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## PARAMETRIC DRAWING OF A CYCLO DRIVE SHORTENED EQUIDISTANT EPITROCHOID GEAR

**Abstract:** Cycloid profile gears have very good working characteristics in both kinematic and dynamic domains. The most frequently used profile of cycloid gears is an equidistant of the shortened epitrochoid. These types of gears commonly have convex on concave contact surfaces, which influences the decrease in stress as well as contact wear. Given that this is a complex curve, this paper gives a program code made in AutoLISP for its automated generating in AutoCAD. Using the input parameters of the cycloid disc the program creates a two dimensional drawing of the cycloid disc profile. The drawing represents a very valuable and time efficient initiate for cycloid drive design.

**Keywords:** cycloid gear, shortened equidistant epitrochoid, automated generating

### 1. INTRODUCTION

Cycloid drives are part of the planetary drive group. Cycloid drives (Figure 1) are widely used in the industry due to their excellent characteristics, specifically, wide range of gear ratios, compact size, smooth transmission, high efficiency, high overload capacity, low noise, long and reliable service life, compact design and suitability for frequent start-stop and reversing duty. Thanks to the afore-mentioned characteristics, cycloid drives have many applications, such as in: conveyor systems, presses, extruders, cranes, spinning machines, processing and automotive plants, mixers, food processing machinery, etc.

The most important element of the cycloidal speed reducer is cycloid disc whose teeth profile is an equidistant of the shortened epitrochoid. In the theoretical case, when machining tolerances are not considered, half of cycloid disc teeth participate at the load transmission process. The basic information about

cycloidal gearing is presented by Kudrijavcev [1] and by Lehmann [2]. Litvin and Feng [3] developed parametric equations for the equidistant of trochoid [4].



**Figure 1. Model of cycloid drive**

Generation and geometry of planar cycloidal gearing has been covered by [5]. Other problems and concepts concerning the geometry, tolerances and analysis of cycloid drives have also been covered by

[6-9].

The cycloid gear has one tooth less than the number of rollers of the central gear (only in some newer cycloid drives this difference can be two teeth). In practice, systems with two cycloid disks which are rotated by 180° of each other are most commonly used (Figure 2).

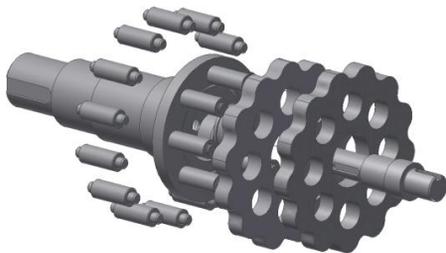


Figure 2. Assembly of cycloid drive

Due to the complex geometry of the cycloid disk, automation of the drawing process is both time conserving and removes the possibility of human error.

Two-dimensional drawings of the gears geometry made in AutoCAD can be used as base sketches for 3D modeling in other programs, as well as for simulation and analysis models. AutoLISP gives a means to automating the process of drawing the cycloid profile by entering input parameters.

## 2. CYCLOID PARAMETERS AND PROFILE

### 2.1 Cycloid Gear Geometry

Tooth profiles can be made of any curve which satisfies the basic laws of meshing. If the profile of one tooth, distance between axis and transmission ratio are all known, then the profile of the second gear can be completely defined. It is a curve of the same character as the profile of the first gear, just with different

$$x = (R_b + R_a) \cdot \cos \alpha + e \cdot \cos(\alpha + \beta) - q \cdot \cos(\alpha + \phi) \quad (5)$$

$$y = (R_b + R_a) \cdot \sin \alpha + e \cdot \sin(\alpha + \beta) - q \cdot \sin(\alpha + \phi) \quad (6)$$

parameters. Roulettes are curves which satisfy the basic rules of meshing and they can be involutes or cycloids [10].

A cycloid is a curve traced by any point on a circle as it rolls along a stationary circle. The stationary circle is also known as the basic circle and it has a radius  $R_b$  (2), while the mobile circle is called the rolling circle with a radius of  $R_a$  (1). Depending on the position of the rolling circle in relation to the basic circle, as well as the position of the point on the rolling curve which traces the cycloid, there are different forms of cycloids. The equi-distant of the shortened epitrochide is most commonly used as the tooth profile for cycloid gears.

$$R_a = \frac{r}{u_{CR} + 1} \quad (1)$$

$$R_b = r - R_a \quad (2)$$

Auxiliary angles ( $\beta$  and  $\phi$ ) are usually used to simplify the calculation of curve coordinates. The equations for these angles (3 and 4), are given as a function of the angle between the starting and current point of contact of the basic and rolling circles relevant to the centre of the base curve,  $\alpha$ , the radiuses of the basic and rolling circles and size of excentricity,  $e$ .

$$\phi = \arctg \left( \frac{\sin \beta}{R_a/e + \cos \beta} \right) \quad (3)$$

$$\beta = \frac{R_b}{R_a} \cdot \alpha \quad (4)$$

Figure 3 shows the auxiliary angles, radiuses and centres of the basic circle  $K_b$ , and rolling circle  $K_a$ .

The equations for  $x$  and  $y$  coordinates for the equidistant of the shortened epitrochide are given by functions (5) and (6).

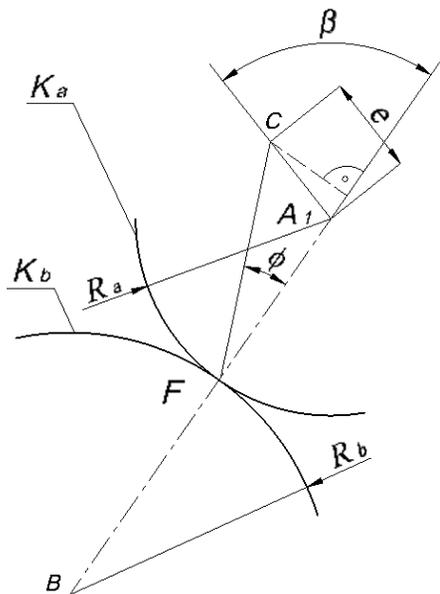


Figure 3. Visual representation of variables [1]

### 3. THE PROGRAM ROUTINE

In this section, the methodology of the program will be explained, as well as a portion of the program code.

The program is written in AutoLISP, a dialect of the LISP programming language adapted for the purposes of AutoCAD, which allows for automatic parametric drawing and other manipulation using AutoCAD commands. Variables are input via the command line in the AutoCAD interface. Writing the code for AutoLISP is possible with the use of any text editor or the Visual LISP editor.

#### 3.1 Programing the geometry in AutoLISP

Aside from drawing the profile of the cycloid gear, the program also draws the shaft opening on the gear from the input value of the outer diameter of the excenter's needle bearing of the cycloid drive as well as the holes for the output mechanism rollers.

The program is written in such a way as to only need the input of the eight values given in Table 1. These values are all previously calculated and/or adopted from standard values for the cycloid drive being designed.

Table 1. Order in which the program requests the input of values

Radius of the pitch circle of the central gear	$r$
Gear ratio	$u_{rc}$
Correction coefficient	$\xi$
Radius of ring gear *	$r_2$
Radius of central gear roller *	$q$
Diameter of output mechanism	$D_{vk}$
Adopted number of output rollers	$u$
Diameter of shaft needle bearing	$D_{cz}$

The values marked with an asterisk (\*) are meant to be adopted from calculated values which the program displays in the first line above the command line (figure 5).

For the sake of keeping the number of variables to a minimum the entire  $x$  and  $y$  coordinate formulas are programmed without the use of auxiliary angles  $\beta$  and  $\phi$ .

#### 3.2 Sample of the program code

The entire program is written as a whole without subroutines due to its simplicity. Given in figure 4 is the part of the program code with a predetermined density of points to be joined by the curve of  $n = 50 \cdot z_1$ . A density of 50 points per tooth gives a very high precision of the curve. This segment of the code is designated for the creation of the profile curve of the cycloid gear.

The rest of the program consists of a similar repeat function for creating the holes for the output mechanism rollers.

The function of creating points for curve generation is repeated  $m$  times, where  $m = n + 1$ , because the spline curve needs a tangent for its final point.

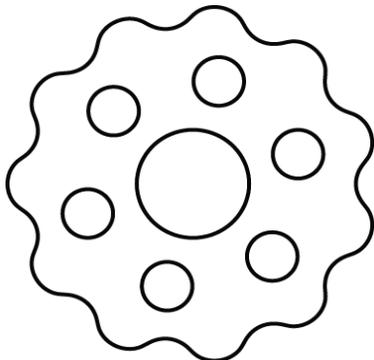
The angle  $\alpha$  changes by  $n/360$  creating



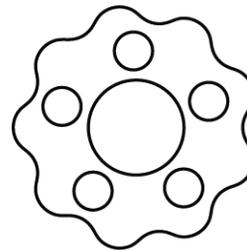
As a result of the program AutoCAD can generate a two dimensional drawing of a cycloid gear by entering requested values into the command line. Table 2 gives the input values for three gears which have been drawn using this program. The resulting drawings for these gears are shown in Figures 6, 7 and 8.

**Table 2. Order in which the program requests the input of values**

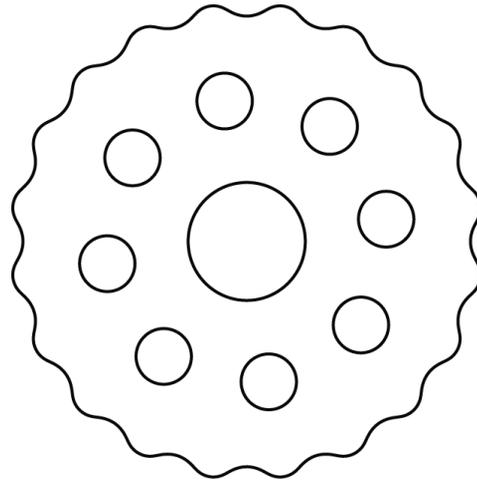
Value	Gear 1	Gear 2	Gear 3
Radius of the pitch circle of the central gear - $r$	72	50	120
Gear ratio - $u_{rc}$	11	9	20
Correction coefficient - $\zeta$	0.35	0.3	0.4
Radius of ring gear - $r_2$	48	35	72
Outer diameter of excenter's needle bearing	10	8	12
Diameter of output mechanism - $D_{vk}$	10	8	20
Adopted number of output rollers - $u$	6	5	8
Diameter of shaft needle bearing - $D_{cz}$	40	35	55



**Figure 6. Gear 1**



**Figure 7. Gear 2**



**Figure 8. Gear 3**

The resulting gear drawings all give the required geometry and features necessary for further use in technical drawings and sketches for three-dimensional modeling.

## 5. CONCLUSION

Cycloid gears have very commendable working characteristics in kinematic and dynamic domains. Their wider use is only limited by the fact that the profile of the cycloid gear has a very complex geometry, a shortened equidistant epitrochoid curve. The production of these profiles is very intricate, especially when compared to involute profile gears, since cycloid gears are very sensitive to change in axial distance [10].

Due to their complex geometry, an

automated method of drawing the gear profile has been developed in this paper. This program enables the drawing of any cycloid gear in minutes, where as this process would take a considerably longer time to do using conventional methods. Also this program reduces the possibility

of human error and the necessary time to draw each gear individually. Having a program like the one presented in this paper can also be of great help in analyzing the dynamic forces which are present in cycloid gears.

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