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GRAPHIC MODELING OF A DRILLING FIXTURE AS A PART OF EMCO MILL 55 CNC MILLING AND DRILLING SYSTEM

Abstract: *The paper presents a drilling fixture that fits on the EMCO MILL 55 CNC working table for machining the holes of some blanks made of materials having low and average hardness. The modeling was carried out with Autodesk Inventor software package, highlighting the essential controls, from basic sketches to the completion of the component parts, respectively the final assembly. At the same time, the paper presents a brief theoretical calculation of the necessary force for fixing the blank into the fixture. Based on the fixture elements, the physical model of the drilling device was drawn. Moreover, a double- straight edged helical drill used for the drilling process was modeled in CATIA environment.*

Key words*: EMCO MILL, CNC machine, fixture, helical drill.*

INTRODUCTION

A fixture is a group of auxiliary mechanisms, its purpose being the serial processing by drilling, of some blanks in the machine building industry. By using a fixture, difficult marking and clamping on the machine's working table are removed, so that the uniformity of the machining process, a reduction of the working time, and operator's safety are achieved [1], [2].

The elements included in the structure of the fixture are subassemblies for the positioning, fixing and fastening the parts on the fixture, and at the same time for guiding the cutting tool during machining [3]. The drilling fixture presented in this paper has removable elements and subassemblies, which must support the blanks to be machined, to enter in and be fixed on easily.

In order to carry out a more rapidly and efficient design of technical products, many 2D and 3D graphical representation systems were developed in virtual environment. These complex software applications can correspond to a certain domain, and others can be generalized such as AutoCAD [4], Autodesk Inventor [5], [6] Pro/ENGINEER, NX Siemens [7], CATIA [8] etc. The advantage of these designing applications consists in the fact that all components are modeled in a 3D environment, which can be optimized in terms of the constructive and geometrical parameters before being physically manufactured.

The drilling fixture presented in this paper was drawn in Autodesk Inventor, a software package that streamlines as concrete and precise possible the 3D modeling of solids. The double straight edged helical drill was drawn in CATIA design software, which provides a wide range of integrated solutions to meet all aspects of design and manufacturing.

2. EMCO MILL 55 CNC MILLING AND DRILLING SYSTEM

The tool-machine which is programmed through a computer interface, using a conventional numeric code, and, at the same time, commanding the same kinematics chain, is called computer numeric control system (CNC).

For EMCO MILL 55 CNC machine, Figure 1, there are four coordinate systems defined: the machine coordinate system (absolute); the reference system, in which the measuring system of the movements is synchronized; the main shaft coordinate system, in which the tool length is measured; the blank coordinate system.

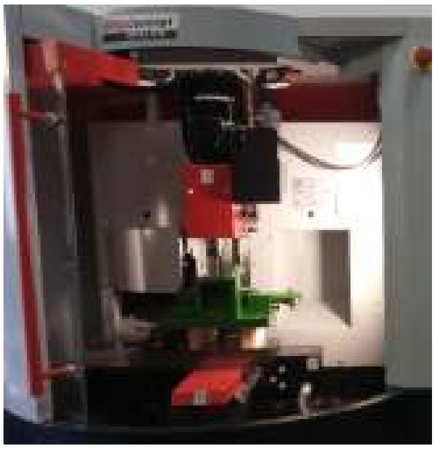


Fig. 1 EMCO MILL 55 CNC milling and drilling system.

Rulers with back face larger than 60x60 mm are used for fixing the blanks, directly on the machine working table.

The most important technical and mechanical characteristics of EMCO MILL 55 CNC milling and drilling system are:

- spindle distance – workbench: $H_{Ap}=77\div337$ *mm*;
- maximum tool diameter: $D_{max}=40$ *mm*;
- the main spindle speed: $n=150\div3500$ *rot/min*;
- maximum cutting time: $M_{tmax}=370$ *daN·mm*;
- cutting power: $N_e=0.75$ *kW*;
- displacement's speed (advance) *X-Y-Z:* $V_f = 0\div2000$ *mm/min*;
- the cutting force (maximum): $F_x=80$ *daN;* $F_y=80$ *daN;* $F_z=100$ *daN.*

EMCO MILL 55 CNC system uses specific tool holders depending on the machining - milling or drilling, with elastic bush 25 ESX type. The cutting tools used for machining blanks are the center drills *d/D= 2/4*; *2.5/6*; *3/8 mm*; spiral drills $D=2\div13$ *mm*, respectively cylindrical milling cutter $d=3\div12$ *mm*; *d=16 mm*.

3. MODELING OF THE DRILLING FIXTURE

Due to the complexity of designing the drilling fixture, each component part was drawn in Autodesk Inventor Part (*.ipt). After that, all parts were assembled and the final model was obtained. The paper presents only a few of the drawn parts, which belong to the fixture, the other being drawn in a similar manner and using almost the same defining commands.

3.1 Modeling of the rectangular base

A projection plan is chosen, in this case the XZ plane in Sketch module, in which a rectangle using the *Rectangle* command is projected, which sizes 225 mm x 195 mm. With *Circle* command, the holes and the fastening holes related to the rectangle base are being edited. Figure 2 presents the virtual model of the rectangle base obtained by using *Extrude* command at a height of 19 mm.

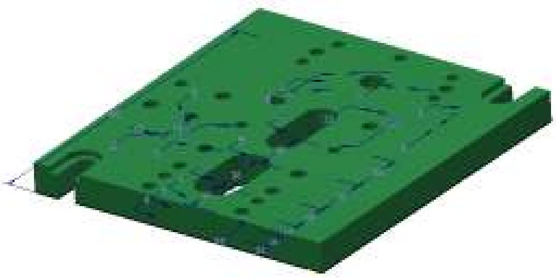


Fig. 2 The rectangular base of the drilling fixture.

3.2 Modeling the blank

In the XY plane, the sketch of the part was drawn, using *Line* and *Circle* commands, Figure 3.

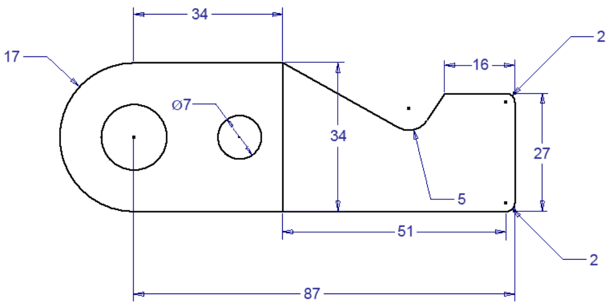


Fig. 3 The part sketch in the XY plane.

By using *Extrude* command, at heights of 31 and 15 mm, the final model of the blank is drawn, Figure 4.

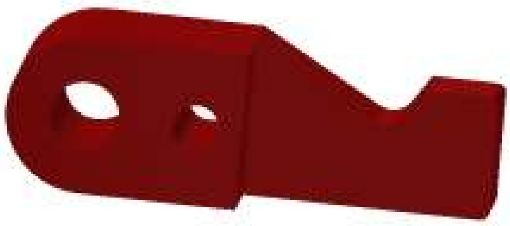


Fig. 4 The 3D model of the part.

3.3 Modeling of clamping-fixing elements

The nuts and bolts, necessary for setting and maintaining the stability of the drilling fixture are many and different. The paper presents only some of them, for drawing them *Line* and *Circle* commands were used, especially editing commands such as *Chamfer* – for chamfering, *Fillet* – for corner filleting, *Mirror* – for drawing the symmetrical of the objects related to a symmetry line etc. When using *Thread* command, the elements threads of clamping-fixing elements are drawn, Figure 5.

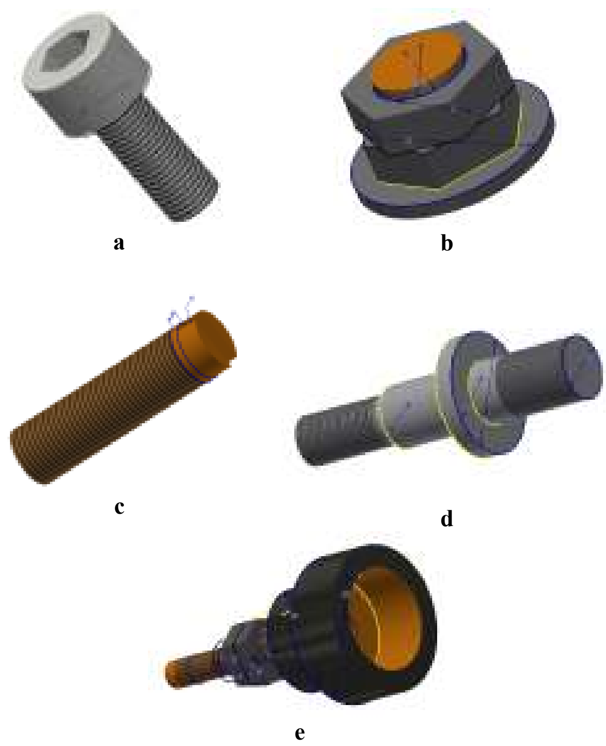


Fig. 5 Virtual models of the clamping-fixing elements.

In Figures 6, 7, 8 and 9, parts and other component elements of the drilling fixture are presented.

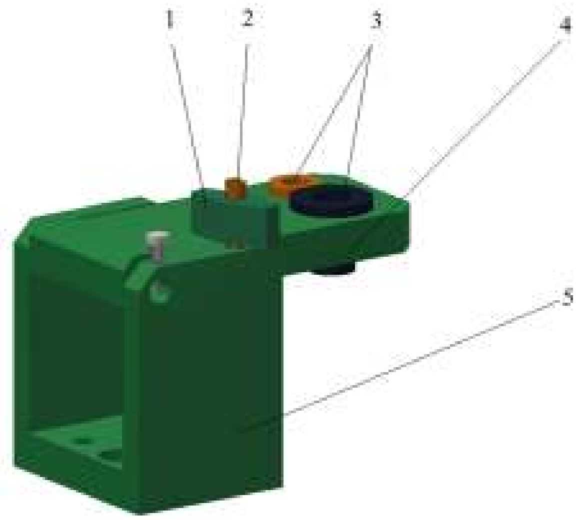


Fig. 6 Subassembly for guiding helical drill: 1 – butterfly nut; 2 – threaded rod; 3 – guiding bush; 4 – guiding plate; 5 – support.

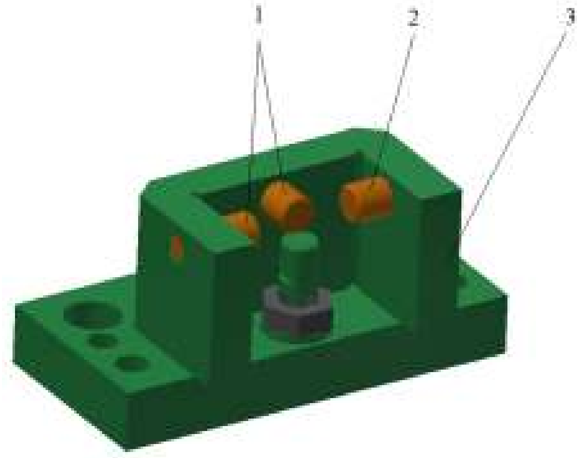


Fig. 7 Blank support subassembly: 1 – bolts for support; 2 – adjustment pin; 3 – support.

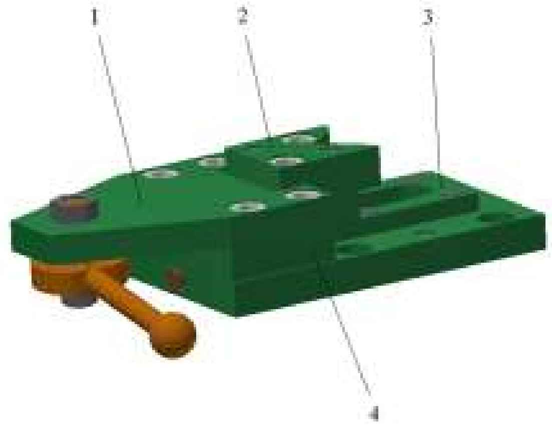


Fig. 8 Subassembly for fixing the blank: 1 – guiding; 2 – prism; 3 – backing plate; 4 – mobile jaw.

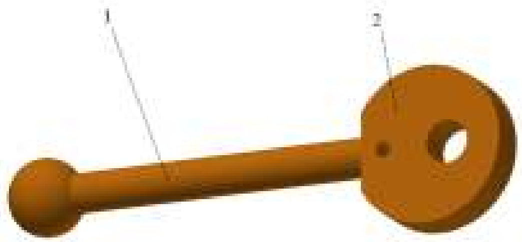


Fig. 9 Eccentric cam with handle: 1 – lever; 2 – cam with eccentric.

The devices fixing scheme shall be set up on the basing schemes and according to the forces and moments that acts during machining. These forces and moments are determined by calculation or are selected from charts, tables etc., depending on the used cutting conditions.

As a basic rule, the size and site of application of the clamping forces (fixing) must be determined so that to avoid any possible movement or displacement, deformation or vibration of the blank during machining. Additional, these mechanisms must allow quick and easy fastening and loosening of the blank during machining.

Depending on the orientation scheme as particularity, a type of the scheme for applying the machining-fixing-driving forces was set up, Figure 10.

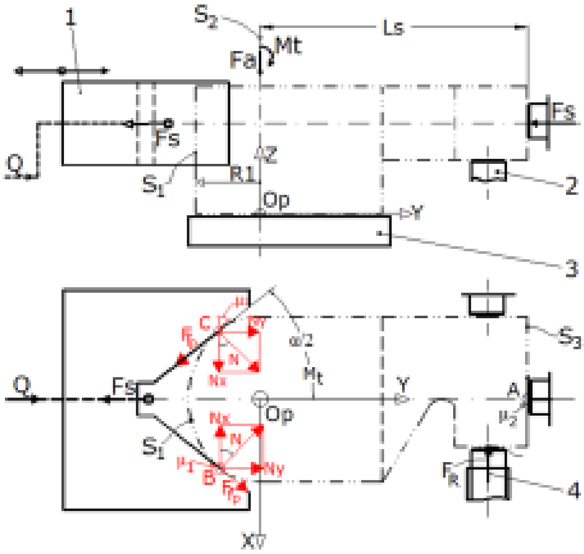


Fig. 10 Scheme for applying the machining-fixing driving forces: 1 – bearing prism; 2 – S_2 axis; 3 – additional support; 4 – backing plate; 5 – adjustment pin.

In figure 10, the applied forces are: F_a – the tool feeding force; M_t – machining moment (torsion); F_s – the clamping force of the blank; Q – the driving force of the fixing mechanism; F_f – friction force; N – normal force to the active surface of the mobile prism.

The friction force blocks the blank on the S_1 surface, respectively S_3, at the physical contact with bearing prism, respectively with support pin. This can be determined from the equilibrium equations of the moments in O_pXY plan and from Y axis forces:

$$\begin{cases} F_{f_s} \cdot L_s + 2F_{f_p} \cdot R_1 - M_t = 0 \\ 2N_Y - F_s = 0, \end{cases} \tag{1}$$

in which:

- L_s is the distance of the force application F_s/O_pA ($L_s = D_1 + D_2$, where D_1 and D_2 are the technological distances in the blank drawing);
- F_{f_s} – the friction force on the surface S_{13} ($F_{f_s} = \mu_2 \cdot F_s$);
- F_{f_p} – the friction force on surface S_1 ($F_{f_p} = \mu_i \cdot N$);
- μ_1, μ_2 – friction coefficient ($\mu_1 = \mu_2 = \mu = 0.15 \div 0.25$, for the contact surfaces, made of steel, carefully machined ($R_a = 3 \div 4\ \mu m$).

$$N_Y = N \cdot \sin\frac{\alpha}{2} = \frac{1}{2} \cdot F_s \Rightarrow N = \frac{F_s}{2 \cdot \sin\frac{\alpha}{2}}, \tag{2}$$

in which α is the angle of the threaded rod ($\alpha = 90^0$).

If N is replaced in equation 1 the following is obtained:

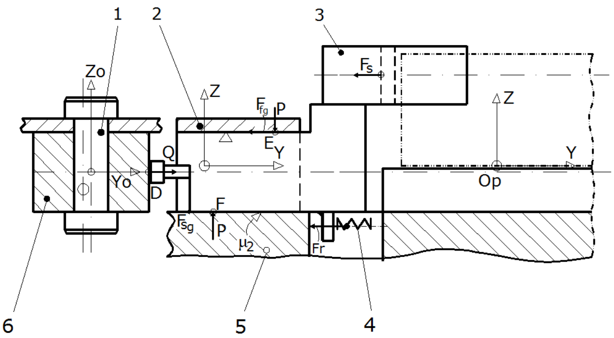
$$\mu \cdot F_s \cdot (D_1 + D_2) + \mu \cdot \frac{F_s}{\sin\frac{\alpha}{2}} \cdot R_1 = M_t \tag{3}$$

For a properly sizing the fixing mechanism, a required fixing force, increased with a safety factor K_s, was used.

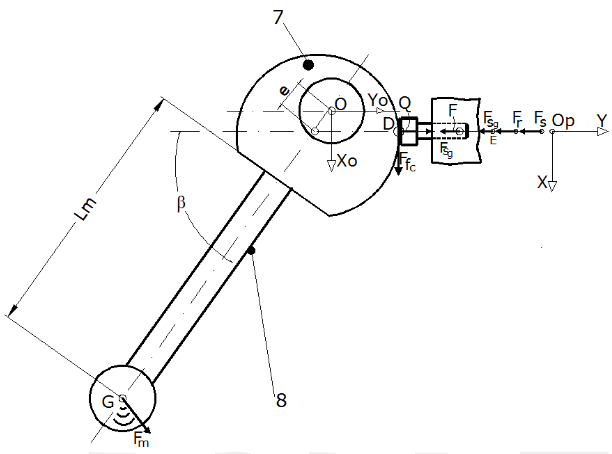
Therefore, general equation for calculating the fixing force is:

$$F_{s_{nec}} = \frac{K_s \cdot M_t}{\mu \cdot \left[(D_1 + D_2) + \dfrac{R_1}{\sin\dfrac{\alpha}{2}} \right]}, [\mathrm{daN}] \quad (4)$$

As a result, the dimensioning of the fixing mechanism with eccentric cam and guiding jaw was proposed, one-sided-fast-clip type, Figure 11.



a



b

Fig. 11 Fixing mechanism with eccentric cam and guiding jaw: 11a: 1 – bolt; 2 – guiding; 3 – prism; 4 – spring; 5 – rectangular base; 6 – eccentric cam; 11b: 7 – eccentric cam; 8 – lever; e – eccentricity.

The friction force F_s, calculated at the prism level is obtained analyzing a chain consisting of two mechanisms: one for driving (lever-cam with eccentric-pin) and one for transmission (mobile jaw-guiding).

3.4 Description of drilling fixture functionality

Figure 12 presents the drilling fixture with the following elements: 1 – butterfly nut; 2 – threaded rod; 3 – guiding bush; 4 – guiding plate for bush; 5 – support; 6 – supporting bolts; 7 – rosette (for operating the adjustment pin); 8 – blank/part; 9 – supporting plate; 10 – rectangular base; 11 – mobile jaw; 12 – eccentric cam with lever; 13 – bolt; 14 – guiding; 15 – prism.

The blank 8 is fixed in the fixture in contact with the surface of the supporting plate 9 which is mounted on the rectangular base 10 of the fixture.

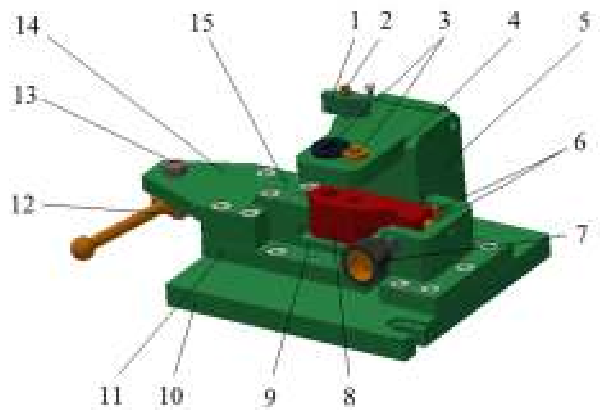


Fig. 12 The virtual model of the drilling fixture.

The blank fixing in the device is made by driving the eccentric cam with lever 12. It is recommended that the optimum working domain for the cam to be performed at the values of the driving angle (rotational) within the domain $\beta = 60° \div 120°$ (normally, $\beta = 90°$). The cam is running the pin 13, which moves the mobile jaw 11 and prism 15 through guiding 14.

To ensure a proper supporting of the blank on the two supporting pins 6, an adjustable force will be applied on the vertical plan surface 5, opposite to the cutting moment, which tends to unbalance the blank. This is done with the thumb screw and pin 7.

After fixing the blank, the guiding plate 4, in which the guiding bushes 3 of the tools are mounted, is folded.

Then, the butterfly nut 1 is turned until the guiding plate is blocked. After machining the holes, the guiding plate is unlocked and folded in the opposite direction to release the part from the fixture.

Based on the virtual model drawn in Autodesk Inventor, the drilling fixture was physically manufactured. The fixture was mounted on EMCO MILL 55 CNC milling and drilling system in order to drill a blank, figure 13.

Fig. 13 The physical model of the drilling system.

4. THE HELICAL DRILL MODELING IN CATIA GRAPHIC DESIGN ENVIRONMENT

The 3D modeling of a helical drill must take into account a number of parameters that define a cylindrical helical line: shape and size of the revolution surface, the axial step and direction of the propeller's winders. A cylindrical helix of constant pitch is associated to the helical drill. The propeller's tilting angle, ω, is defined by the relation: $tg\omega = p_E / \pi \cdot D$, with p_E – the helical step, D – the drill's diameter.

The 3D modeling of a double-edged straight helical drill in CATIA graphical environment includes several components: the clamping part – clamping and the drill cutting part: the drill body, winding channels, the back face, the transverse cutting edge and the guiding facets. The main geometrical parameters of a double-edged straight helical drill (standard) are defined in Table 1 and Figure 14.

Table 1

The values of the helical drill geometrical parameters.

D [mm]	7	L [mm]	109
l [mm]	69	α [mm]	6
Df [mm]	0.34	ω [º]	30
R [mm]	3.5	2κ [º]	118
r [mm]	1.4	γ [º]	10
f [mm]	0.88	ψ [º]	55

where: D is the drill diameter; l – the length of cutters; Df – the height of the facet; R, r – radii of the helical channel; f – the size of the facet; L – the drill length; α – the back angle; ω – the tilt angle of the propeller channels for the chip removal; 2κ – working angle; γ – rake angle; ψ – the tilting angle of the transverse cutting edge.

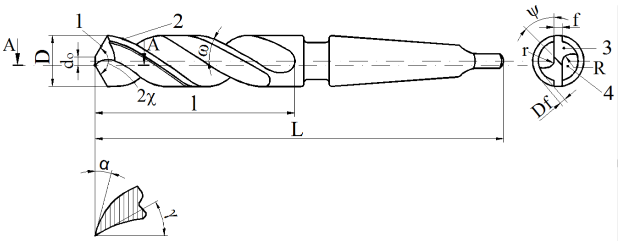


Fig. 14 Helical drill: 1 – the main cutting edge; 2 – secondary cutting edge; 3 – tooth; 4 - channel.

4.1 Defining the geometrical parameters

Geometric modeling of a helical drill with the diameter $D = 7mm$, starts by creating a *Part* file type that contains the graphic input, origin position and the coordinates system of the helical drill. After drawing the base circle and the one that defines the drill's core and after applying the constraints from the sketch, the main geometrical parameters were defined.

4.2 Modelling the drill helical channel

When determining the channel profile, the following aspects are to be considered: the thickness of the drill core (d_0), the channel width (B), the drill edges forms, the amount of the working angle (κ) and the helical pitch of the groove (p_E). The drill core diameter (d_0) shall be adopted according to the outer diameter (D). In the case of the drills with D = 7 mm, the core diameter is considered

$$\frac{d_0}{D} = 0.19 \div 0.15 \quad for\ 1.5 \le D \le 12\ mm.$$

For rapid steel drills, the channel width is should be larger than the tooth width ($B = 0.58 \cdot D$ – for $D = 7...13$ mm), figure 15.

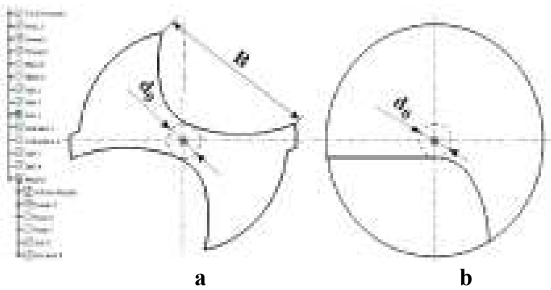


Fig. 15 Modelling of helical channel: cross section (a); front view (b).

The drill channel profile must be determined so that, from its intersection with the main back face on the tooth, the rectilinear shape of the cutting edge will result.

In CATIA environment graphic representation the *Helix* command is used for drawing the twisted curve, Figure 16. The curve will multiply by shifting the π radians, to achieve the second tooth. Drill channel profile determination is done in a perpendicular plane on the helix axis. In order to obtain the helical channel, the *Swept* command is used, from the generating profiles of the channel shape, the profile of the cutting edge and the chip discharge channel. By symmetry, the helical surface of the drill is obtained, along the two propellers, considered guiding elements of the complex generated cross, figure 17.

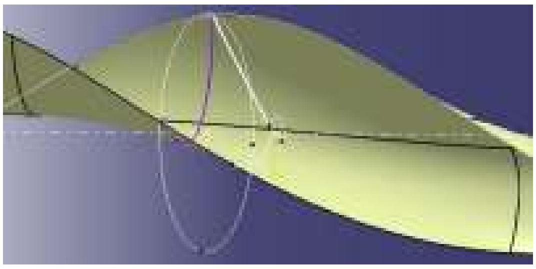


Fig. 16 Helical channels generation: Helix command.

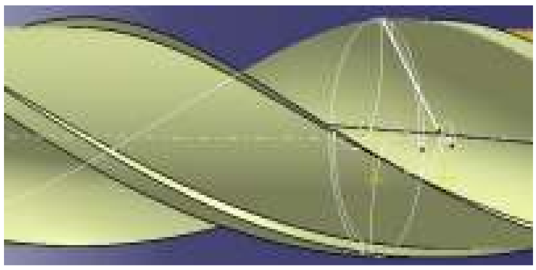


Fig. 17 Helical channels generation: Swept command.

In order to draw the back face, the two straight edges will be designed in longitudinal section of the drill, so they will have an angle between them, at the top side, usually, $2\kappa = 118^0$, figure 18.

The contact surface of the main cutting edge is generated in Z-axis helical movement and a helical parameter (p_E), with the *Helix* command.

The second cutting edges back face modeling is also based on helical guide elements, which lead to the removal of material excess equal to facet height – *Df*.

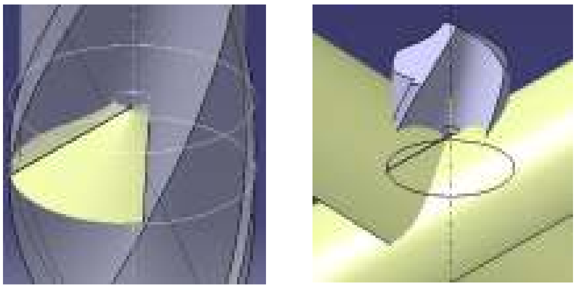


Fig. 18 The back face modeling.

The conical tail with Morse cone which allows the drill to be mounted in the machine shaft is obtained by rotating its longitudinal section around the drill axis. Drill with straight-edge tail modeling can be drawn from a basic outline, which defines the dimensional parameters of cone Morse 2, the commands used for that are *Sketch*, *Pad*, *Pocket*, *Mirror*, *Groove*, figure 19.

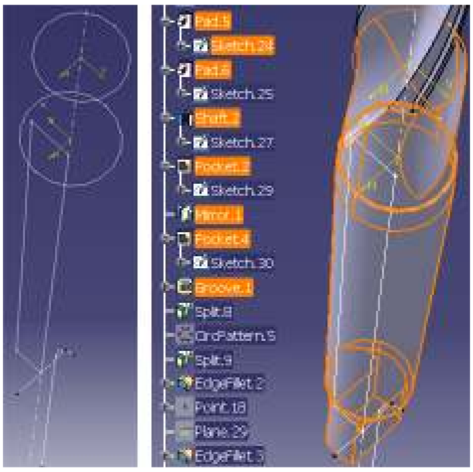


Fig. 19 The drill tail modeling.

Figure 20 shows the solid model of the double- straight edged helical drill, drawn in graphic design in CATIA.

Fig. 20 The solid model of the helical drill.

5. CONCLUSIONS

Boring, as technological machining process with the tools called drills, aims to achieve holes that will be further processed to achieve very precise and well-defined cylindrical surfaces.

In order to do this, during drilling, the blank/part to be machined should be fixed, the drill being driven in rotation and feeding movements through special fixtures mounted on the drilling machines.

Modeling the parts presented in this paper is simplistic realized, highlighting Autodesk Inventor software and CATIA packages ability to apply specific commands for the virtual representation of a drilling fixture.

The fixture was physically conducted subsequently to solve an important practical problem, the device being used to machine some educational parts using EMCO MILL 55 numerical command machine.

This equipment is part of the of Manufacturing Engineering Department logistics, "Dunărea de Jos" University of Galați.

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