

On the Milling Process Simulation of an Injection Mold Part

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Abstract. *The paper presents the 3-phases milling process simulation of a surface of a polystyrene injection mold, by using CATIA software. The cutting regime parameters are computed and are used, together with other data, as inputs for the simulation process. On the basis of milling process simulation, the software generates the manufacturing program for the NC machine tool.*

Keywords: *milling, simulation, die casting, mold, CATIA.*

1. Introduction

Injection molding is a current method to obtain polystyrene components of various shapes and sizes. Research on proper operation of this manufacturing process is accomplished, for example regarding the detection of interference elements and release directions [8], the coating of cavities [9], or the process simulation [1], [13].

Usually, a mold is composed of a fixed part and a mobile one. The mold parts are frequently obtained by milling on numerical control (NC) machine tools. The NC program can be entered manually by the machine tool operator, or it can be provided by a specialized software, as a result of the milling simulation process. The *NC Manufacturing* module, a component of CATIA software, offers this possibility [3], [4], [6], [10]. The 3D model of the part to be milled is necessary, and it can be obtained by using the *Part Design* module [5], [7], [11] of CATIA software, or another software [2] - and then imported in CATIA.

The paper presents the manner of 3-phases milling process simulation of the concave side of a fixed mold part, by using CATIA *NC Manufacturing* module.

2. The 3D models of the Mold Part and of the Semi-Finished Part

The 3D models are achieved by using CATIA *Part Design* module and are presented in fig. 1.



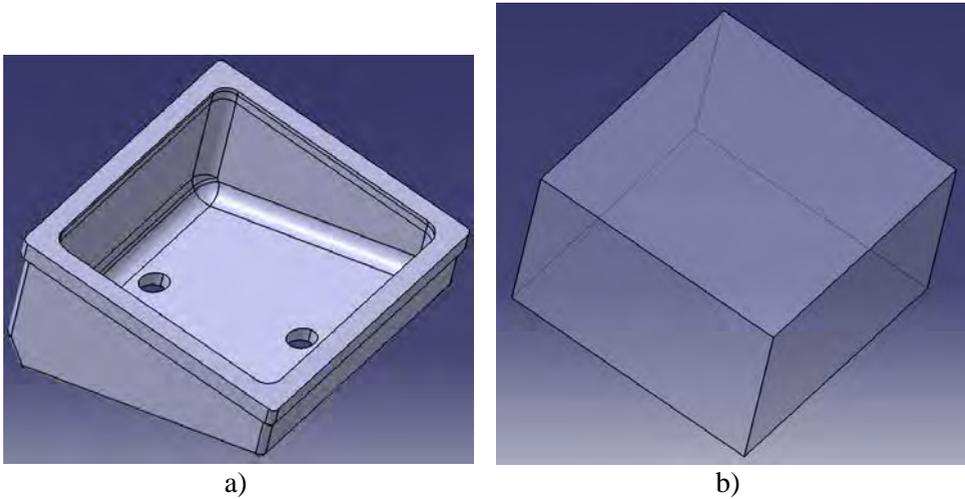


Figure 1. The 3D models of the fixed mold part (a) and of the semi-finished part (b).

In order to simulate the milling process, the 3D model of the *mold part - semi-finished part* assembly is necessary. This assembly is achieved by using CATIA *Assembly Design* module and is presented in fig. 2.

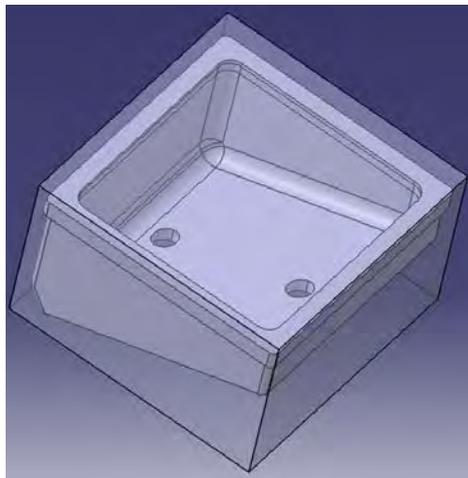


Figure 2. The 3D model of the *mold part - semi-finished part* assembly.

3. The Cutting Regime Parameters

The parameters of the cutting regime are computed for the roughing and finishing phases [3], [4], based on the relations from [12].

Thus, the computed cutting regime parameters used as input data in the simulation settings are as follows [3], [4]:

1. For the rough milling with the Ø50 mill,

- the spindle speed chosen for the machine tool is:

$$n_{mt} = 750 \text{ [turn/min]}, \quad (1)$$

based on the computed spindle speed:

$$n = \frac{1000 \cdot v_c}{\pi \cdot D_c} = \frac{1000 \cdot 119}{\pi \cdot 50} = 757.578 \text{ [turn/min]}, \quad (2)$$

where: $v_c = 119$ [m/min] – the cutting speed, computed in [2], [3];

$D_c = 50$ [mm] is the mill diameter.

- the feed rate:

$$v_f = n_{mt} \cdot z \cdot f_z = 750 \cdot 5 \cdot 0.067 = 251,25 \text{ [mm/min]}, \quad (3)$$

where: $z = 5$ [tooth] – the number of the mill's teeth;

$f_z = 0.067$ [mm/tooth] is the feed per tooth, computed in [2], [3].

2. For the finish milling with the Ø25 mill,

- the spindle speed chosen for the machine tool is:

$$n_{mt} = 1500 \text{ [turn/min]}, \quad (4)$$

based on the computed spindle speed:

$$n = \frac{1000 \cdot v_c}{\pi \cdot D_c} = \frac{1000 \cdot 119}{\pi \cdot 25} = 1515.155 \text{ [turn/min]}, \quad (5)$$

where: $v_c = 119$ [m/min] – the cutting speed, computed in [2], [3];

$D_c = 25$ [mm] is the mill diameter.

- the feed rate:

$$v_f = n_{mt} \cdot z \cdot f_z = 1500 \cdot 4 \cdot 0.067 = 402 \text{ [mm/min]}, \quad (6)$$

where: $z = 4$ [tooth] – the number of the mill's teeth;

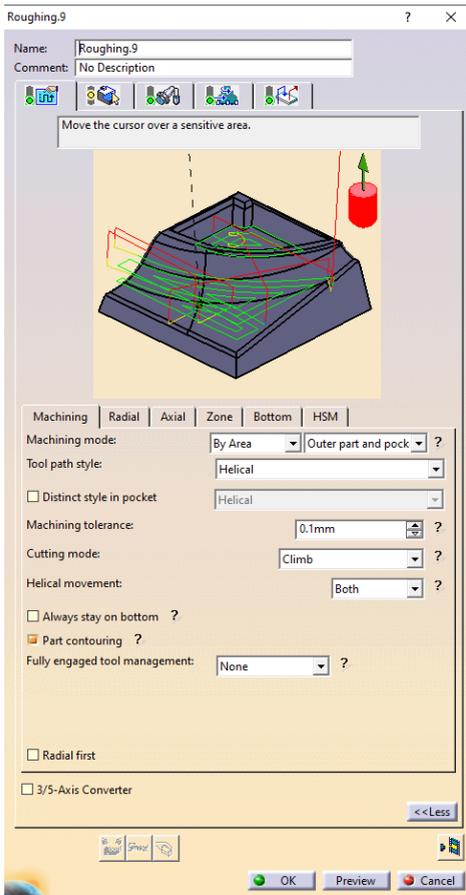
$f_z = 0.067$ [mm/tooth] is the feed per tooth, computed in [2], [3].

4. Simulation of the Milling Process

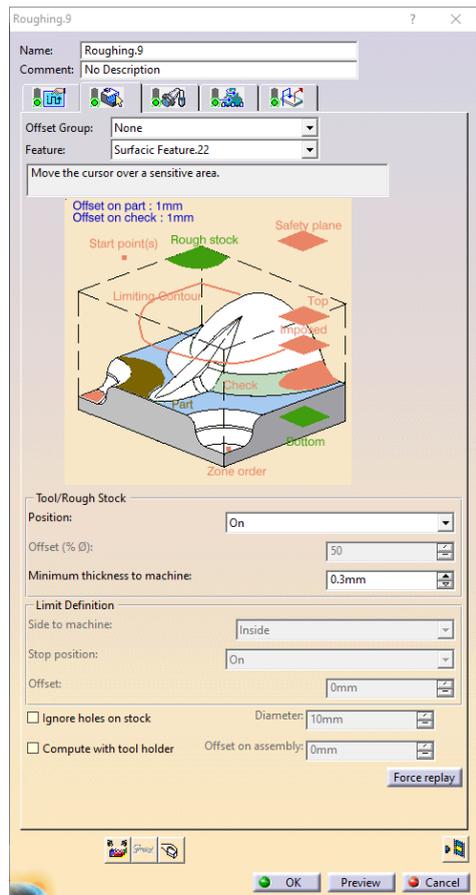
The simulation of the milling Process is accomplished for 1 roughing and 2 finishing phases of the concave side of the fixed mold part by using CATIA *Advanced Machining* module, as below.

4.1. Simulation of the Rough Milling Phase of the Concave Side

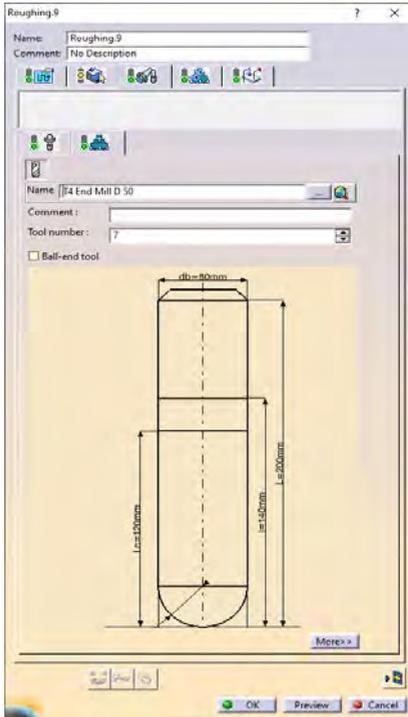
For this simulation, *Roughing* option is used. The setting of parameters for the rough milling phase is shown in fig. 3.



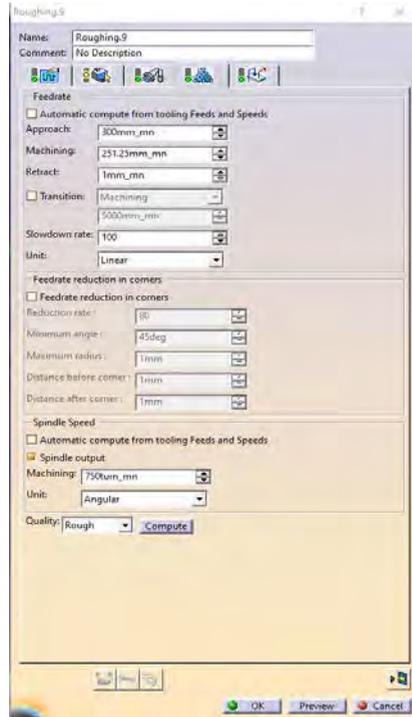
a) The work strategy.



b) The surfaces.



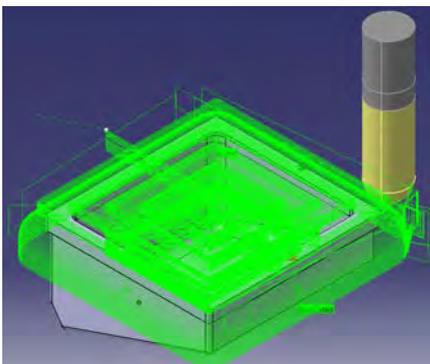
c) Shape and dimensions of the mill.



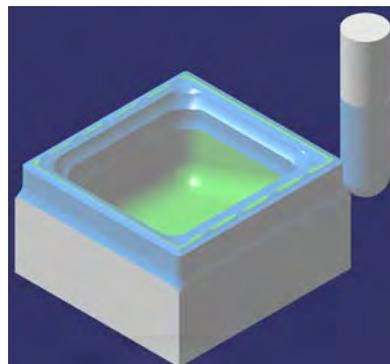
d) The values of the milling regime parameters

Figure 3. Setting the parameters for the rough milling phase.

In fig. 4 there are presented screen captures taken during the simulation of rough milling phase.



a) Tool Path Replay mode.



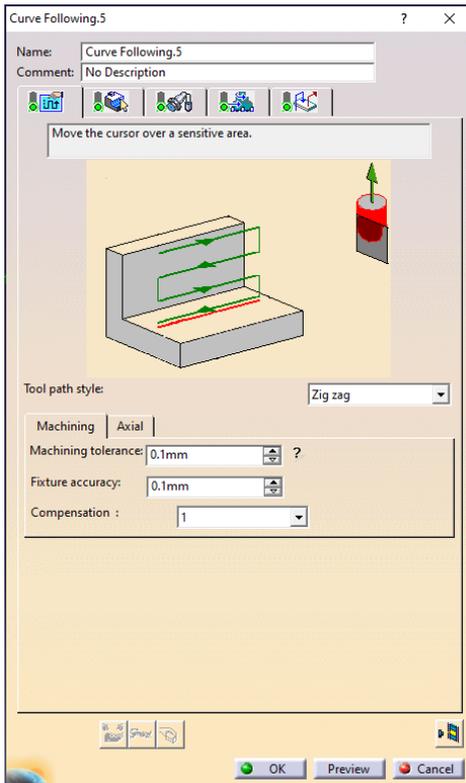
b) Video mode.

Figure 4. Screen captures during the simulation of rough milling phase.

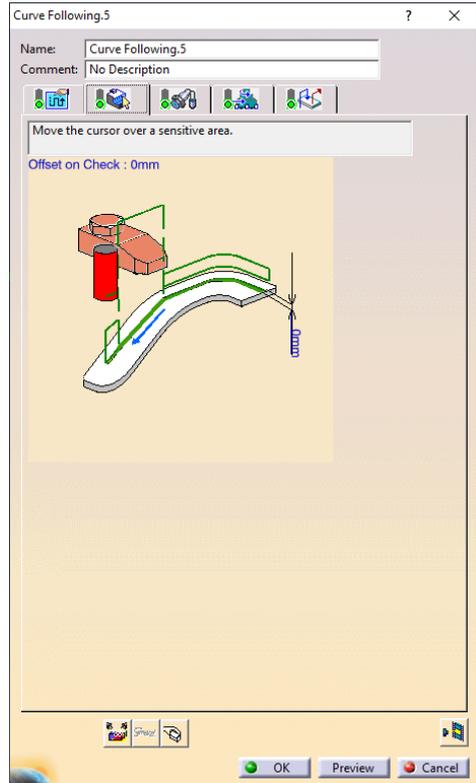
In fig. 4, a), the trajectory of the mill tip can be observed in the *Tool Path Replay* mode, while in fig. 4, b), a more realistic visualization of the process is accomplished in *Video* mode.

4.2. Simulation of the Finish Milling Phase of the Upper Side

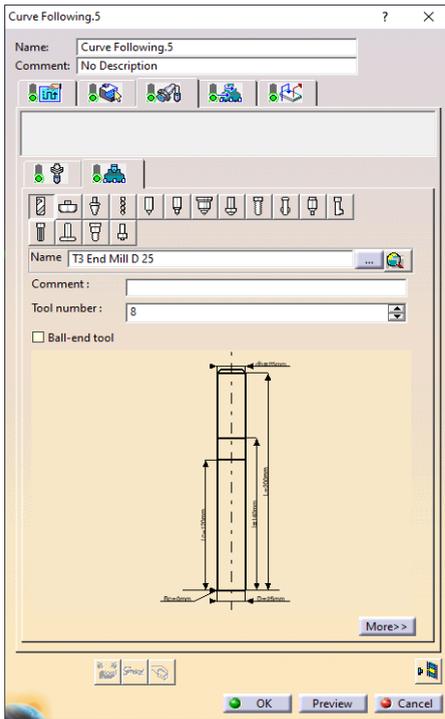
For this simulation, *Curve Following* option is used. The setting of parameters for the finish milling phase of the upper side is presented in fig. 5.



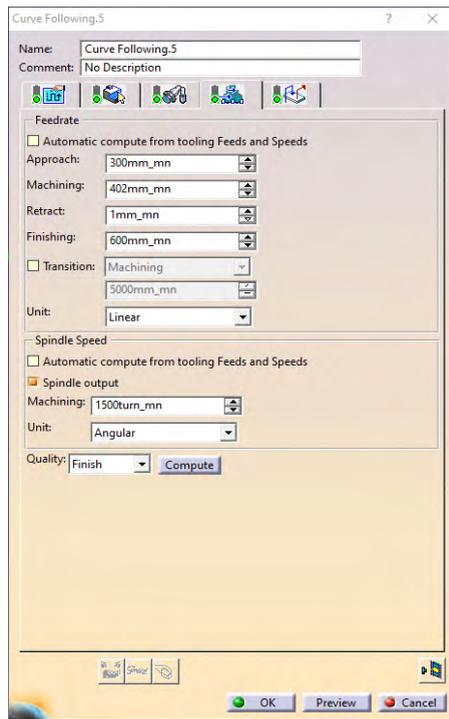
a) The work strategy.



b) The surfaces.



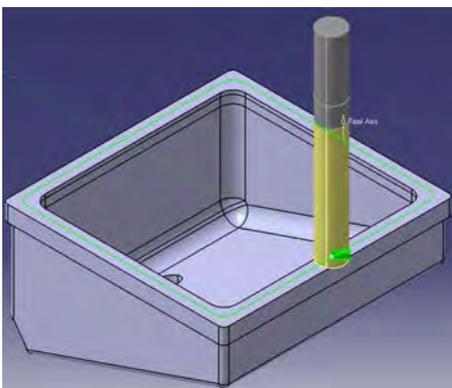
c) Shape and dimensions of the mill.



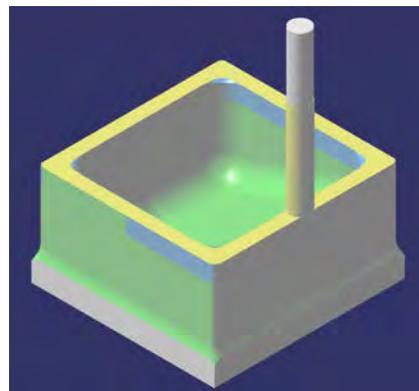
d) The values of the milling regime parameters.

Figure 5. Setting the parameters for the finish milling phase of the upper side.

In fig. 6 there are presented screen captures taken during the simulation of finish milling of the upper side. The plane face of the tool sweeps the processing surface.



a) Tool Path Replay mode.

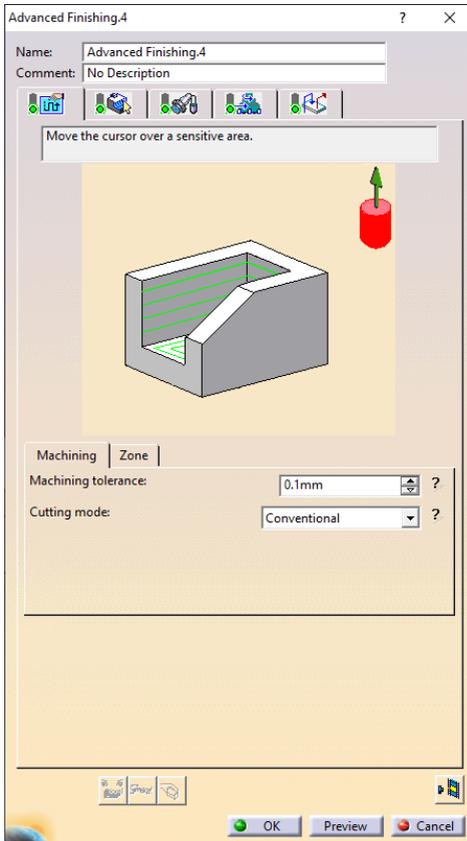


b) Video mode.

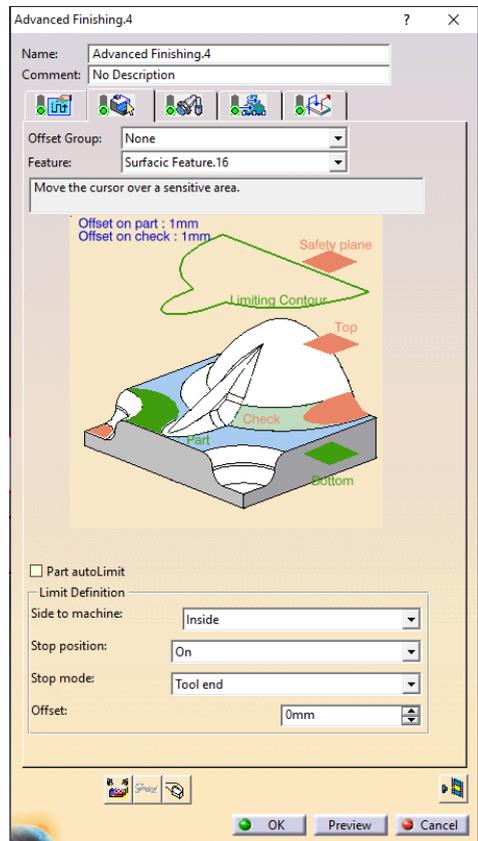
Figure 6. Screen captures during the simulation of finish milling of the upper side.

4.3. Simulation of the Finish Milling Phase of the Concave Side

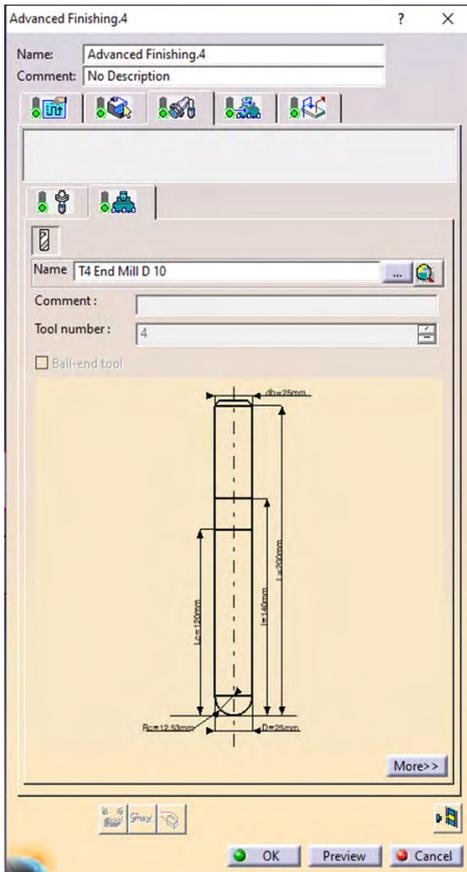
For this simulation, *Advanced Finishing* option is used. The setting of parameters for the finish milling phase is presented in fig. 7.



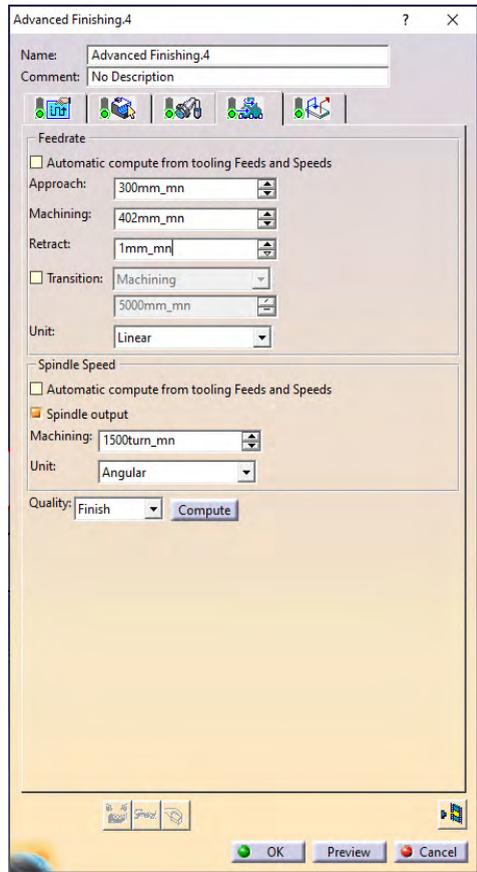
a) The work strategy.



b) The surfaces.



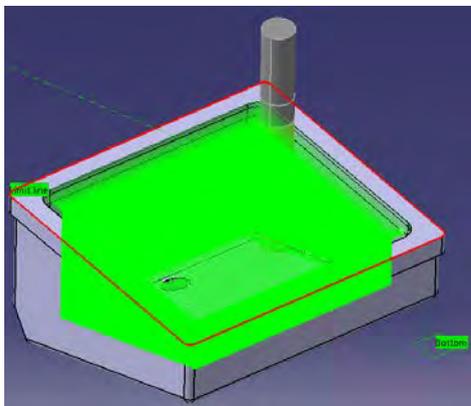
c) Shape and dimensions of the mill.



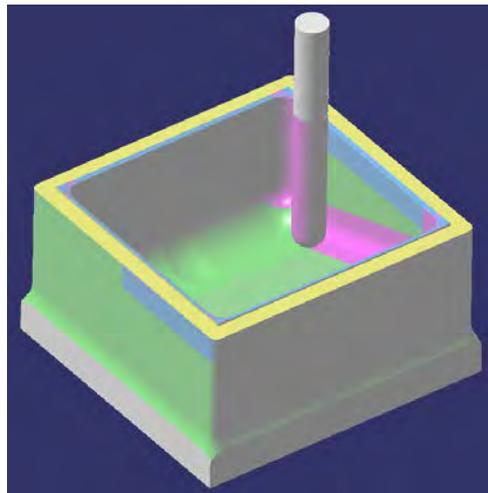
d) The values of the milling regime parameters.

Figure 7. Setting the parameters for the finish milling phase of the concave side.

In fig. 8 there are presented screen captures taken during the simulation of finish milling of the concave side.



a) *Tool Path Replay* mode.



b) *Video* mode.

Figure 8. Screen captures during the simulation of finish milling of the concave side.

In this finishing phase the tool sweeps all the concavity in order to obtain a high quality surface.

4. Conclusions

The simulation of the milling process, including the roughing and finishing phases, of the injection mold part is accomplished. On the basis of this simulation, CATIA software can generate the program, in NC or APT format, for manufacturing on NC machine tool. The post-processor has to be chosen, depending on the type and model of the machine tool.

The same manner of simulation can be used for other types of manufacturing processes, like drilling or turning.

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