

UTILIZATION OF COMPUTER PROGRAMS IN CAD AND 3D - MODELLING OF TOOTHED WHEELS AND GEARS

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Abstract: The paper presents aspects regarding the utilisation of computer programmes for CAD and 3D graphical modelling of cylindrical toothed wheels forming up gears. There are described some results of software applications in the domain of computing the points that define the profile and the line of tooth flanks, as well as their 2 and 3 D representation; in modelling and animation of gears.

Keywords: Computer Aided Design, hypocycloid, involute, toothed wheels, pitch circle, gears, 3D modelling and animation

1. INTRODUCTION

The tooth wheel mechanism (gear) is largely used in conveying circular motion under specified conditions of speed, stress (forces and torques) and precision. Gears ensure safety and high durability in operation, high output and small overall dimensions, as compared to other mechanisms that perform the same function. Unfortunately, gears have certain disadvantages, such as: noise and vibrations during operation, rather complex analysis calculation, design, machining technology and analysis studies of operation behavior, ending in high costs, in some cases.

The paper presents modelling phases of an external cylindrical involute-tooth gearing with parallel axes, without correction, with curved toothing. The particular feature resides in the curved shape of tooth flanks, namely their lines represent sectors of an extended and shortened hypocycloid. The two curves defining tooth flanks are the involute (profile) and the hypocycloid (line).

The involute profile is widely used, as a result of superior kinematic, functional and technologic characteristics as compared to other curves. The hypocycloidal line of flanks provides higher bending resistance, localization of contact spot, tooth curving and as a result, a good behaviour when deviations appear during assembly and gear operation.

The paper presents a gear with the following geometrical parameters: number of teeth $z_1 = z_2 = 47$, module $m = 2.5$ mm, width $b = 25$ mm, reference profile according to STAS 821 unchanged, distance between axes $a = 117.5$ with the precision degree 7, according to STAS 6273 [1]. The phases of geometrical design are such as they are described in the specialised technical documentation. Design data are established in accordance with functional criteria.

The paper has a strong didactic and application character. Computer aided design of wheels and gears are based on the utilisation of the following programs: C++ for automatic generation of the two curves (involute and hypocycloid), CAD for 2D and 3D drawing and 3D Studio Max for gear modelling and animation.

2. REPRESENTATION OF WHEELS AND GEARING

2.1. Utilization of C++

In order to establish the co-ordinates of points defining the tooth profile, a program was elaborated, called *Ec Evolventa* (fig.1), which is based on the parameter equations of the involute profile kinematically generated by rolling on the pitch circle [2] of the form:

$$\begin{cases} X_{P_e} = \left[\left(k \frac{m\pi}{4} - R_r \varepsilon_p \right) \cos \alpha_0 + k \xi m \sin \alpha_0 \right] \cos \alpha_0 \cos \varepsilon_p + \left[\left(k \frac{m\pi}{4} - k R_r \varepsilon_p \right) \sin \alpha_0 \cos \alpha_0 + \xi m \sin^2 \alpha_0 + R_r \right] \sin \varepsilon_p \\ Y_{P_e} = 0 \\ Z_{P_e} = \left[\left(k \frac{m\pi}{4} - R_r \varepsilon_p \right) \cos \alpha_0 + k \xi m \sin \alpha_0 \right] \cos \alpha_0 \sin \varepsilon_p - \left[\left(k \frac{m\pi}{4} - k R_r \varepsilon_p \right) \sin \alpha_0 \cos \alpha_0 + \xi m \sin^2 \alpha_0 + R_r \right] \cos \varepsilon_p \end{cases}, \quad (1)$$

where geometric parameters are identified that affect the shape and precision of the generated involute profile: α_0 - pressure angle, $p_d = m\pi$ - tooth pitch, ξm - displacement of profiles, R_r - radius of division and rolling pitch, including the rolling angle, ε_p - kinematic parameter.

In these equations, the generating reference profile has rectilinear flanks and does not include the reference connection radius to the tooth root. The program generates a *scr* file (fig.2) for profile drawing (fig.3).

In a similar way, it was elaborated the *Ec Hipocicloida* program for generating the flank line on the basis of the parameter equations of the hypocycloid [3].

```

#include <math.h>
#include <stdio.h>
#include <conio.h>
#include <string.h>
#include <stdlib.h>
#include <time.h>
#include <windows.h>
#include <conio.h>
#include <string.h>
#include <stdlib.h>
#include <time.h>
#include <windows.h>
...

```

Fig.1 Program scris în C++

Fisier Evolventa_dr.scr

```

filedia 0
pline 2.6321,55.781
2.5910,56.114
2.529,56.504
2.441,56.960
2.322,57.47
1.973,58.689
1.734,59.38
1.447,60.127
1.11,60.925
0.713,61.771
filedia 1

```

Fig.2 Involute generation file

2.2. Definition of entities in AutoCAD 2000

In order to generate a tooth, the following elements must be considered: tooth profile (fig. 3) - an involute profile; interior flank line - a shortened hypocycloid; exterior flank line - an extended hypocycloid. An involute toothing with hypocycloidal flank line is generated by drawing up the plane tooth divided into two sectors (fig.4). This is done by using *Polyline* command of the *Draw* menu [4].

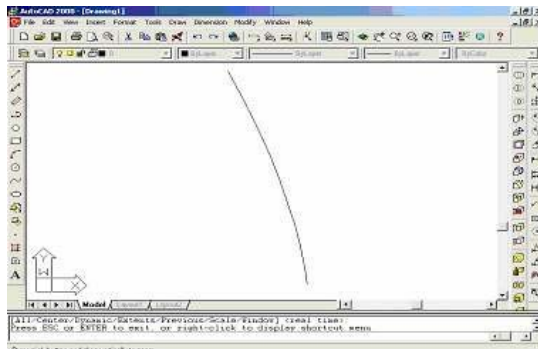


Fig.3 involute

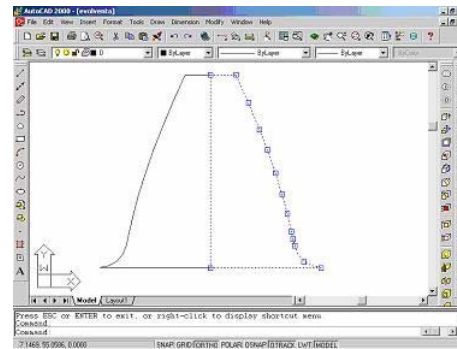


Fig.4 2D involute tooth

The two hypocycloids (extended and shortened) are drawn up on the basis of the file generated in *Ec Hipocicloida* by means of *Run Script* command of *Tools* menu (fig.5). Every tooth sector is extruded along the two hypocycloids (fig.6) by means of *Extrude* command of the *Draw Solids* menu [4].

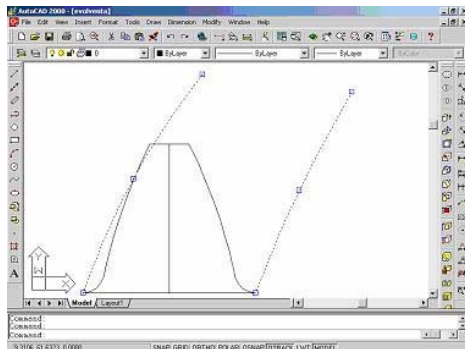


Fig.5 Hypocycloids and tooth

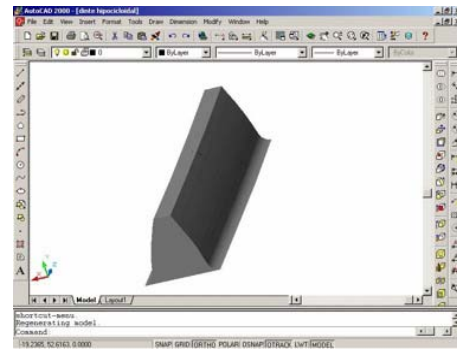


Fig.6 3D Tooth

Further, the pitch circle is drawn up by using *Circle* command of *Draw* menu and the tooth is located on the pitch circle by *move* command (fig.7). The entire toothing is generated by *3D array* command of the *Draw Solids* menu (fig.8).

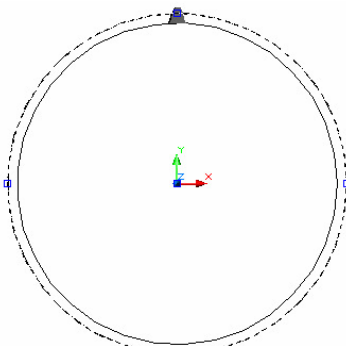


Fig.7 Tooth location on pitch circle

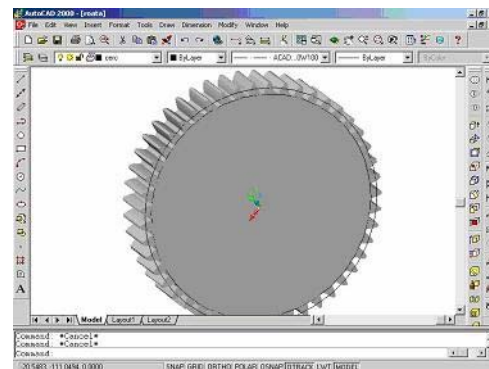


Fig.8 3D wheel construction

2.3. Animation of gear in 3D Studio Max 4

The animation of a parallel gear containing two cylindrical wheels can be obtained by using the 3D Studio Max program [5], produced by Discreet, a division of Autodesk.

The graphical model, representing a cylindrical wheel was previously generated using AutoCAD 2000, on the basis of mathematical equations and saved under DWG format on the hard disk. This format, as well as the DFX format are recognised and imported by 3D Studio Max, which undertakes the objects drawn up parametrically, accurately, in order to animate them. Usually, AutoCAD is used to generate such objects, according to specified technical dimensions.

Having on the hard disk the file *roata cilindrica.dwg* saved by AutoCAD, 3D Studio Max is set out to work. This file is selected from the File menu, by *Import* option. No option must be activated in the dialogue box (fig. 9).

Further, 3D Studio Max will be processing vectorial information contained in AutoCAD file and displays the 3D model of the wheel, under the form that is shown in (fig. 10):

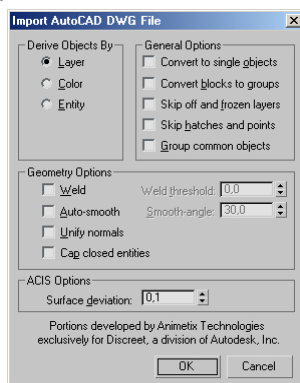


Fig. 9 import of dwg file

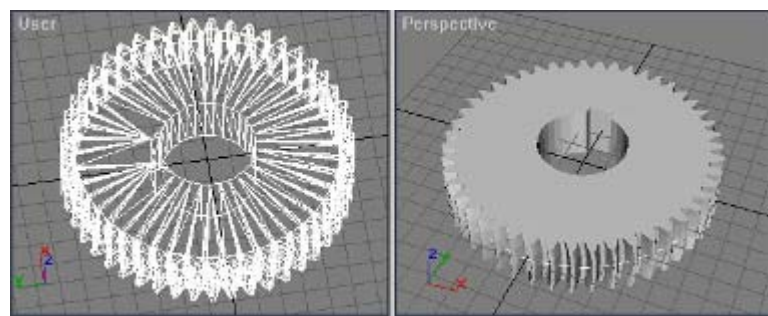


Fig.10 3D model of wheel after its import in 3D Studio Max

Figure 10 shows two representations of the wheel. The left one represents the model with “wireframe” aspect, while the right one is a real “render”– type representation.

To produce the second wheel, which is identical to the first one, *Clone* option of the *Edit* menu is used.

3D Studio Max generates the new wheel using the parameters of the first wheel, resulting two identical superimposed objects. One of the wheels is selected and displaced to the right, with the result that can be seen in figure 11.

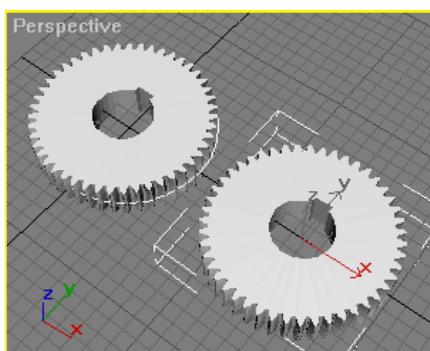


Fig. 11 Identical wheels

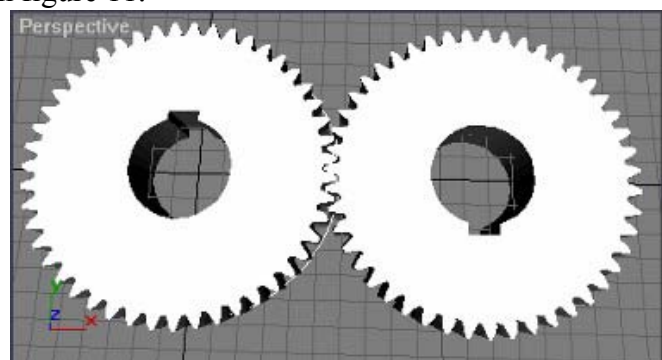


Fig. 12 Rotation of a wheel by 180°

Since the wheels have curved toothing, they cannot engage in the position shown in figure 11. Therefore, one of them must be rotated by 180°, in order to make gearing possible. The second wheel must be selected (the one obtained by cloning) and rotated by 180° (fig. 12), along X-axis. Figure 13 shows an intermediary image during rotation:

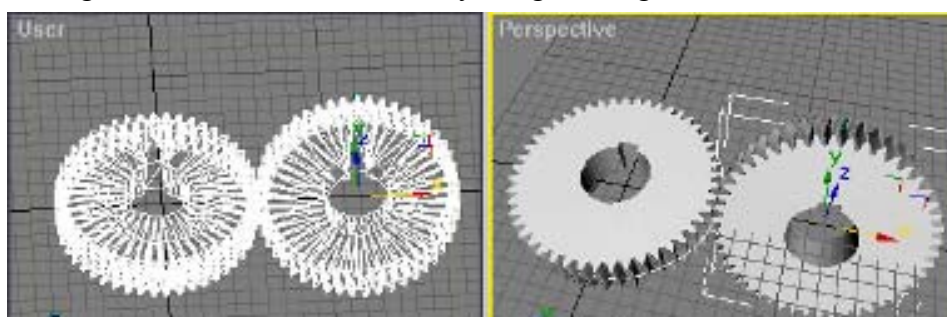


Fig. 13 *Rotation image*

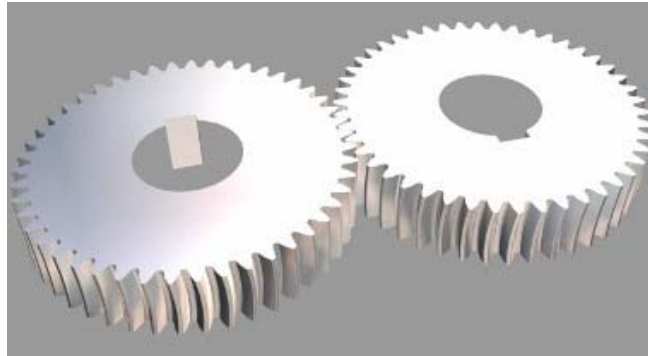


Fig. 14 *Animated gearing wheels*

Animation is performed for every wheel in its turn. Therefore, one wheel will rotate around its own axis at an angle of 360° in trigonometric direction and the other one at the same angle in counter trigonometric direction. In order to provide the animation of both wheels, options of the *Motion-Parameters* Section must be used [6]. The rotation speed is established in function of the number of animation frames. For instance, 360 frames can be used for an angular pitch of one degree for a complete rotation.

As a particular case, we may assume that gear wheels are made of steel (fig. 14), while taking into account that 3D Studio Max has an option that permits to add certain characteristics specific to various materials (metal, glass, plastics, wood etc.) on the surface of the created entities.

The methodology described above may be used in 3D design and modelling of various types of tooth wheels and gear – based mechanisms. As an example, figures 15 and 16 shows two mechanisms containing involute-tooth bevel gears with rectilinear flanks and constant tooth height.

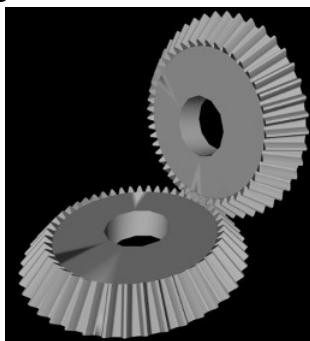


Fig. 15 *Bevel gearing*

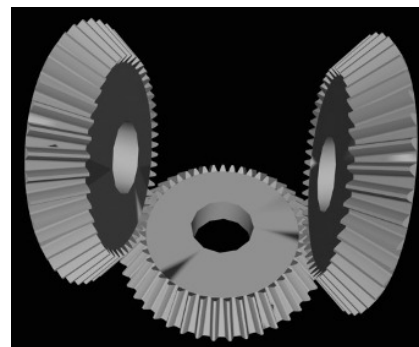


Fig. 16 *Differential mechanism*

3. CONCLUSION

2D and 3D models that were obtained may be used to elaborate optimisation studies in point of constructive geometry, correction, stress, behaviour in operation, simulation, etc. by further using specialised programs (ANSYS, Mstruct, Mmotion, Mtherm). Moreover, the

models obtained may be used, in order to make conspicuous construction changes and the effect of assembly errors on gear generation.

The methodology described combines some of the facilities of the above-mentioned programs, resulting in the reduction of design and modelling time for wheels and gears.

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