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DETERMINATION OF CUTTING TOOLS PROFILE USED FOR PROCESSING THE NON-INVOLUTE PART PROFILES USING GEO GEBRA SOFTWARE

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Abstract: *In manufacturing engineering designing the appropriate profile of cutting tools to manufacture non involute parts profile is a challenge and a necessity, dimensional and shape precision of the machined parts depending on tool profile and geometry. Machining of the work pieces are more precisely using tools that works by rolling processing and it is important to define precisely their profile. The paper aim is to present a method to determine tools profile for the processing of non-involute profiles using a geometric method based on Camus' theorem and GeoGebra software package. The paper presents four possible tool profiles for pinion cutter for mortising inner and outer surfaces, hob type milling cutter and comb rack type cutter profiles for processing a non-involute profile using the software program.*

Key words: *cutting tools profile, non-involute profile, rolling process, pinion cutter, comb rack cutter, hob.*

1. INTRODUCTION

The metal cutting tools industry helps sectors like industrial manufacturing, construction, aerospace, automotive and, in recent years, has registered an increase due to the demand for products from metallic materials in the mentioned sectors [1]. In this situation, the constant interest in developing cutting tools innovative design is an important issue.

The cutting tool profile and geometry depends on its intended function and thus it is important for the designer to choose or design the correct tool for a given task [2, 3]. It influences the dimensional and shape precision of the machined parts and is one of the critical factors in machining [4].

The cutting tools designers have to consider many aspects because the final part shape accuracy and geometrical design specifications depends partially upon the cutting tool geometry. These characteristics influence the design or selection of the tool holding and guiding device, work holder, and are also related with machine kinematics, various process conditions and not at last the work piece. In industry, along with the involute profiles of the parts, (e. g. gears), also other types of profiles - non-involute profiles- are often found. From this category we can mention some examples of parts such as grooved shafts, ratchet wheels, disc cutters, polygonal shafts, etc. In manufacturing engineering field, the profile of cutting tools design is a specific problem, but the design process of the profiled shape of cutting edges is less investigated compared to papers that have as subjects measuring the profile, its wear, and its influence on the part's geometrical precision [5].

There are a multitude of methods that have been developed over time that address generating surfaces by enveloping A general classification of these methods for determining conjugate curves associated with running centroids can be done from a mathematical point of view, thus we have graphic methods, analytical methods, graphical-analytical methods, solid modeling method and finite element method. Consequently, the cutting tool profile can be determined using these methods. The numerical models are based on spatial and temporal discretization of the targeted work piece geometry and the machining motion. The analytical method is based on the general equation of meshing together with a fundamental condition of contact [6].

The element underlying the processing of non-involute profiles by rolling (Rolling can be defined as the relative movement of two curves that have the possibility of being in contact all the time) is compliance with the fundamental property of conjugate curves [7].

Beside tools used for manufacturing parts with involute profiles there are also cutting tools that process non-involute profiles by the rolling method, such as: hob type milling cutters for processing grooved shafts, hob type milling cutters for processing wheels chain, etc. In the case of tools for processing non-involute profiles, an important problem is determining the profile of the tool, which will process the profile of the given part by the rolling method. The tools that can be designed can be like basic rack-type cutter, gear hobs (hob type milling cutters) or pinion cutter (cutting wheel) type.

In this paper the work piece is considered to get its final shape in a generation motion. The envelope of the generation motion for the cutting tool profile is the same with the resulting work piece geometry. The cutting tool profile is determined by taking the process kinematics into consideration.

In order to determine the tools profile for the processing of non-involute profiles - the generation of conjugate surfaces on machine tools by the rolling method without sliding - a geometric method will be used. This is based on Camus's theorem. In accordance with this theorem, taking different points on the work piece profile it can be found points on the tool's profile, in accordance with the cinematics of some kinds of tools (pinion cutter, rack type cutter or hob). Determining the profile of tools for processing non-involute profiles can be facilitated by using the free GeoGebra package [8].

2. CUTTING TOOL PROFILE USING GeoGebra SOFTWARE

For the profile of the piece shown in figure 1 - profile delimited by two characteristic circles of radii r1 and r2 - the pitch line of the part is considered the outer circle of the part and its radius is Rr.

The cutting tools with which this part profile can be processed are:

1. Inner pinion cutter (cutting wheel) for inner mortising a bore with profile in figure1;
2. Pinion cutter (cutting wheel) for mortising a shaft with profile in figure1;
3. Comb rack cutter (basic rack type cutter) for mortising a shaft with profile in figure1;
4. Hob type milling cutter for milling a shaft with involute profile in figure 1;

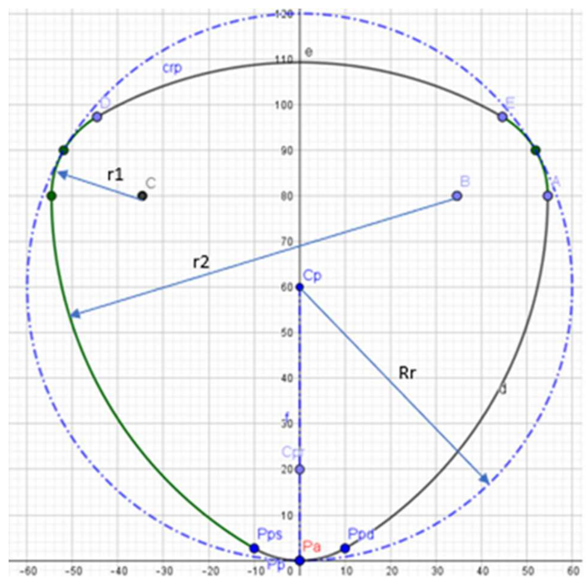


Fig.1. Final part profile.

These cutting tools profiles can be determined based on Camus' theorem and using GeoGebra software package.

2.1 Determining the profile for cutting wheel for inner mortising a bore

In order to determine the profile for inner pinion cutter (cutting wheel) used to inner mortising a bore (Cri) the rs cutting wheel radius, rs radius of pitch line is set. It is considered rs=40 mm (Cs circle in figure 2). The profile is determined in accordance with the Camus theorem [7] applied in the GeoGebra software. Thus, the fundamental problem of the conjugate curves is that the normal to the two (the profile of the piece to be made and the profile of the tool), at the characteristic point, passes through the instantaneous center of rotation, also called the gearing (meshing) pole (Pa in figure 2).

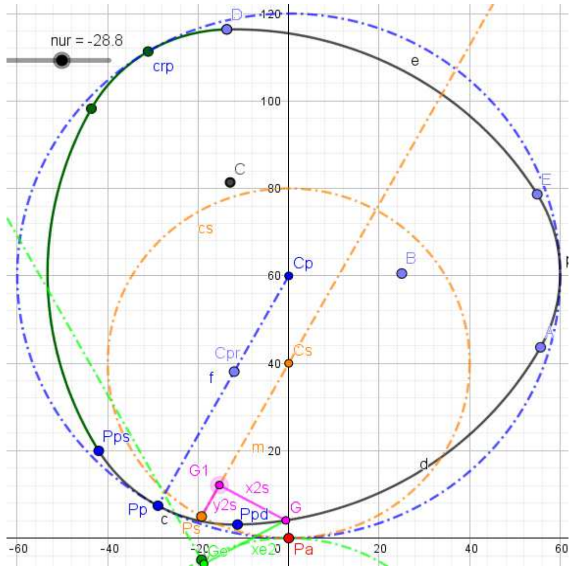


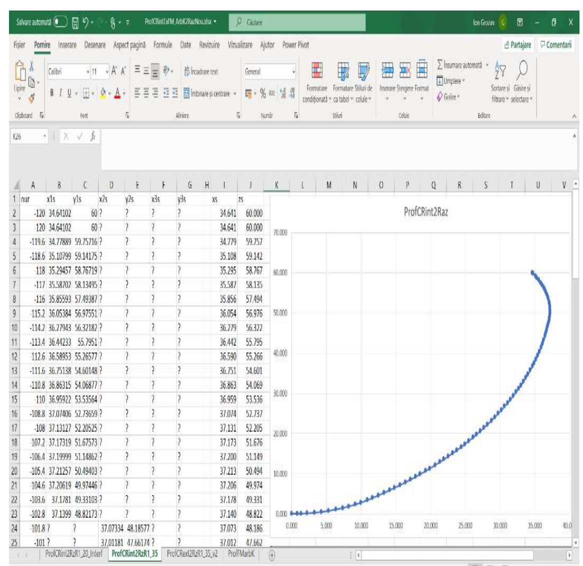
Fig. 2. Profile coordinates for inner cutting wheel.

The profile of the part in discussion is composed of circular arcs of type c (radius r1) and type d (radius r2) (see figure 2). From the gear/meshing pole Pa, normals to different points on the profile of the part (see $\overline{PaG}$ figure 2) are considered. The point of intersection of the normal to the profile from Pa with the profile of the part (point G in figure 2) generate a common point of the profile of the part and the tool. It should be noted that the part and the tool rotate with an angle $up^0 = us^0$ (up – the rotation angle of the part, and us- the rotation angle of the tool), so that the normal at the characteristic point G passes through the gear/meshing pole Pa.

Initially, in the case of up=us=0, the points Pa and Ps (Ps – is the point of origin of the reference system attached with the SRs tool) are overlapping. When rotating the part and implicitly rotating the tool, the gear/meshing pole Pa is fixed, but Ps changes its position (see figure 2). The y_s axis of SRs becomes $\overline{PsCs}$, and x_s axis will be normal to y_s.

The coordinates of the characteristic point on the part profile (G) transposed in SRs (tool reference system) are the segments x_{is} (i=1,2,3 because at an angular step of the part profile the arcs were included: 1/2c, then d and the following 1/2c), respectively y_{is} (in figure 2 the coordinates x_{2s} and y_{2s} are presented).

The GeoGebra software allows the recording of desired values, thus the xis and yis coordinates were recorded. These coordinates, transposed in



Excel, allowed the graphic representation of the tool profile (see figure 3).

Fig. 1. Inner pinion cutter profile.

Checking the meshing between the profile of the part and that of the CRint is also done using Geogebra software. Although 1/3 of the CRint profile was determined, the software allows to multiply it and obtain the full CRint profile. The GeoGebra allows to create an animation of the meshing of the two profiles, thus verifying the correctness of the determination.

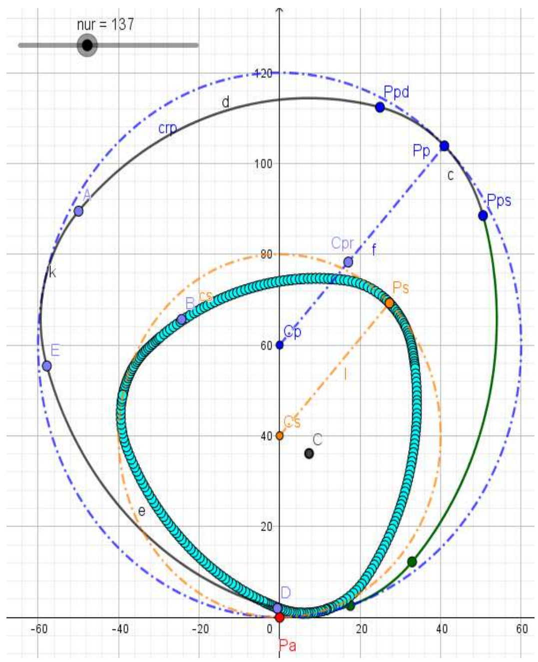


Fig.4. Gearing part profile with inner pinion cutter

Figure 4 shows an image of meshing of the profile of the piece with that of the CRint. By changing the nur cursor, different rolling angles of the part and implicitly of the tool are obtained. This check is very useful, especially in the case of CRint, where when rolling the part and the tool, in some cases interference of the CRint profile with that of the tool may occur.

For example, if the piece had right-hand segments instead of d type arcs, the mentioned interference would occur. The generated motion leads to undercutting of the workpiece.

2.2 Determining the profile for pinion cutter used for mortising a profiled shaft

Similar to CRint it can be determined the profile for mortising wheel external involute profiles (CRext). In figure 5 is presented, also the case of determining the CRext profile (green color).

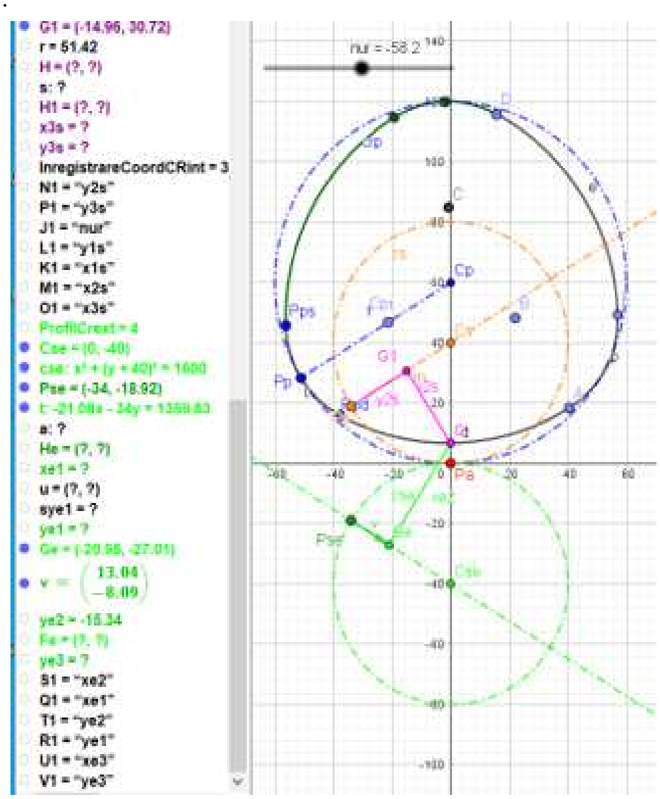


Fig.5. Inner pinion cutter (CRint) and outer pinion cutter (CRext) profiles.

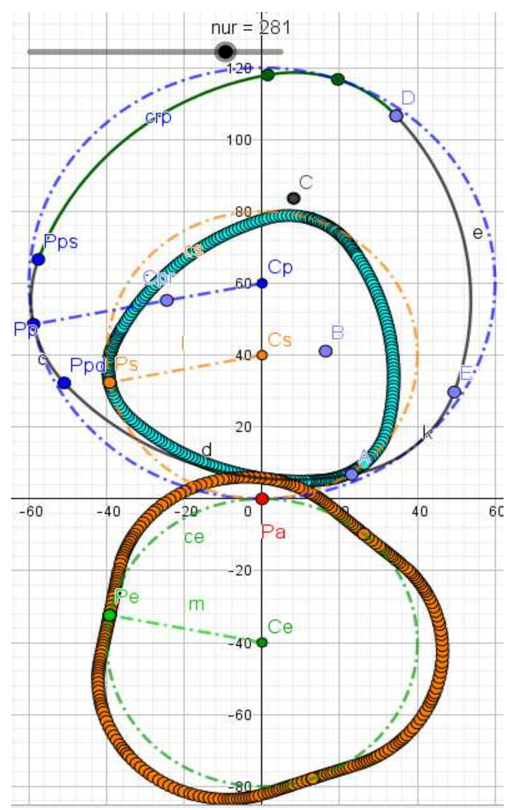


Fig.6. Meshing of part profile with CRint and CRext profiles.

Similar to CRint, the CRext profile can be obtained and the meshing of this profile with the profile of the part to be made can be achieved. In the case of CRext, there is no longer the restriction of its interference with the part profile.

2.3. The hob type milling cutter (FM) and rack type cutter (CP) profiles

Because the hob type milling cutter (FM) can be assimilated with a sequence of offset basic rack type cutters (CP) arranged on a cylinder, the tool profile can be obtained similarly.

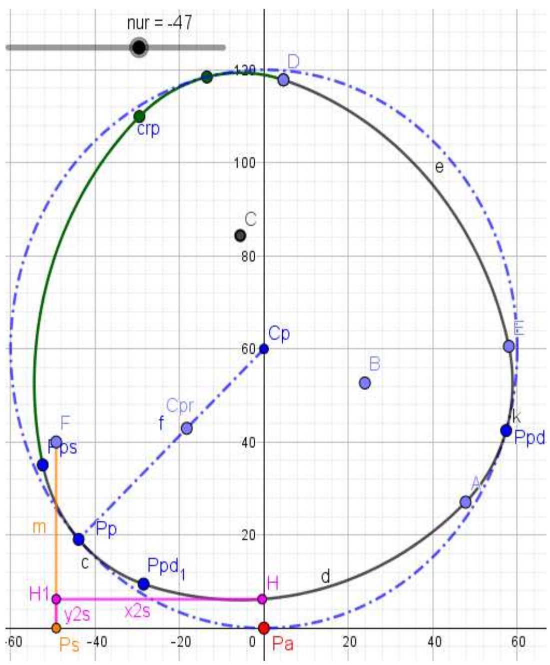


Fig. 7. Profile coordinates for comb rack cutter (CP) and Gear Hob (FM).

Consider 1/3 of the profile of the part (an angular step) which includes ½ arc type c, circular arc type d and again ½ arc type c. On these circular arcs different characteristic points of the profile will be considered (see fig. 7-point H), and through these points the normal(s) to part profile are plotted/drawn.

The part rotates by the angle upg (in degrees) until the normal passes through the gear/meshing pole Pa. Since a rolling of the rack without sliding is considered, relative to the profile of the part, the origin of the reference system of the rack Ps is moving from the point Pa (where it was initially, for the case upg=00). The point Ps moves on the Ox axis of the fixed reference system, with the length $La = \frac{up_g*\pi}{180^0}$. The characteristic point H, which is processed, corresponds to the coordinates in the solid reference system with the tool x_{is} and y_{is} (i=1,2,3), (in figure 7 it is x_{2s} and y_{2s}).

By recording the tool profile coordinates for a series of points on the part profile, the series of points on the CP profile is obtained. Transposing these profile points in the GeoGebra software, over the profile of the work piece, an animation of the engagement of the tool with the work piece can be created and in figure 8 is rendered only an image of this gear/meshing. By changing the nur slider (part rotation angle) different gear positions can be obtained

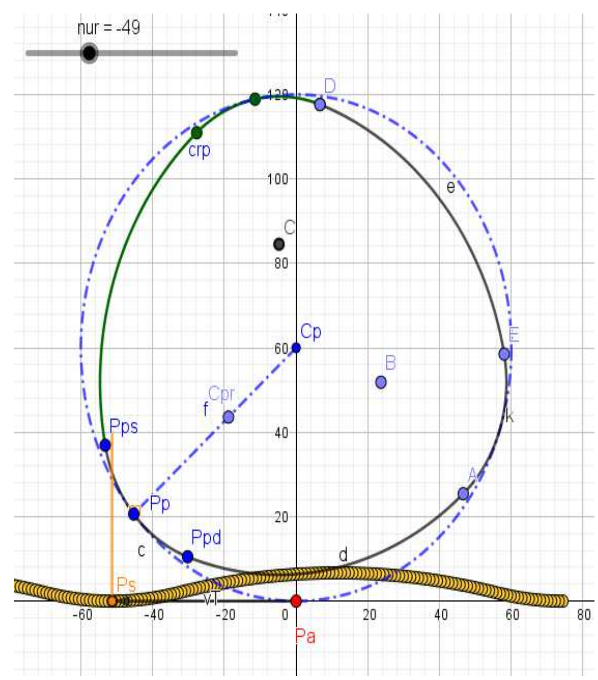


Fig.8 Animation of the pinion cutter with the work piece.

3. CONCLUSION

Cutting tools design is challenging and requires designers with good knowledges in areas like cutting tools profile, cutting tools geometry, materials (part and tool material), part machinability, machine tool kinematics, etc.

In this paper were presented the cases of profile determination, assisted by the GeoGebra software, for:

- the profiles of pinion cutter for the processing of non-involute bores

- the profile of pinion cutters for the processing of non-involute shafts
- profile of the comb rack cutter for the processing of non-involute profiles and
- profiles for hob mills for the processing of non-involute profiles.

The results of this paper offer a contribution to the improvement of the design technology of hob cutters, to enhance the manufacturing processes of helical cutting tools, and to assist tool-related industries in upgrading their technology and competitive abilities.

The use of tools that process non-involute profiles by the rolling method allows to increase the processing precision. This precision, however, is determined by the accuracy with which the tool profile is determined and obviously by the precision with which the tool profile is executed. Determining and at the same time verifying the determination of the tool profile is greatly facilitated by the existence of some software that assists the designer and greatly facilitates his work.

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DETERMINAREA PROFILULUI SCULELOR ASCHIETOARE UTILIZATE PENTRU PRELUCRAREA PROFILURILOR REPERELOR NEINVOLUTIVE UTILIZAND PROGRAMUL GEO GEBRA

Rezumat: Sunt cunoscute sculele pentru prelucrarea pofilelor evolventice prin metoda rostogolirii. Există de asemenea scule care prelucrează prin metoda rostogolirii profile neevolventice, cum sunt: frezele melc pentru prelucrarea arborilor canelați, freze melc pentru prelucrarea roților de lanț, etc. Prelucrarea pieselor este mai precisă prin procedeul de rostogolire, la acest tip de scule este importantă definirea profilului sculei. În cazul sculelor pentru prelucrarea unor profile neevolventice, o problemă importanta este determinarea profilului sculei, care va prelucra prin metoda rostogolirii, profilul piesei date. Scopul lucrării este de a prezenta o metodă de determinare a profilului sculelor pentru prelucrarea profilelor neevolventice de tipul cuțitelor pieptene, frezelor melc sau cuțitelor roată folosind o metodă geometrică bazată pe teorema lui Camus și pachetul software GeoGebra.

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