Instructions for Using the Software Product

«TRAINING SIMULATOR OF A ROBOTIC TECHNOLOGICAL COMPLEX BASED ON A CNC LATHE»

1. General Description and Purpose of the Program

The training simulator of a robotic technological complex based on a CNC lathe is a virtual computer simulator designed to familiarize students with the principles of building a control system, devices of their structural hardware components, methods and programming tools for the operation of automated equipment.

Unlike computer-aided design systems, this simulator has a limitedly low accuracy of simulation of cutting and measurements (at least 0.5 mm). The main goal of the simulator is to demonstrate and teach programming how to process a part on a robotic technological complex based on a 16K20 lathe with a 2P22 control system.

2. System Requirements and Running the Simulator

For the program to work correctly, your computer must meet the following minimum system requirements:

- processor frequency not lower than 2.0 GHz;
- the amount of RAM is not less than 2.0 GB;
- the amount of video memory is at least 512 MB;
- free disk space: at least 300 MB;
- minimum supported screen resolution: 1024x768x32;
- the presence of a sound card and speakers (or headphones);
- operating system Windows XP / Vista / 7 and higher;
- Installed DirectX drivers version 9 and higher.

The software product was tested on a number of personal computers, while the optimal configuration of the equipment was installed:

- Pentium (R) Dual-Core E5300 2.60 GHz processor;
- the amount of RAM 2.00 GB;
- NVidia GeForce GTX 460 video adapter, 768 MB;
- Acer V193 monitor, resolution 1280x1024x32.
- Realtek HD sound card.

For the simulator to work on the computer, the Microsoft Visual C ++ library package (vcredist x86/x64) must be installed, the distribution of which is attached to the program folder. To start working with the simulator, run the file «SimulatorRTK.exe».

3. User Interface Elements

After starting the program, a splash screen will appear on the screen (Fig. 1).
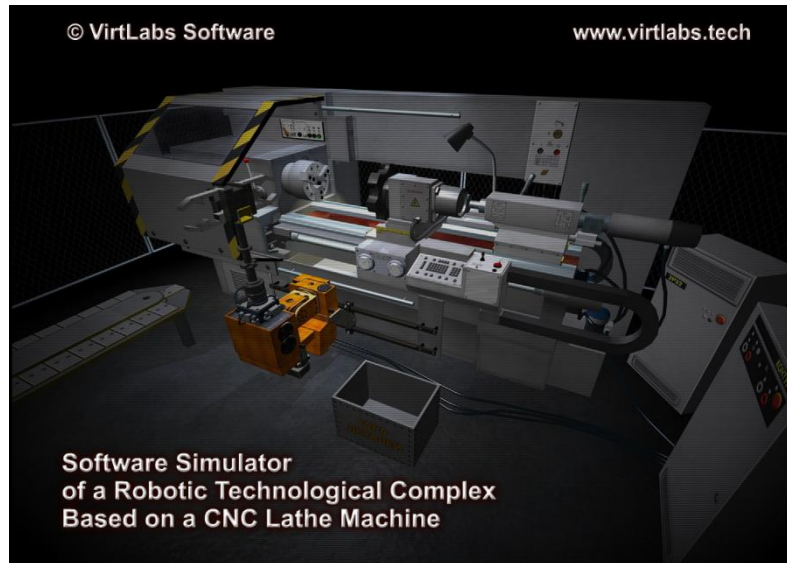

Fig. 1. Splash Screen

After the splash screen appears, the blank selection menu opens (Fig. 2). To select a specific size, left-click on the blank icon and click on the «OK» button. The workpiece L100 D50 is selected by default (length 100 mm, diameter 50 mm).

Fig. 2. Workpiece selection menu

Then the menu for selecting the cutting tool opens. Depending on whether the workpiece size is short (length 100...150 mm) or long (length 200...300 mm), the available tools will be displayed in the tool selection menu. In the case of short workpieces, all tools are available – turning and boring tools, as well as drills (Fig. 3. a). if a work piece is selected with a length of 200 mm or more, only turning tools are available (Fig.3.b).

Fig. 3. Cutting Tool Selection Menu:
a – set for working with short workpieces; b – set for working with long workpieces

To select the desired tool or drill, click on the image of the tool with the left mouse button, and the image of the selected tool will be highlighted in red. Next, you need to select the position of the selected tool in the turret. The turret contains 6 positions. To select the required position, click on the button with the image «T1 ... T6». The tool will be set to the selected position. The tools installed in the position can be changed, for this, select another tool, and set it in the same position. To continue working, you must select at least one tool and set it to the «T1» position. After completing the turret, click on the «OK» button.

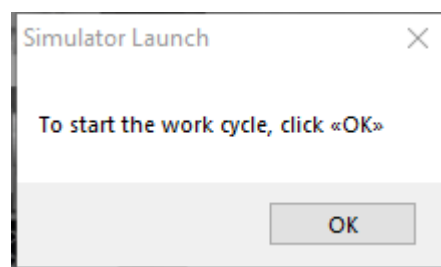After loading the 3D environment of the simulator, a message appears (Fig. 4).

Fig. 4. Message on Readiness to Start Work

When you click on the «OK» button, the automatic work cycle of the industrial robot will begin, including the movement of the workpiece on the clock table, the capture of the workpiece by the robot and its installation in the machine cartridge. Camera control is not available during an automatic cycle. After the industrial robot returns to its original position, the screen will display: a window showing the longitudinal section of the workpiece (Fig. 5.a) centered on the base point of the current tool, and a window for the text editor of control programs (Fig. 5.b).
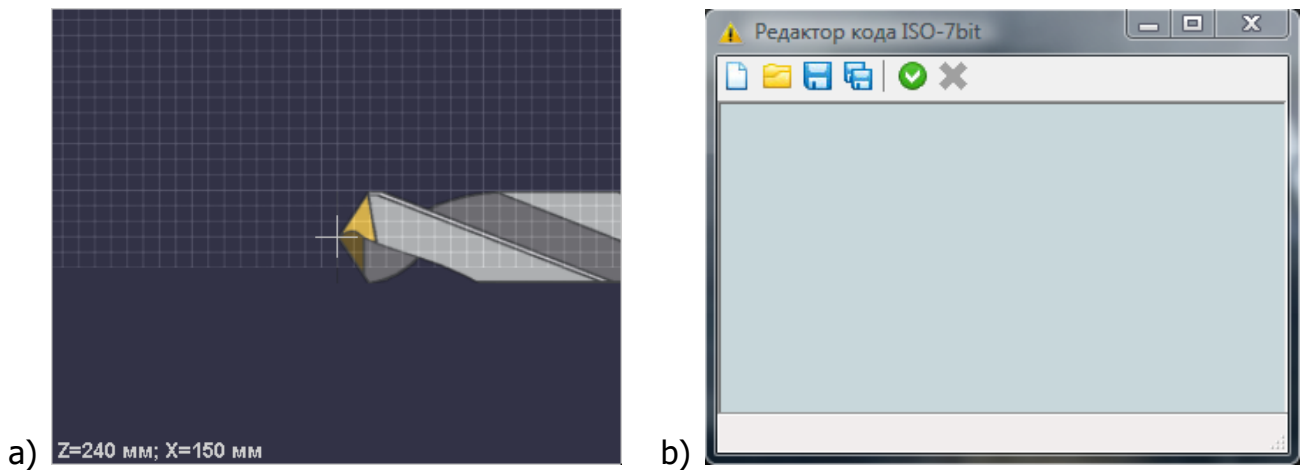
a) Z=240 мм; X=150 мм   b)

Fig. 5. Window View of the Longitudinal Section of the Workpiece (a) and the Window of the Text Editor of Control Programs (b)

In the lower part of the main 3D view, there is a status panel (Fig. 6), which reflects the necessary general information.

FPS:61   n0= об./мин; So=0 мм/об.   Lз=150 мм; Dз=70 мм   ca=0; cb=0; cr=1300

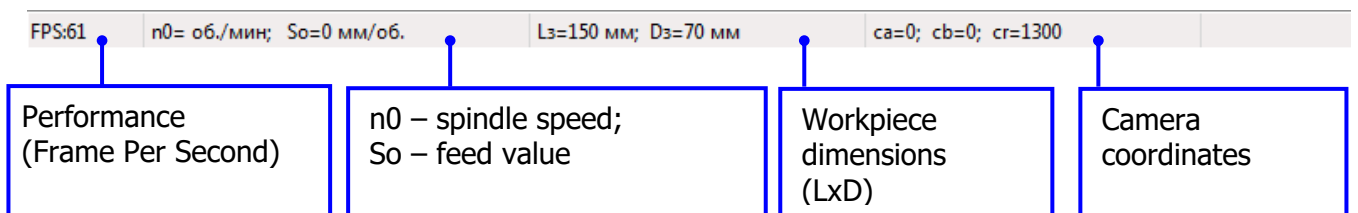| Performance (Frame Per Second) | n0 – spindle speed; So – feed value | Workpiece dimensions (LxD) | Camera coordinates |

Fig. 6. Status Bar and its Elements

Graphics performance (FPS) is directly dependent on the specifications of the computer. The optimal graphics display speed corresponds to at least 60 FPS. During the simulator's operation, the FPS will change as a result of various resource-intensive operations. The most resource-intensive operation is to simulate the cutting process.

The cutting mode (n0 and So) is set later in the control program.

The initial dimensions of the workpiece correspond to its selected size and do not change throughout the entire technological cycle.

The angles of the camera's viewing point are the coordinates of the position of the 3D viewing camera in a spherical coordinate system (Fig. 7). The camera is centered on the axis of the machine.
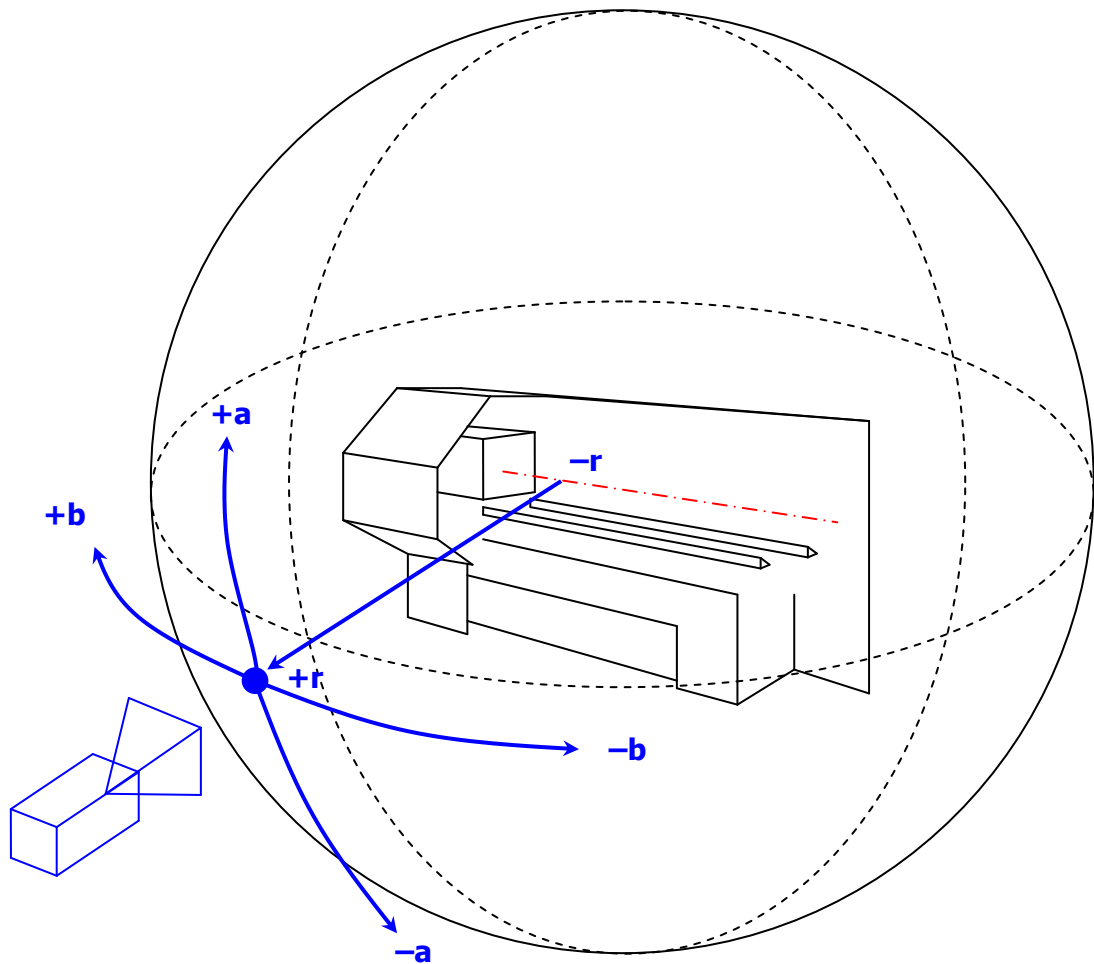
Fig. 7. 3D Viewing Camera Coordinate System

Moving the camera (in the directions a and b) is carried out using the cursor keys or by moving the mouse pointer to the edges of the screen. Zoom in / out of the camera (in the r direction) is done by rotating the mouse wheel.

In the upper right corner of the main 3D view, there are 4 function buttons (Fig. 8).

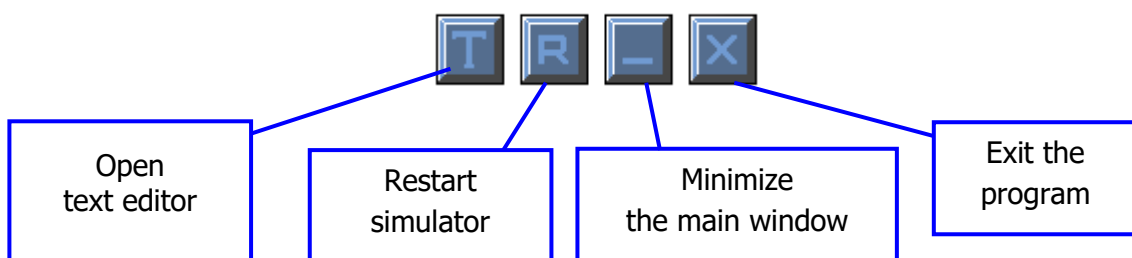| Open text editor | Restart simulator | Minimize the main window | Exit the program |

Fig. 8. Function Buttons of the Main 3D View

The button «Open text editor» displays the window of the text editor on the screen if it was closed.

The button «Restart simulator» is intended for restarting the program, while the work starts again from the workpiece selection menu.

The «Minimize the main window» button minimizes the simulator window and displays it as a button on the Windows taskbar.

The «Exit the program» button serves to exit the simulator.

In the window of the text editor of control programs, the toolbar is located at the top, and the status panel at the bottom, in which the current frame of the control program is displayed (Fig. 9).
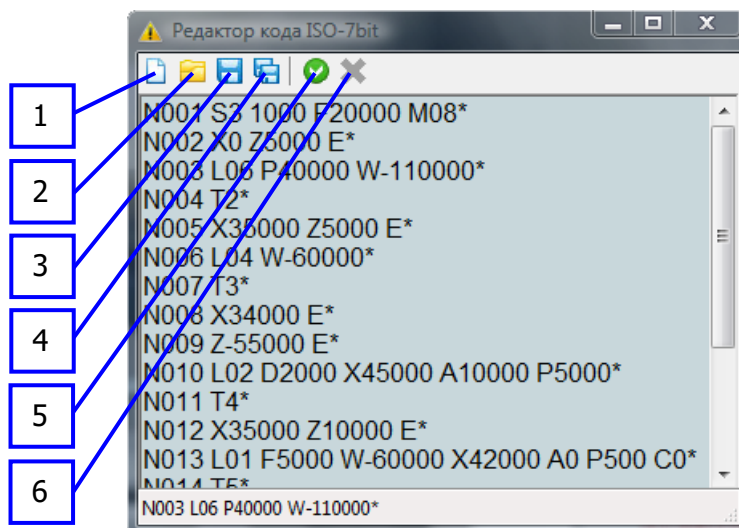

Fig. 9. Functional Buttons of the Window of the Control Programs Text Editor

The main elements of the toolbar:

1 – create a new document;
2 – open an existing document;
3 – save the current document;
4 – save the document into new file;
5 – run the control program;
6 – stop the execution of the control program.

Control program files are saved in *.rtf text format. Buttons 1-5 are not available during execution of the control program. If an error is detected during the execution of the control program, the execution of the program automatically stops.

In the upper part of the main 3D view window there are two icons (Fig. 10) that display the state of the spindle (rotation/static state) and coolant supply.

Fig. 10. Spindle Status and Coolant Icons

After executing the control program, if the workpiece has not been turned over by the other side (second setting), an action selection window will appear on the screen (Fig. 11).
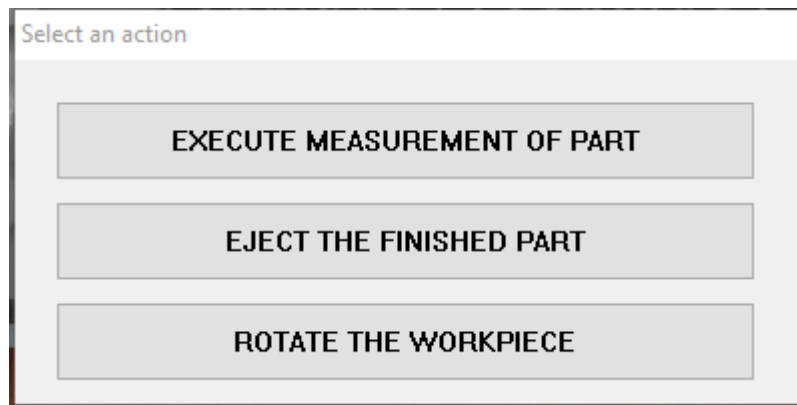
Fig. 11. Window for Selecting an Action After Processing the First Side of the Workpiece

The button «Execute measurement of part» allows you to open the window of the editor for measuring the dimensions of the longitudinal section of the workpiece (Fig. 12).
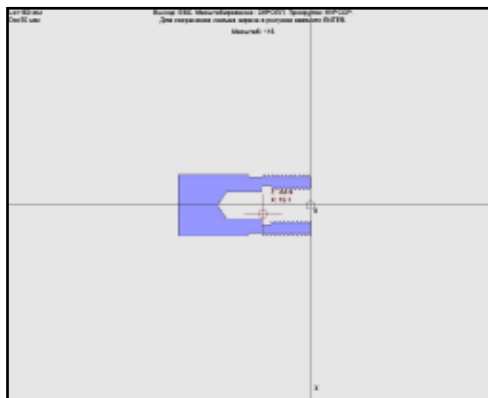

Fig. 12. Editor for Measuring the Dimensions of the Cross Section of the Workpiece

The coordinate system X⊕Z and the longitudinal section of the machined part are presented on the screen of the editor for measuring the dimensions of the section. The system view can be scrolled using the arrow keys and scaled by rotating the mouse wheel. The mouse cursor is represented by a crosshair with current coordinates. Measurements are made by measuring the coordinates of two points in the direction of the axes. The measurement accuracy corresponds to a cutting accuracy of 0.5 mm. Pressing the «ENTER» key captures the screen image and opens a dialog box for saving the picture in *.jpg format. Exit the measurement editor by pressing the «ESC» key.

The button «Eject the finished part» starts the automatic cycle of the industrial robot, at the end of which the turned part is unloaded in the container for parts and the working cycle of the simulator ends.

The button «Rotate the workpiece» turns on the automatic cycle of the industrial robot, which consists in removing the blank from the cartridge, rotating it 180 degrees and installing it in the cartridge. When the cycle is executed, the current UE is closed with the possibility of saving changes.

In the case of completion of the control unit, after the workpiece has been reinstalled, the screen for selecting an action is displayed on the screen (Fig. 13), with the missing button «Rotate the workpiece».
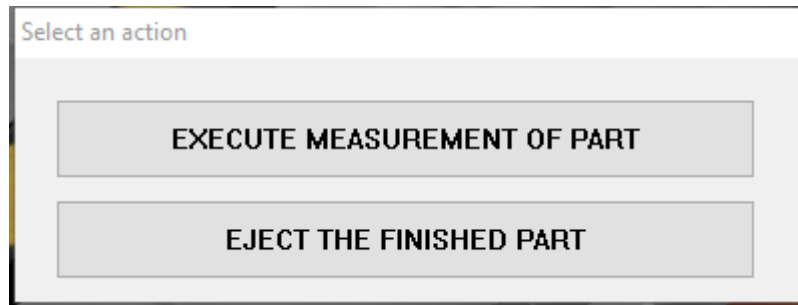

Fig. 13. The Window for Selecting the Action after Processing the Second Side of the Workpiece

4. Part Programming Basics

The information in the unit is recorded in frames. Each frame contains information words consisting of letter addresses and several numbers. The first word of the frame is its number «N...», the last - the symbol «*».

The order of the intermediate words is arbitrary. In one frame, you cannot specify words with the addresses «F» and «E», words with the same addresses. Movements can be set in absolute («X», «Z»), relative («U», «W») and mixed («X», «W» or «U», «Z») coordinates. Separate frames encode the time delay («D...»), the words «G10» (constant cutting speed mode), «G11» (cancel «G10»), «M02» (end of program). To control the machine also use the words (commands): «M08», «M09» (turning the coolant on and off); «M17» (end of the part outline description); «L01 ... L10» (standard cycles), etc.

4.1. Programming of spindle rotation, tool movement speeds, its change and time delay.

The speed n is set with the address «S» with numbers, for example: «S2–800», where 2 is the subrange n2=63...900 rpm; «–» clockwise rotation with a frequency of 800 rpm. Counterclockwise rotation is unsigned. Two other sub-ranges: 1 – for n1=20...375 rpm, 3 – for n3=160...2240 rpm (n is continuously adjustable). When setting a constant cutting speed (by the «G10» command).

The working feed is set with the address «F» with the value of the reverse feed in pulses (1000 pulses per 1 mm / rev), for example, for So=0.25 mm/rev. encode «F250». The feed is assigned by any of the coordinates «X», «Z» (it is the geometric sum when given simultaneously by «X» and «Z»). The feed range is 0.01...40 mm/rev.

The accelerated caliper travel (inlet, outlet) in both coordinates is set with the address «E» without a number. Retraction to the initial position is not programmed, because it is performed by the command to change the tool or by the command «M02». Accelerated Speed $V_x=V_z=5000$ mm/min.

The tool change is programmed with the address «T» with a number indicating the position of the tool on the turret, for example, «T6».

The time delay is set by address «D» with the number of seconds expressed in pulses (1000 pulses per 1 s). For example, for a shutter speed of 1.5 s, «D1500» is programmed.

4.2. Programming of working moves (longitudinal, transverse, contour).

The longitudinal transitions in absolute coordinates are specified by the address «Z» with the number of pulses corresponding to the position of the transition end point in the $X \oplus Z$ system, taking into account the sign. For example, for the position of the transition end point Z=−12.5 mm, «Z−12500» is set. In relative coordinates, the address «W» is set with the number of pulses corresponding to the displacement $\Delta Z=Z_j-Z_{j-1}$, where j – the end point of the transition. For example, for Z_j=−40 mm, Z_{j-1}=−10 mm, ΔZ=−40−(−10)=−30 mm, the «W − 30000» program.

For transverse transitions, the address «X» is programmed in absolute coordinates with a number equal to the final diameter D_j of the junction (in pulses), and in relative – the address «U» with a number equal to the difference (D_j-D_{j-1}) of the diameters in the pulses, for example, «X−40000» (the end point of the transition corresponds to D_j=40 mm), «U−10000» (displacement to the line of centers from D_{j-1}=40 mm to D_j =30 mm).

When programming the processing of cones, displacements along both axes are set in one block in relative («U», «W») or absolute («X», «Z») coordinates. For example, «U22000 W−30000» (processing of a straight cone with a difference of diameters of 22 mm and moving along the Z axis towards the spindle by a length of 30 mm).

4.3. Programming Standard Cycles for Typical Transitions.

The «L01» thread cutting cycle is programmed in one block with the phrase: «L01 F... W... X... A... P... C...», where «F» is the thread stroke, «W» is the stroke length, «X» is the internal diameter of the thread $(X \approx D_{thread}-1,4 \bullet F)$, "A" is the slope of the tapered thread (A=Dmax−Dmin; «A0» for cylindrical thread); «P» - the greatest depth of cut (per radius) for 1 pass, P≤0.2•F; «C» is the thread run (C=1000 if the run is F and C=0 if the run is not provided). All parameters are in pulses. The L01 cycle is multi-pass, each passage contains a working stroke for the length «W», a retraction along the «X» by 1 mm, a retraction along the Z (at W) and a lead at the starting point of the cycle along the X by 1 mm. The starting

point 0_j of the cycle is set before frame L01. Its coordinates are $X_j=D_{ext}$ (or D_{int}), $Z_j=Z_{str}+2\bullet F$, where Z_{str} – he coordinates of the beginning of the thread in the $X\oplus Z$ system.

The cycle «L02» of grooving has the following structure in the frame: «L02 D... X... A... P...», where «D» is the time delay for stripping, «X» is the inner diameter of the groove, «A» – the width of the groove, «P» – the width of the cutting edge of the cutter (all in pulses). In the frame before the L02 cycle, the starting point (X_j, Z_j) of the cycle is set, which should be 1-2 mm from the initial diameter of the groove along the X axis, and correspond to the coordinate of its left end face along the Z axis. The L02 cycle is multi-pass if A>P. In this case, for cut-ins with overlap, P in the frame is set to 0.5-1.5 mm less than the actual edge width, and parameter A is reduced by the same amount. Stages of the cycle: working feed up to the X coordinate; time delay D; accelerated retraction to the starting point; the displacement of the cutter along Z by the value of P; work feed to X coordinate, etc. At the end, the cutter is relegated to a point with coordinates $X_k=X_j$; $Z_k=Z_j+A-P$.

Cycles «L03» and «L04» for external and internal turning according to the «loop» scheme are single-pass; structure of the record: «L03 (or L04) W...», where «W» is the length of the stroke with a sign. The cycle contains: a stroke of length W; retraction along the X axis by 1 mm; withdrawal along the Z axis by the length W and supply along the X axis by 1 mm to the initial point of the cycle.

The cycle «L05» – «end loop» is similar to the previous ones and is realized when cutting ends. The structure of the cycle «L05 X...», where X is the final diameter of the cut end.

The deep-drilling cycle «L06» is multi-pass, with a periodic output of the drill. The structure of the cycle «L06 P... W...», where P is the drilling depth for 1 pass, W is the total drilling depth. Stages of the cycle: working stroke to a depth of P; retraction to the starting point of the cycle; approach to a point 3 mm closer than the previous drilling; working stroke to a depth of (P+3) mm; retraction to the starting point, etc.

5. Functional Limitations of the Simulator

1. There is no possibility of turning fillets and arcs;

2. There is no possibility of programming cycles L07, L08, L09, L10.