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## **Comparative Study for Optimization of CNC Milling MU Technological Processes**

*The present paper presents a study regarding technological optimization of wooden eyeglasses frames manufacturing process on CNC machine tools using 3 respectively 4 working axes. The general conclusion which arises from this study is that 4 axes manufacturing process reduce substantially the production necessary duration compared with 3 axes machining process.*

**Keywords:** machine-tool, CNC, CAD, CAM, CAE

### **1. Introduction**

Numerical control generally refers to the automation of machine tools by programming command sets which will be recorded or programmed on an external device. According to this definition, we can consider that the first CNC machine was designed by Jacquard (1720) which, to embroider cloth fabrics having various simple patterns, used perforated tape for storage and execution of different instruction set.

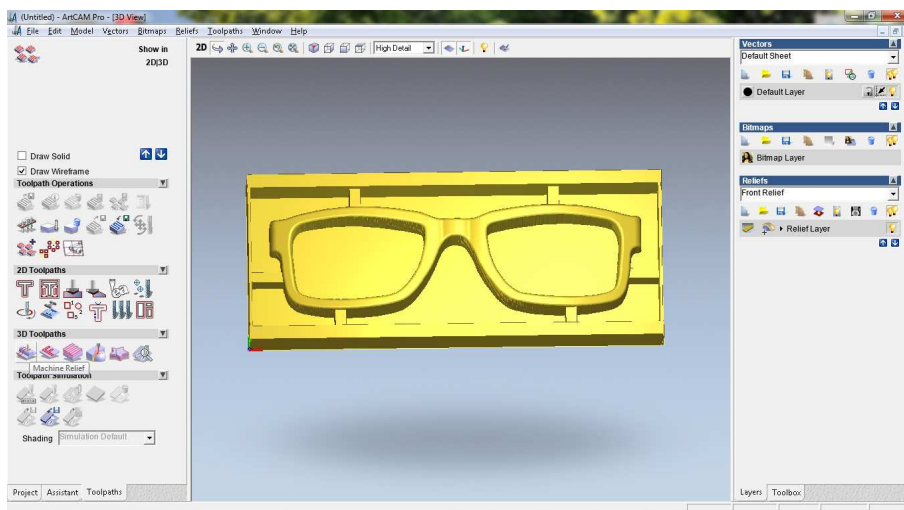
First and second generation of machine tools had no memory storage for programs. The instructions were stored on punched paper tape and were sent to machines one by one. After the machine received and executed an instruction, executes the next instruction required. The third generation integrated circuits were used and introduced as modular storage memory for programs.

Nowadays, we can talk about the fourth generation of numerical control machines. The machine controller is based on microprocessor technology and computers.

Today, processing machine tools implementation is one of the most important activities for industrial support and development. Among the industries benefiting from the products made by these machine tools, the most important is the car production industry.

## 2. Establishing and simulation of the work strategy using 3 axis with ArtCam software

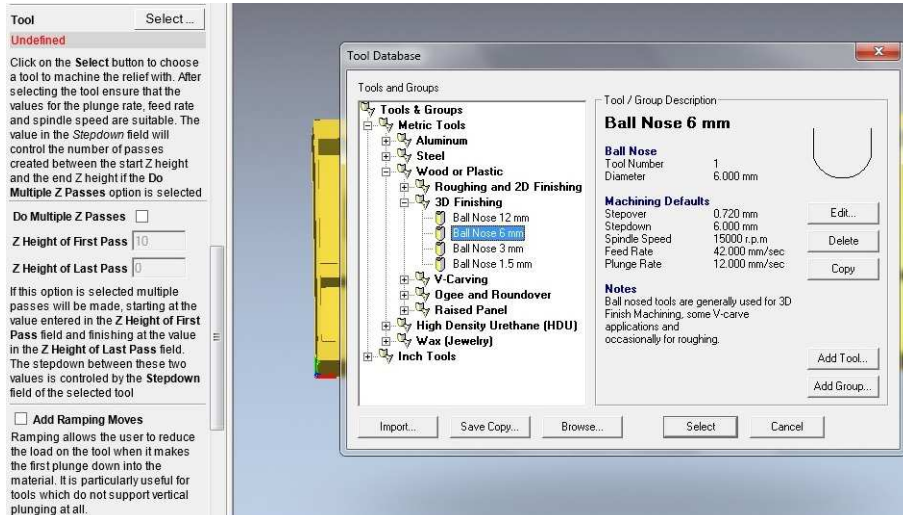
In order to establish the 3 axis strategies, first step represents importing the 3D model as STL file. The 3 axis strategies suppose to rotate manually the prime-material. In this case, is necessary to import the 3D model for two times, first time with the front view layer of the model and the second time using the back view layer of the model.



**Figure 1.** The imported 3D model.

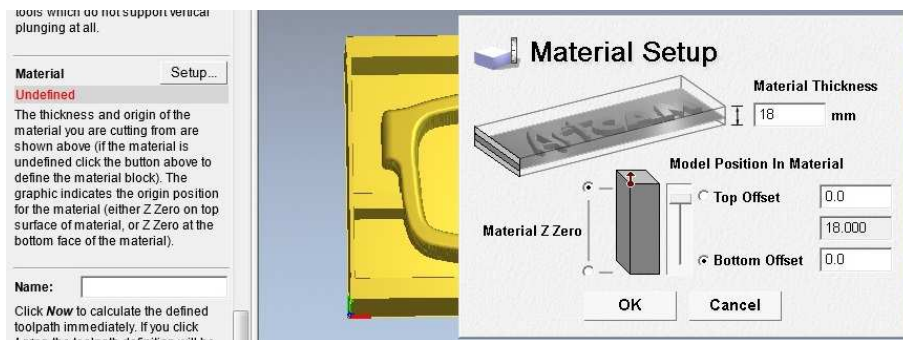
Once imported the 3D model, it follows the processing strategy selection. During the strategy definition must be selected first the cutter type and dimensions. Also must be defined the geometrical material dimension.

For this study were used three cutters of the same type, but with three different diameter's values. First cutter was used for roughing, a ball nose tool with a 6 mm diameter. The second cutter used for rough finishing was a ball nose tool with a diameter of 3 mm. The last cutter was used for finishing too, being a ball nose tool with 1,5 mm diameter. For all three cutters the CNC program is designed following the same working strategy and the same steps.



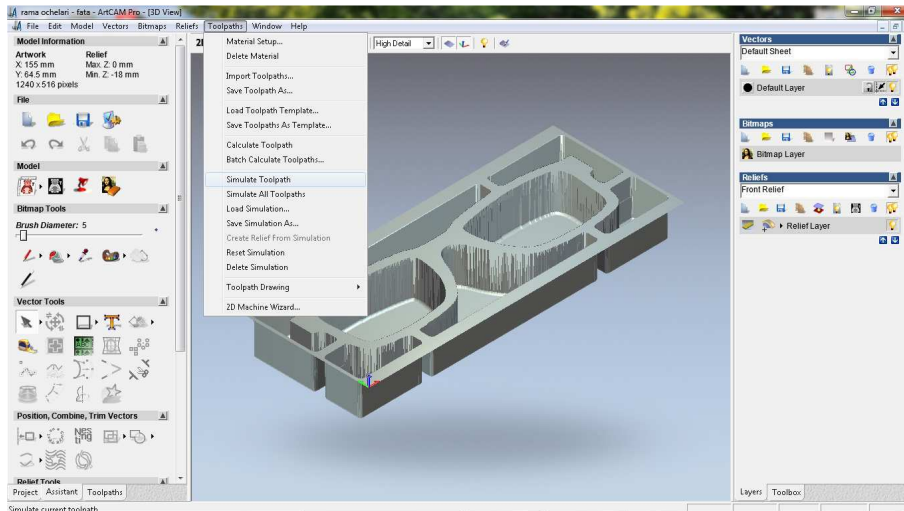
**Figure 2.** The cutter tool type selection.

Figure 2, presents the selection operation of the cutter type and dimensions. Figure 3 highlights how to define the geometrical material dimension.



**Figure 3.** Definition of material dimension.

After the work strategy definition ended, before calculating and defining the routes which must be followed by the cutter tool, as safety measure, it is possible to simulate the process. The visual simulation provides the form of the product what will be obtained after the operation is done.



**Figure 4.** The product obtained after the simulation.

The last step represents the developed strategy file export to the CNC machine software. Using the ArtCam software, we export the CNC program under a file having PLT extension.

For the remaining back view operation fulfillment, is necessary going through the same steps as for the front view operation.

### **3. Establishing and simulation of the work strategy using 4 axis with DeskProto software**

For establishing the work process to be done with 4 axis strategies, as in the process using 3 axis, first step represents to import the 3D model as STL file.

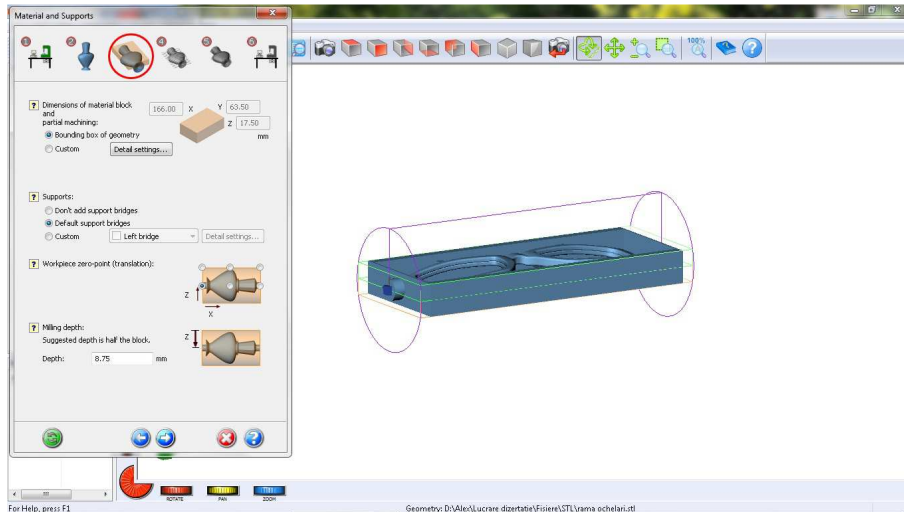
The difference between 4 axis and 3 axis milling represents the insertion of automatic rotation axis along the X or Y axis. In this case is necessary to import the 3D model just once, not two times like in the previous 3 axis case, because the switch from front view on the back view is done automatically. DeskProto software, in difference to ArtCam software, contains a function called "Start Wizard". With this function is much easier do design a CNC program, which offer few assisted steps for guidance. The "Start Wizard" option insures even for a beginner operator to be able to obtain a basic CNC program.

Another advantage to use DeskProto vs. ArtCam is the advanced user interface, witch allow programming the strategy in a manner to speed-up the production time during the milling process. In the advanced user interface is possible to use more milling strategies or several tools for the same segment of the 3D model.

The software offers the possibility to split the model in unlimited segments, for each segment being possible to define more strategies, more cutter tools types

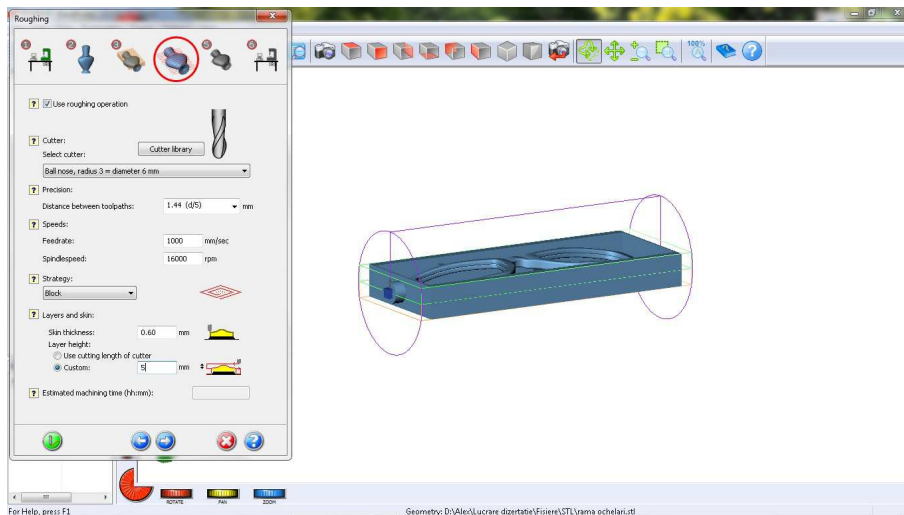
with fewer cutter dimensions. All this customizations offer the opportunity to the user to gain higher quality of the final product and, in the meantime, to reduce substantially the processing duration.

It is very easy to import the 3D model using the "Start Wizard" function.



**Figure 5.** The 3D model imported in DeskProto

Also is very easy to select the cutter type, cutter dimension, precision, milling speeds and strategy.



**Figure 6.** Working process setup

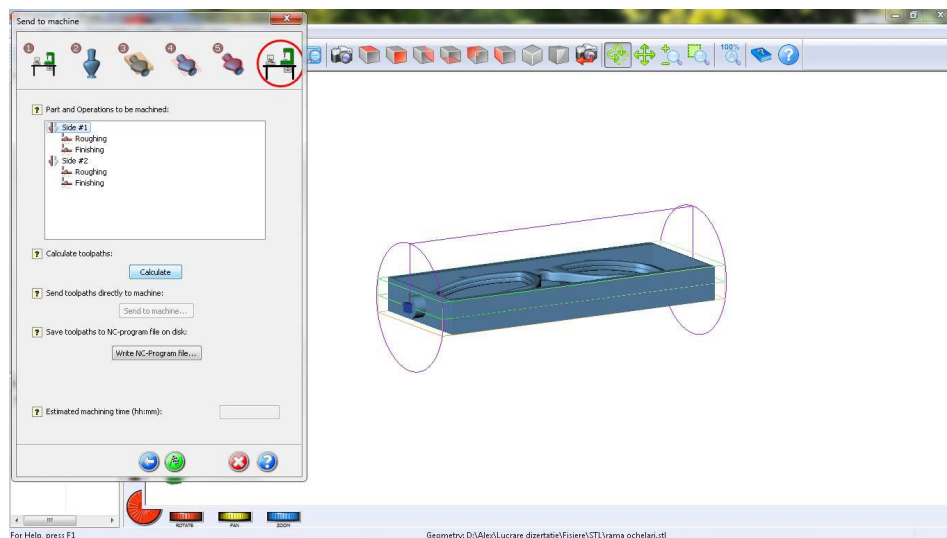
The last step of "Start Wizard" option contains the toolpaths calculation function. After pressing the "Calculate" button from the menu, will remain available just two other options:

- one, for sending the toolpaths directly to the machine,
- the second option represents exporting the CNC program as CNC file format.

Using the option "Send toolpaths directly to machine" allows the operator to send the command directly to the CNC machine which starts working immediately, the defined strategy being not possible to use again after woods in any circumstances.

In the case that the same process is needed to be performed again, all the previous presented steps need to be reworked again.

While the exported CNC file offers the possibility to store the working strategy which can be used unlimited times after woods, by importing direct the CNC file to the machine operating software.



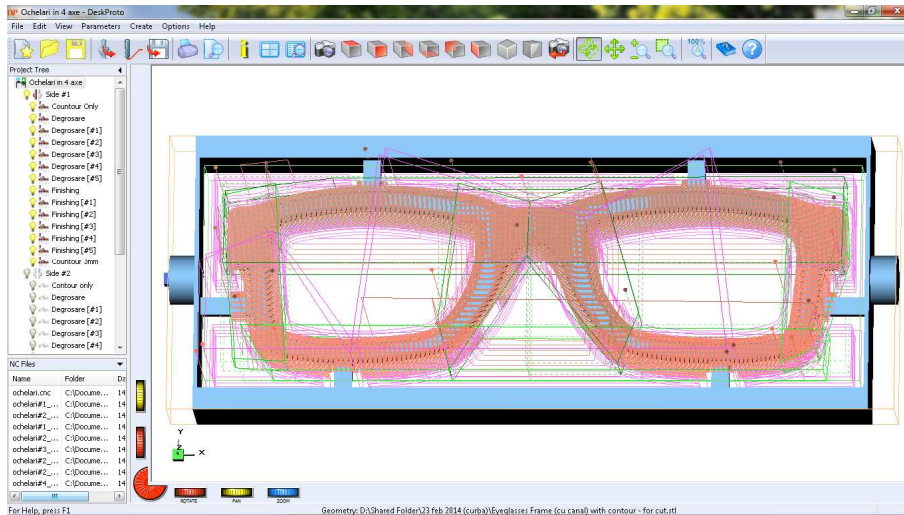
**Figure 7.** Toolpaths calculation.

In this study was used the advanced user interface, not "Start Wizard" option. All CNC build-up programs used the same number of 5 cutter types and six working strategies.

The following picture presents the best CNC program of the 5<sup>th</sup> CNC programs tested during the study. This CNC program contain 5 working strategies divided in 14 segments for each side, as follows:

- one strategy for contour only operation, made by a flat nose tool with 6 mm diameter;
- 6 roughing operations, with a ball nose with a diameter of 6 mm;

- 6 finishing operations, with a ball nose with a diameter of 3 mm;
- one finishing operation, with a ball nose with diameter of 1 mm.



**Figure 8.** CNC program using advanced user interface.

#### 4. Measuring and comparison of the obtained values

The following table presents only the best obtained values throughout the study, for each processing technology (using 3 and 4 execution axis).

**Table 1.**

	Processing using 3 axis	Processing using 4 axis
Time	11 hours and 43 minutes	2 hours and 18 minutes
Processing errors	-0,15 mm	-0,2 mm
Sides difference	0 - 0,5 mm	0,15 mm

Throughout the study, for the work using 3 axis, have been tested three different processing programs, using in each program more cutters types and dimensions. For the considered "best obtained" CNC program, have been used three cutters, all of them having ball nose but with different diameter dimensions.

For the milling process using 4 axis, throughout the study, have been tested five different CNC programs. Each program contained more strategies and a stuffed library of cutters types and dimensions. For the considered best obtained CNC program, have been used four different strategies, two cutter types and three cutter dimensions.

## 5. Conclusions

The conclusions arising from the comparative study have shown clearly that the method of processing wood frame glasses by 4-axis technology in comparison with 3-axis strategy is far optimal, due to the following reasons:

- the processing using 4 axis lasted for a period of time substantially reduced, from 11 hours and 43 minutes to 2 hours and 18 minutes;
- the processing errors in macroscopic examination are imperceptible, the values measured and determined fits in the limits of admitted tolerance, from -0,15 mm to 0,2 mm;
- the measured frame's dimensions gap between front and back sides using the 4 axis technology appeared only as a longitudinal gap, being constant (0,15 mm), in meantime, the gap which appered during the 3 axis milling process where random, the gap dimensions being in the 0 – 0,5 mm interval.

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