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MODELING OF UNDETACHED CHIP SHAPE ON FINISHING PROCESSING TOOLPATH

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Abstract

During milling cutting of spherical surfaces, the added material is removed in the form of chips. The controlled conditions that determine the size and shape of the undetached chip are defined by the technological parameters (feed per tooth and depth of cut) or by the geometrical parameters (thickness and width of the chip). The shape of the undetached chip is influenced by the geometry of the tool, by the milling mode (cut-up milling, cut-down milling), by the feed direction. There are mathematical models, mostly plane, for defining the shape of the undetached chip. These mathematical models become extremely complicated when considering machining of a spherical or a non-analytical surface. This paper presents a parametric model built in a CAD environment that determines the shape of the undetached chip when machining a spherical zone with a torodial end mill.

Key words: chip shape, milling, corner radius end mill, roughness, 3D parametric modeling

1. Introduction

The formation of the chip is influenced by technological elements, by geometrical elements of the tool or of the semi-manufactured product, and by the ones that define the finishing path. The motivation for this study comes from the need of competitiveness in the modern technological industry, which entails a fine line between two fundamental requirements, productivity and quality. As such, in addition to the development of production means, machine tools, tools, materials, it is required a very careful process management. Finishing is a process phase situated at the intersection of the two fundamental requirements. Modern CAM applications offer today various possibilities to generate milling paths for surface finishing, whose shape is controlled by various parameters, technological and geometrical ones. The assessment of the finishing strategy has a deep impact on surface quality and on the processing time. I consider that the geometrical formation of the chip is directly influencing the surface quality and the endurance of the cutting tool, as it will be demonstrated.

2. Assessment of toolpath types

The main cutting motion is the rotating motion of the milling tool. A mill-finished surface implies the existence of a feed motion between the milling tool and the workpiece, a main feed motion and a secondary feed motion for repositioning. The workpiece is considered to be stationary and the cutting tool to perform both movements (Figure 1).

We consider a geometric surface is described by an envelope curve that drifts on a directory curve. This is the easiest way of understanding the surface generation on a machine tool.

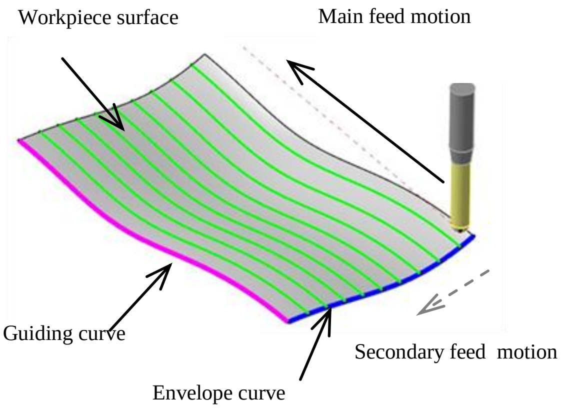


Fig. 1 Directory curves and envelope curves

As such, we can consider that when machining a surface, the main feed motion (continuous) follows a guiding curve, while the secondary feed motion (intermittent) follows an envelope curve. These curves can be of a constant shape or can vary during machining. Also, the curves are always at right angles with one another because of the construction of the machine tool carriages, which drift on guide ways perpendicular to one another (figure 2).

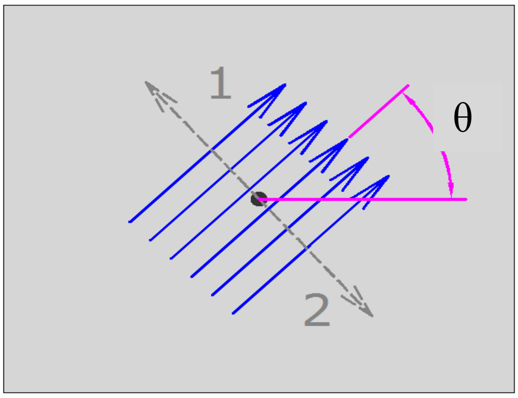


Fig. 2. Finishing directions of a surface

There is an infinite number of ways in which a surface can be *swept* by a milling cutting tool for finishing. The main feed motion can be positioned in any desired manner to the surface to be finished. In figure 2, the θ angle that defines the orientation of the main feed motion, can have infinity of values between 0 and 3600. The secondary feed motion, always at right angles to it, may in turn have two repositioning directions of the cutting tool (1 or 2).

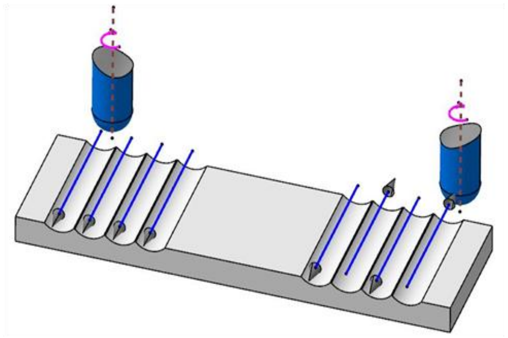


Fig. 3 Unidirectional and bidirectional finishing directions

These paths can be unidirectional or bidirectional (Figure 3). The bidirectional paths are in fact, two different unidirectional paths of tool movement of workpiece surface. In order to keep the same operating conditions (the way in which the cutting edge forms the geometry of the chip), we will consider only unidirectional paths.

3. Parametric modeling of the undetached chip

The existing CAD platforms are powerful tools for parametric design, that allow the geometric elements that define the shape and size of the workpiece to relate, being especially useful when designing a family of geometries. Considering the direction of the main feed motion positioned by the parameter θ, the direction of the secondary feed motion at right angles to the main one in a way or another, as well as other technological and geometrical elements of the cutting tool or of the machined surface, we will build up a geometric model of the shape of the undetached chip.

a. The determination of parameters and of the geometric model

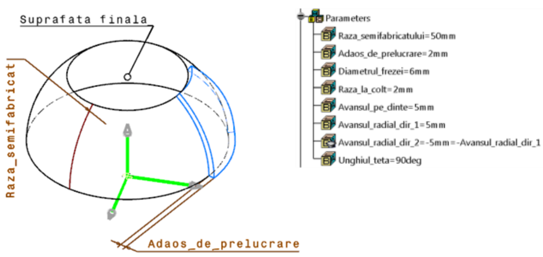


Fig. 4 Determination of parameters and of the geometric model

In the first phase, the geometrical and the technological parameters are defined by default values. Then, a spherical sector is built with the parametric radius *Raza_semifabricatului* (Workpiece radius), on which is attached a segment with the thickness *Adaos_de_prelucrare* (Machining_stock) (Figure 4).

b. The positioning of the cutting tool on the main feed path

We consider a starting point in a random position and belonging to the spherical area where the sector that represents the machining stock can be found. Next, we attach three geometries (position 1, 2 and 3) representing the cutting tool, in such way these are positioned on a curve that belongs to the sphere (we consider the milling tool to be tangent to the sphere), are passing through the considered point and belong to a plan that forms the θ angle with the horizontal plane, defined by the parameter *Unghiul_teta* (Figure 5a).

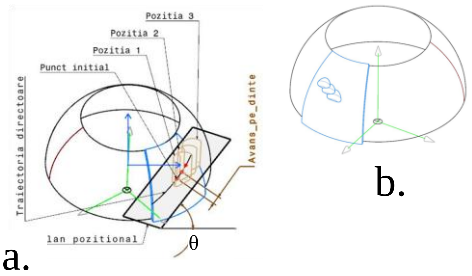


Fig. 5 Position of the cutting tool on the main feed path

The parameter *Avans_pe_dinte* (Feed per tooth) sets the distance between the three geometries. The geometrical parameters of the cutting tool are *Diametru_frezei* (Milling tool diameter) and *Raza_la_colt* (Corner radius). By eliminating the interference between the three geometries and the one of the machining stock, we obtain the track of a machining path for a three chip detachment cycle (Figure 5b).

c. The positioning the cutting tool on the secondary feed direction

As mentioned previously, the secondary feed motion is a motion at intervals on an envelope curve situated in a perpendicular plane to the one containing the guiding curve. We reposition the three previously created geometries (in fact, the geometry of the cutting tool) on this envelope curve after direction 1 or 2 (see Figure 2, secondary feed motion) and we obtain the position 4, 5 and 6. Next, we eliminate the interference between the machining stock left after the first three chippings, and the positions 4 and 5. After this stage, the interference between position 6 of the cutting tool and the machining stock left represents exactly the geometry of the undetached chip (Figure 6).

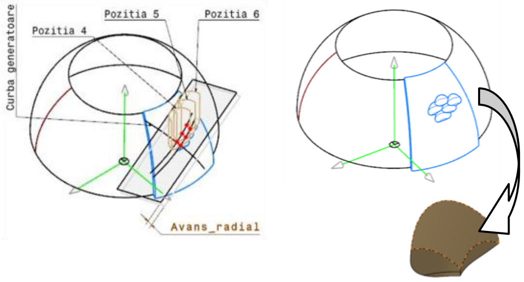


Fig. 6 Obtaining the geometry of the undetached chip

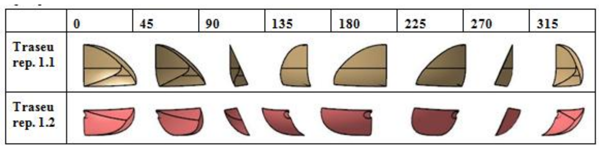
4. Geometries of the obtained undetached chip

As will be seen in the experimental part in the next chapter, we will take into consideration only the cases when the θ varies from 0 to 360^0 with a 45^0 angular pitch. There are 8 cases, each one with two possibilities of secondary feed motion. The finishing strategies, with a total number of 16, are attached to a segment of a spherical area with the thickness of the machining stock. Considering the input:

Milling tool diameter D	6	[mm]
Tool corner radius R2	2	[mm]
Workpiece radius Rs	50	[mm]
Feed per tooth fz	0.5	[mm]
Radial feed ap	0.5	[mm]
Machining stock	1	[mm]
Angle θ	0 - 360	[grade]

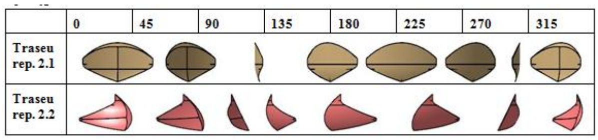
Case no. 1

$\theta = 0^0$



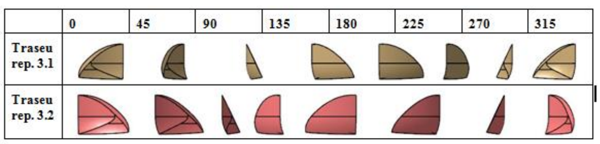
Case no. 2

$\theta = 45^0$



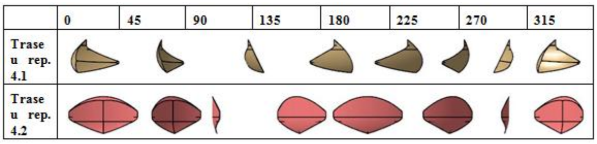
Case no. 3

$\theta = 90^0$



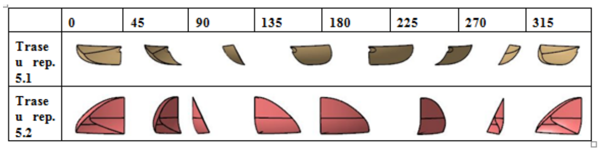
Case no. 4

$\theta = 135^0$



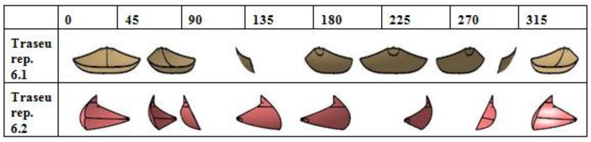
Case no. 5

$\theta = 180^0$



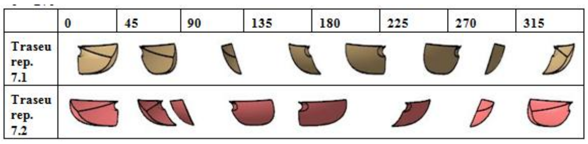
Case no. 6

$\theta = 225^0$



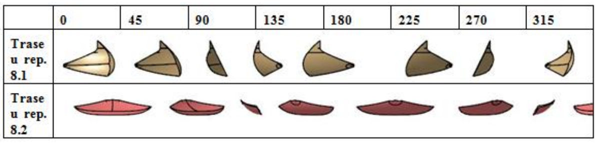
Case no. 7

$\theta = 270^0$



Case no. 8

$\theta = 315^0$



5. Conclusions

The study provides a method of theoretical determination of the shape of the undetached chip for a mill-finished spherical surface with an end mill cutter**.** Roughness size, generated by the chipping cyclicity, is influenced by the geometrical parameters of the cutting tool (diameter, corner radius), by the geometrical parameters of the part (workpiece radius, tool position when finishing) and by the technological parameters (feed per tooth, cutting speed).

Apart from the previously mentioned parameters, the spatial shape of the undetached chip is also influenced by the size of the machining stock and by the paths of the main feed motion and secondary feed motion. Following, a presentation of a parametric geometrical construction using CATIA V5 as a modeling environment (any other parametric environment can be used). The shape of the undetached chip is displayed in certain situations.

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