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# Precision plunge milling for angled vertical walls, on three axis machining center

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**Abstract.** In this study the authors will construct a type of milling based on the plunge milling and raster milling toolpath strategy, only this time it is not going to be used for roughing but only for finishing vertical and angled surfaces of particular components of injection molds, with the help of a three axis vertical machining center. This particular toolpath strategy designed, with a commercial CAM program, for finishing the vertical and angled walls, offers a better surface roughness, and a better dimensional control (accuracy), both for the milling tool and also for the work piece.

## 1. Introduction

The advance methods of milling as plunge milling or vertical raster milling have been improved in order to provide a better material removal rate. For some molds an efficient method of material removal is vertical raster milling. A lot of methods have been taken into consideration [1,2,3] but only few of them have been proposed for study and implemented into CAM software and almost none of them have taken into account the quality of angled wall surfaces inside of an injection mold, milled by a three axis CNC [1].

The proposed type of milling is based on the raster milling; only it is not used for roughing but only for finishing of the determined surface. The vertical raster milling it is different from the conventional types [4], of tool-path strategies such as offset area clear model or contour milling. The vertical raster milling or plunge milling is based on three phases: the first phase has its foundation on tool compensation, the second phase is when the tool goes down executing in the same time the milling operation, the third phase is when the tool goes up to a predefined z (inputted by the CAM software user), after this phase it will restart the cycle again with a predefined stepover or the tool will retract to the safe Z point.

The feed rate is considered maximum during the compensation phase; therefore the tool working time is depended on the number of ups and downs and also the depth of of the selected wall. The main force [3] that is involved in this particular strategy is the axial force, reducing in the same time the tool vibrations (compared to the conventional milling strategies). The experiments showed that the angled walls within the deep cavities of the injection molds are more precise than those which are milled with conventional strategies.



## 2. Methodology and Experimental procedure

The above presented research is based on the plunge milling toolpath strategy, and represents a machining process used to remove material rapidly during roughing operations [1]. It can be used to achieve major increase in productivity especially in the case of deep milled work pieces. Some experiments [4] showed the necessary preparations for building a plunge milling toolpath strategy in a CAM program and they are based on selecting the right tool with the admissible length that offers a safe working environment, the identification of the valid entry points, the depth of the procedure.

Therefore before the milling strategy is generated, the first step is selecting the areas that need to be finished and generating a border that will represent the limit for the working tool. The second step is defining the stock material and the direction of toolpath (along X axis or Y axis). The third step refers to the calculation of the cusp height. This takes into consideration the value of the side step, the diameter of the tool and the type of mill insert. A greater number of side steps improve the milled surface giving it a better roughness coefficient.

### 2.1. Study Case I

The first study case was conducted on a spacer of an Injection Mold (1.1730 material-C45), which has an angled surface (figure1.). That particular area is going to be processed using CAM software (PowerMill). This area will be subjected to several milling strategies such as roughing, pre-finishing and finishing. The roughing toolpath will be executed by a mill with 4 round inserts, that have a radius of 6mm plate. The speed was set at 1200rpm and a feed rate of 3600mm/min. The side step over is set at 24mm with an axial step of 0.5mm. The wall offset was set at 0.4mm. Time needed to perform the operation was 83 minutes. In the below picture is represented the simulation of toolpath strategy. The areas that have green lines represents the tool trajectories and the red dots, the points where the tool changes the trajectory. The grey area suggests the material that has to be machined.

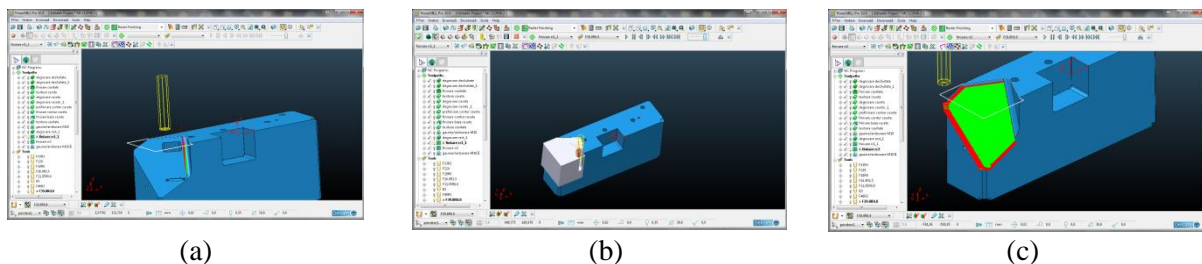


Figure 1. The simulation of the finishing toolpath strategies of the Mold Spacer, starting with the vertical wall (a), loading up for simulation the stock-model (b) and the final stage, showing the implemented toolpath (c), the feed movement being marked with green lines

Prefinishing toolpath strategy was carried out by a mill with 6 triangular inserts that have a radius of 0.8mm, designed specifically for deep milling areas. The speed and feed were set as follows: 1200 rpm and a feed of 1400 mm / min with a side step of 0.7 mm step, the maximum depth of the milling is 182 mm. The side wall offset was set at 0.15 mm. The entire operation took 55 min. The finishing strategy was carried out with the same tool and the same cutting data. Both strategies were designed like a plunge milling strategy, but in this case were used for finishing the discussed piece.

## 2.2 Study Case II

So on a plate, (figure 2.) within an injection mold (1,2311-40CrMnMo7 material), which has a cavity, that holds the active parts of the injection mold (figure 3.) will be milled using a CAM software. This particular area is important because it centers and fixes the active part of the mould. It is designed two vertical walls and two incline walls (with an angle of two degrees). This area will be subjected to a roughing, and pre-finishing and finishing strategy.

The assembly of the two components is shown in figure 4. Roughing will be conducted by a mill cutter with four round inserts, and a diameter of 52mm. The radius of the insert is 6mm. The machining parameters are set at speed of 860 rpm and a feed rate of 3600mm / min. The side step is set at 34mm and the step down is set at 1,1mm. The radial and axial offset is set at a thickness of 0,8mm. The time needed to perform the entire operations was 668 minutes. Because of a calculated data that indicates the life span of the mill inserts at 90 min., we divided the toolpath into 8 programs.

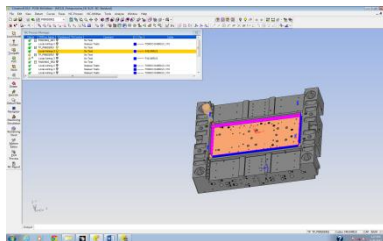


Figure 2. The centering plate that holds the active parts of a mold

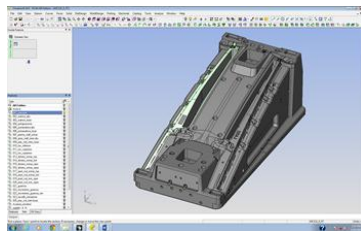


Figure 3. The active part of the mold

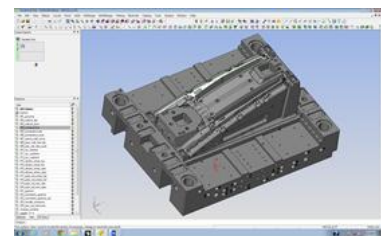


Figure 4. The assembly of the two components

The pre finishing toolpath was carried out by a tool with 5 rectangular inserts that have a radius of 0.8mm (figure 5.). The tool has a diameter of 35mm and it designed especially for milling deep cavities.

The actual data for the mill diameter was taken from a tool presetter as shown in figure 6(a). The tool presetter offers the possibility to measure accurate the diameter and the length of the tool. The values appear on the device screen (figure 7(b).) and they can be easily implemented on the CNC machine. The machining parameters: the speed is set at 1500 rpm and the feed rate at 1000 mm / min with a side step of 0.7 mm, the maximum depth of milling being 65 mm. The wall offset was set at 0.15 mm. The time needed to perform the entire operation was 120 minutes. The finishing toolpath was carried out with the same mill and same machining parameters. Both finishing and pre finishing toolpath strategies were based on the plunge milling method.

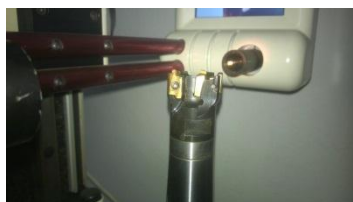
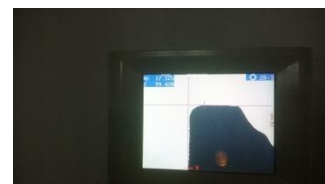


Figure 5. The Tool with a diameter of 35 mm and a Radius of 0.8



(a)



(b)

Figure 6. The Tool presetter (a) with the milling tool prepared for measure with the dimensional parameters being shown on the presetter monitor (b)

As we stated in the introduction these particular finishing strategy based on plunge milling is better in terms of surface quality (figure 7.) and also the dimensional control, both for the cavity walls and the mill diameter.

We took some data, from various molds, for the same centering plate of the active part, and analyzed it, in comparison with the convention milling strategies. The data is shown in table1. The picture below illustrates the differences between the conventional strategy (the surface outside the red square) and the finishing strategy based on plunge milling (the surface inside the red square). The red arrow suggest the vertical toolpath of the cutter.



Figure 7. The differences between conventional milling and the finishing method based on the plunge milling strategy

**Table 1.** The table shows the differences between measured surfaces, with different types of milling, at a precision level

Nominal Dimensions of the measured part	Surface precision for Conventional milling	Surface precision for Plunge Milling Finishing Strategy
900x800x210	0,07	0,02
1050x900x156	0,08	0,02
800x760x226	0,08	0,02
986x736x166	0,04	0,02
620x520x150	0,07	0,01
918x710x220	0,08	0,02
1396x640x249	0,04	0,01
1100x900x210	0,07	0,01

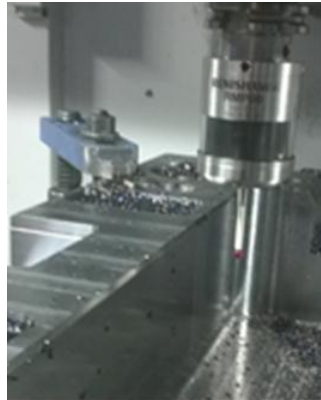


Figure 8. The RMP60 measuring the angled wall of the plate

The measurements were collected using an inspection probe from Renishaw, model RMP60 (figure 8.). The RMP60 is a compact spindle probe, with radio signal transmission and together with the Inspection Plus software [5] which is installed on DOOSAN 750L, provided accurate and easy to use data. The DOOSAN 750 L is a vertical machining center which is designed for high speed and precision of medium to large work pieces such as the plates presented in the study.[6]

### 3. Conclusion.

The present study shows that the quality and the dimensional control of the angled walls, which are machined on a 3 axis CNC, are superior in the case of the finishing method based on the plunge milling toolpath strategies in comparison with the conventional milling strategies. Also the thermal stability of the tool and the machining center is more stable during this type of milling and this offers a better life span for both of them. All these factors give a better advantage in terms of mold manufacturing.

### References

- [1] Danis I, Wojtowicz N, Monies F, Lamesle P and Lagarrigue P, 2013, Cutting conditions and surface integrity during dry plunge milling of a wrought magnesium alloy, *The Manufacturing Engineering Society International Conference, MESIC 2013*, vol **63**, pp 36-44
- [2] Ko, J.H. and Altintas, 2007, Dynamics and stability of plunge milling operations, *Journal of Manufacturing Science and Engineering, Transactions of the ASME*, vol **129**, no 1, pp 32-40
- [3] Rafanelli F, Campatelli G and Scippa A, 2015, Effects of cutting conditions on forces and force coefficients in plunge milling operations, *Advances in Mechanical Engineering*, vol **7**, no 6, pp 1-9
- [4] Rauch M and Hascoet J, 2012, Selecting a milling strategy with regard to the machine tool capabilities: application to plunge milling, *The International Journal of Advanced Manufacturing Technology*, vol **59**, no 1, pp 47-54
- [5] <http://www.renishaw.com/en/machine-tool-probes-and-software--6073>
- [6] [http://www.doosanmachinetools.com/en/product/detail.do?CATEGORY\\_ID=mten020300&PRODUCT\\_ID=mtenp0071](http://www.doosanmachinetools.com/en/product/detail.do?CATEGORY_ID=mten020300&PRODUCT_ID=mtenp0071)

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