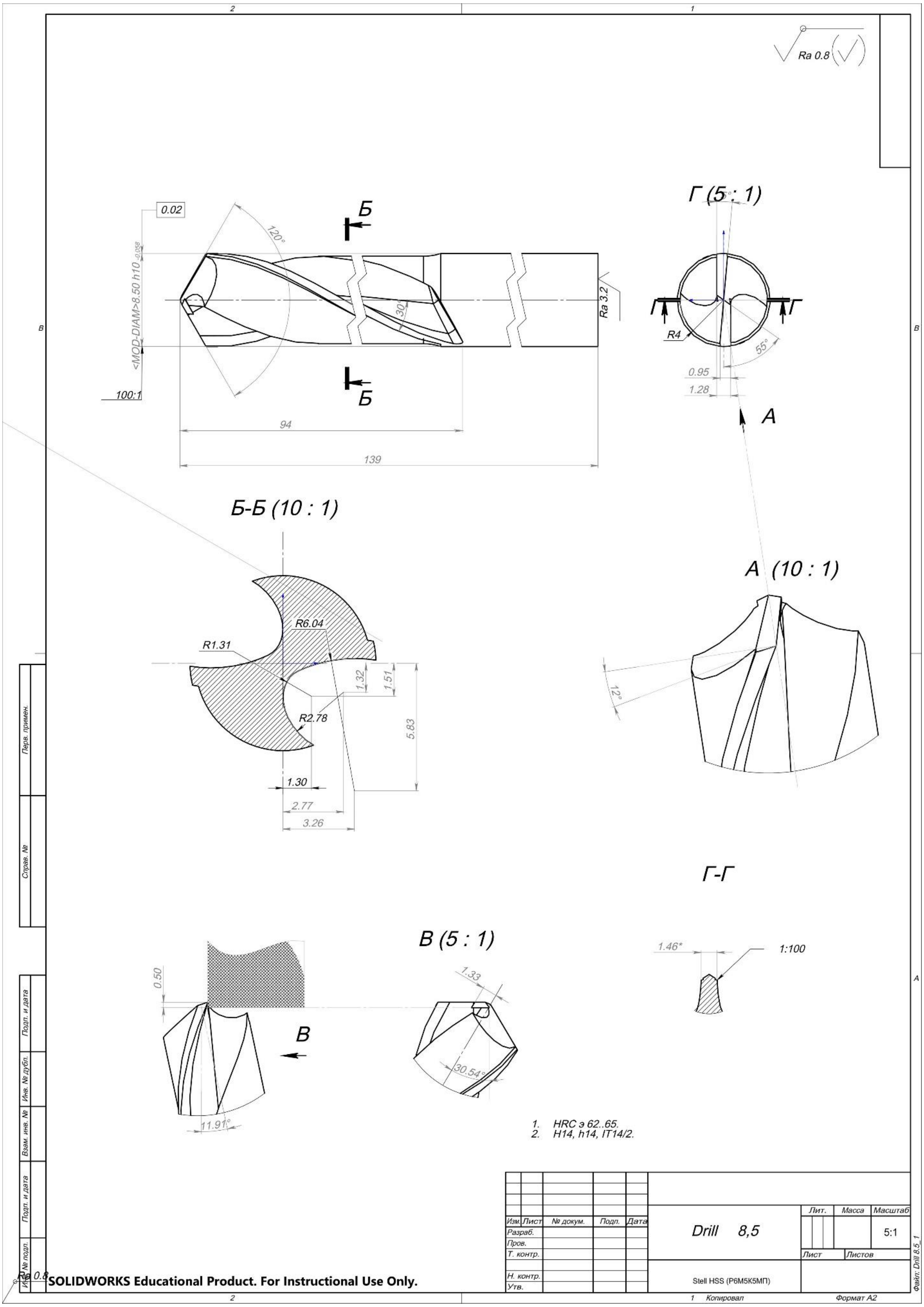


Fig 3.29

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