UP TO DATE CONSTRUCTIVE GEOMETRY TO DIMENSIONING OF BEARING PATTERN OF CYLINDRICAL WORM GEAR DRIVING HAVING A PROFILE CIRCLE ARC IN AXIAL SECTION

Dr. Balajti, Zsuzsa

Dr. Univ., PhD, senior lecturer,
Department of Descriptive Geometry, University of Miskolc,
H-3515 Miskolc- Egyetemváros, Hungary,

ABSTRACT

The goal of this paper is to review the developing of the analysis of the bearing pattern to the designing of the arched worm gear drive pairs to achieve good efficiency. The connection between the geometrical parameters and the contact surface is showing in this article based on our research work [2]. This paper provides our error analysis of the connection between the necessary parameters of design conditions for the meshing of an arched worm to establish the located bearing pattern. The first geometrically correct arched worm in axial section with the purpose of suitable efficiency and required considerable lifespan was manufactured in 1972 [3]. Later this method was licensed and the current research is based on this experience [5, 6].

1. INTRODUCTION

It is very important to determine the relationship between the geometrical parameters of the cylindrical worm (a, q, m, p, x, γ, ρ, K) and its tooth surfaces to find the connection and limits of these data for dimensioning [9].

The arched profile is determined by an arc of a circle in axial section. The geometrical data of Archimedean screw surface are the p parameter, the R_k radius of the middle line and the ρ radius of the circle in the axial section of the worm surface. Design engineers determine or calculate the R_k and ρ radius according to different considerations [2, 3, 6, 8]. The p parameter of Archimedes screw surface must be corresponding to the p parameter of the worm.

2. OWERWIEW OUR METHODS TO APPROPRIATE THE RIGHT CONNECTION

The comparison of contact surfaces can be examined with three typify in our research work.

Surface of the worm can be written in the next form, similar [9]

$$\mathbf{r}_{1F} = \mathbf{r}_{1F}(\eta, \vartheta), \qquad \mathbf{r}_{1F} = x_{1F}(\eta, \vartheta)\mathbf{e}_x + y_{1F}(\eta, \vartheta)\mathbf{e}_y + z_{1F}(\eta, \vartheta)\mathbf{e}_z \tag{1}$$

Normal vectors of the worm surface can be written in the next form

DOI: 10.26649/musci.2015.063

$$\mathbf{n}_{1F} = \frac{\partial \mathbf{r}_{1F}}{\partial \eta} \times \frac{\partial \mathbf{r}_{1F}}{\partial \vartheta} \tag{2}$$

Velocity vectors are written in the next relation using transformation matrixes

$$\mathbf{v}_{1F}^{(12)} = \mathbf{M}_{1F,2F} \cdot \frac{d}{d_t} \mathbf{M}_{2F,1F} \cdot \mathbf{r}_{1F} \tag{3}$$

Equation of the meshing gives us contact points from the next implicit form

$$f(\eta, \vartheta, \varphi_1) = \mathbf{n}_{1F} \cdot \mathbf{v}_{1F} = 0 \tag{4}$$

The contact points with a fixed moving parameter give us the contact lines.

2.1. TOTAL LENGTH OF CONTACT LINES

The bearing pattern is characterized by the total value of the length of contact lines.

$$\mathrm{L} = \sum_{j=1}^{m} L_j = \sum_{j=1}^{m} \int_{\eta_l}^{\eta_f} ds \tag{5}$$

where

- L is length of contact curve
- ds= $\sqrt{(x(\eta,\vartheta))^2 + (y(\eta,\vartheta))^2 + (z(\eta,\vartheta))^2}$
- m is the number of examined lines,
- η_l is the value on root cylinder,
- η_f is the value on tip cylinder.

According to the secretion criterion the maximum value of the length of contact lines.

$$L_0 = \max\{L_j(\eta, \vartheta)\} \tag{6}$$

where

- z is the number of examined versions,
- L_j is the length of connecting lines in case of j,
- L_o is the length of the longest connecting lines.

The most appropriate for example in terms of capacity this proceeding.
The (1)-(6) relations can be determined by [4,9].

2.2. RELATION OF CONTACT LINES AND VELOCITY VECTORS

In this respect the optimum is the time of the smallest difference of the average value of the angle of the tangent of the contact line $(\mathbf{t}_t)$ and the relative velocity vector $(\mathbf{v}_{1F})$ from the right angle.
The next forms give us the solution to this examination:

$$H = \frac{1}{L}\sum_z H_z \text{, where } \quad H_z = \sum_i \mathbf{v}_{1F\ i}^{(12)} \cdot \mathbf{t}_i \tag{7}$$

where

- $\mathbf{t} = \dot{x}(u)\cdot \mathrm{e}_x + \dot{y}(u)\cdot \mathrm{e}_y + \dot{z}(u)\cdot \mathrm{e}_z$ is the tangent vector
- i is the pointer of the examined points on a contact
- j is the the pointer of the examined contact line.

Advantageous at valuation is the minimum of these:

$$H_0 = \min\{H_z(\eta, \vartheta)\} \tag{8}$$

where

- z is the number of investigated versions,
- H_z is the value of H in case some investigated versions,
- H_0 is the values of H at different investigated versions.

This characteristic relevant is in terms of coming into being and capacity of the oil film [9].

2.3. LOCALIZATION OF CONNECTION LINES

The third evaluation serves to modification of the maximum and minimum values of the previous two evaluations. This evaluation awards the placing knots from aspect of the good efficiency of the driving. The dimensioning of bearing pattern of cylindrical worm gear driving having a circle arc in axial section profile depends from the place of the knots. The knot on entrance side must be 1/6 width of the gear width from the central point to achieve the good efficiency [4,5,9]. The centre angle of the vectors from the axe to knots in the frontal section determines the placing of the bearing pattern. This method gives us the optimal geometrical parameters to achieve the ideal place of the connecting surfaces.

3. MESHING AXES AND KNOTS IN PROJECTIVE SPACE

The knowledge of meshing axes (I. and II.) appearing in the kinematics of the drive helps discover the connection between the above mentioned parameters. Ample professional literature is concerned with the topic of meshing axes [1,2,6,7]. The meshing axes compared to Archimedean screw surface are shown in Figure 1. The parameters of the axes: R_1 and γ_1 - can be given except for the p parameter where $p= R_1 \cdot \tan \gamma_1$.

Limit position appears in meshing, when the normal of the tooth surface is in parallel position with the meshing axis I. or II. This phenomenon is presented in Figure 1. The plane section fitting on the meshing axes is in the foreground of the Figure. One of the planes is fitting axis I. and the axis of the worm, in which there are normal n^{II}, parallel with axis II., and the other plane is fitting axis II. and parallel with normal n^I. The meshing of the tooth surface occurs in both planes. The meshing axis I., the normal n^{II}. - n^{II}. and the axis of the worm are on one plane, and normals n^{II} intersect knots V_1, V_2, V_3, V_4 from the surface of teeth. The projections of these points appear in the frontal section as knots.

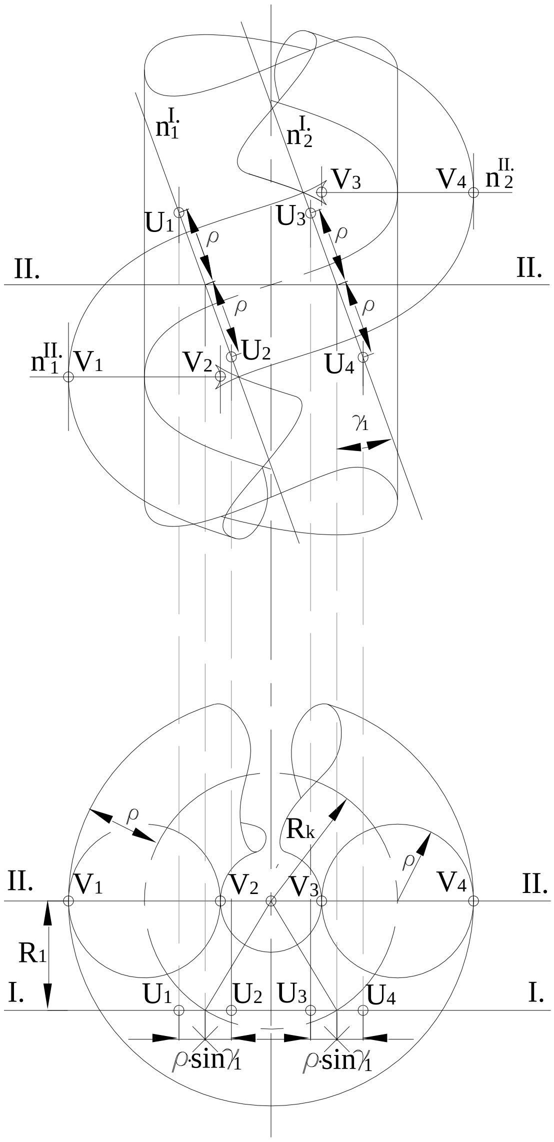


Figure 1. The Archimedean screw surface

Likewise normals n^I. - n^I. are in a plane, in which the meshing axis II. is parallel with the axis of the worm and points U_1, U_2, U_3, U_4 of the surfaces of teeth, which can also be seen as knots in frontal section.

Figure 2. shows that the number of knots is eight, which is the highest possible number. This number can be less in case of certain parameters R_k and ρ, since R_k =ρ gives us the covering some knots, and if $R_1 > R_k$ some knots may disappear. In operation the worm is turning, and the knots are moving on the lines of knots. The investigation of knots and lines of knots is shown in research [6].

To know the momentary position of knots and lines of knots is important, as the lines of knots start from knots and go to cross other knots [7]. A design engineer can get information about the bearing pattern without discovering the characteristic lines in the pre-design process.

The knowledge of meshing axes (I. and II.) appearing in the kinematics of the drive helps discover the connection between the above mentioned parameters. Ample professional literature is concerned with the topic of meshing axes [1, 3, 6, 7, 8]. The meshing axes compared to Archimedean screw surface are shown in Figure 1. The parameters of the axes: R_1 and γ_1 - can be given except for the p parameter where p= $R_1 \tan \gamma_1$.

The usefulness of this method can be following in our pre-design of arc worm drives.

The developed method makes the position of the knots simple and expressive during the design process (Figure 2.). The basic dimensions of the worm with particular reference to the equation:

$$r_{w1} = R_1 = r_{01} + x_1 \cdot m_{ax} = \left(\frac{q}{2} + x_1\right) \cdot m_{ax} \tag{9}$$

$$\tan \gamma_1 = \frac{z_{f1}}{q + 2x_1} = \frac{z_{f1}}{Q} \tag{10}$$

$$Q = \frac{z_{f1}}{\tan \gamma_1} \tag{11}$$

where

- q is diameter ratio can be set according to the diagram (Figure 3);
- m_{ax} is axial module of the worm, 1.5 > x_1 > 1 – specific set of tool;
- $p = \frac{z_{f1} \cdot m_{ax}}{2}$ screw parameter of the worm;
- z_{f1} number of teeth, indents on the worm, $\tan \gamma_1 = \frac{z_{f1}}{q + 2x_1}$;
- γ_1 lead angle on the r_{w1} pitch circles.

The next relation can be seen on Figure 2.

$$R_k = R_1 + \Delta R \tag{12}$$

where
- R_k isthe radius of the middle spiral of Archimedes screw surface,
- $\Delta R \cong m_{ax}$ is parameter, which is affected by the following formulas:

$$\sin \alpha_{ax} = \frac{x_1 \cdot m_{ax} + \Delta R}{\rho} = \sin(21^\circ ... 24^\circ) \tag{13}$$

and

$$\frac{\Delta R}{\rho} = \sin(\Psi_f), \quad \Psi_f = 7^\circ ... 10^\circ \tag{14}$$

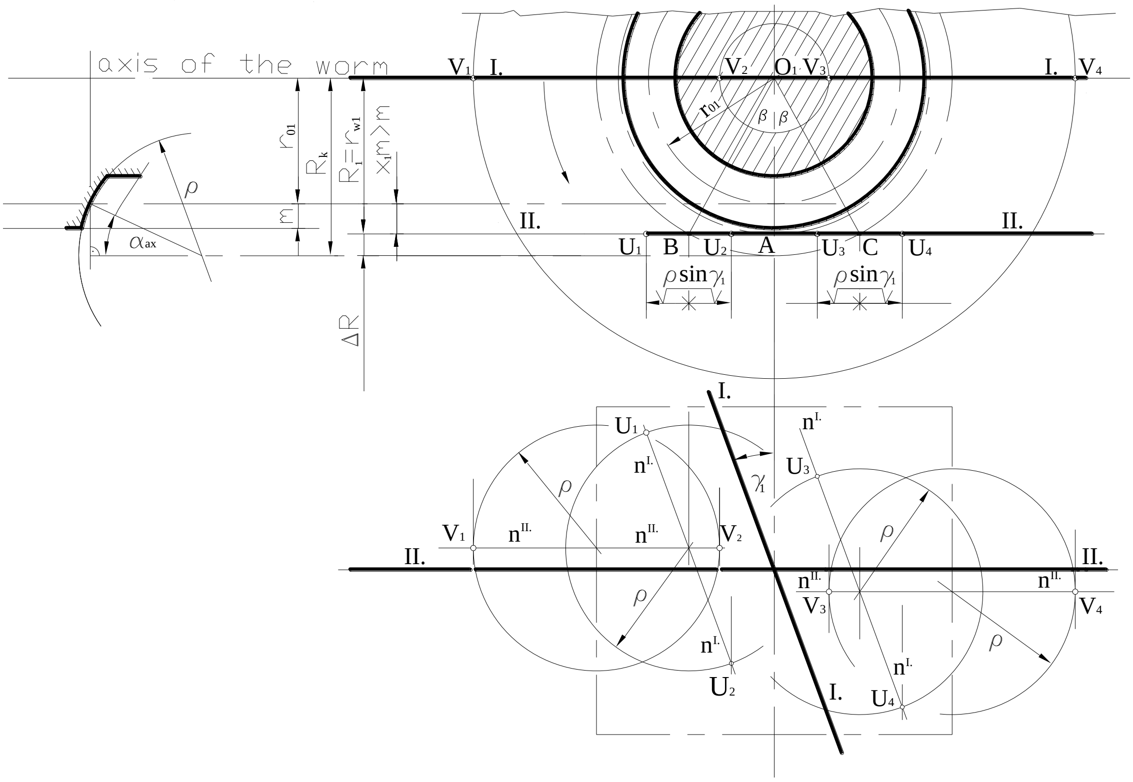


Figure 2. Position of knots

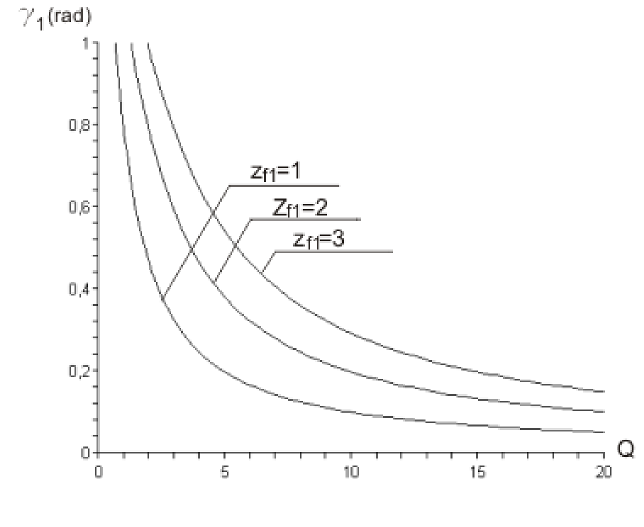


Figure 3. The selection of q diameter ratio using Q = q + 2x equation

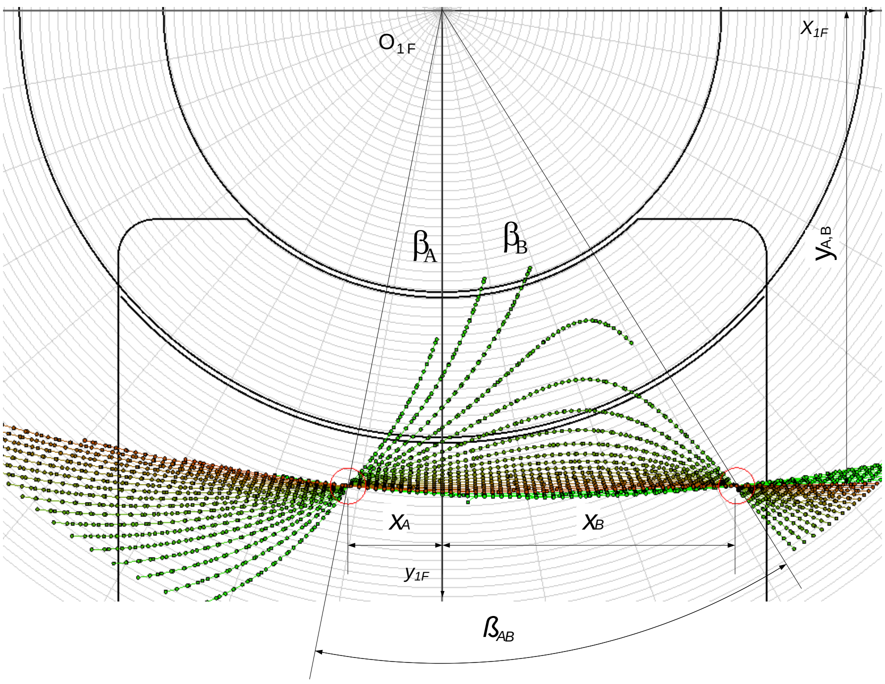
ρ is the radius of the circle section of Archimedean screw surface, normally $r_{01}<\rho<R_1$, considering equation (3) and (4). What is suggested by the design engineer must be considered optimal in the process of interactive pre designing. This can be changed according to specifying viewpoints. The projections of the front view of knots (shown in Figure 2.) contribute to create the good bearing pattern. The position of the connected characteristic line as well as that of the bearing pattern is determined by the fact which tooth surface domain of Archimedean tooth surface in connection. The bearing pattern is determined by the characteristic lines in the area between knots V_2- U_2-V_3-U_4. The lines of the knots are parallel with axis. These knots have same projection in the frontal section, and

it's distance is the pitch in the axial section. The designer is helped to optimise design of the arched worm by the suitable using of correlations and accurate initiations of the shown method in the pre-design.

5. EGZAMINATION OF THE BEARING PATTERN

Figure 4. demonstrates that the optimal geometrical parameters of the ideal connecting pattern are determinable.

On the ground worm surface, which is developed by the developed method, such helicoid surface is generated, at which the ($K_B \equiv U_2$) knot of momentary contact line is laying on the connected line, at about a distance of 1/6 B from the main contact point C, where B is the face width of worm gear. In this case, the o-called lubricating wedge, which is necessary to lubricating fluid between the mating surface, and the desired limited field for teeth contact are forming. The profile correction under these conditions is x_2= 0.8-1.5 [5].



β_{AB}= 38,999957°
X_A= -19,67 mm
X_B= 38,24 mm
i_{21}=0,0857142
K = 69,5mm
a = 285mm
x_2 = 1
p = 18,75 mm

z_{ax} = 0mm
ρ = 45mm
φ_1 = -30 – 200°
η = 38,75 – 58,75mm
ϑ = -60 – 60°
nv<=0,001

Figure 4. The β_A *és* β_B angles f the knots, ρ_{ax} radius of the circle profile and K distance between the worm axis and the centre of the circle profile with the input data in the given case [8]

A programme has been developed in C language using concrete dates to arched worm drives. The knots in the entry must be 1/6 to the face width of worm gear and the angles of the worm and the knots determine the placing and dimensioning of the load bearing pattern [9].

The optimal parameters can be obtained at a given type of drive with this procedure, which make possible the ideal placing of the contact lines.

6. SUMMARY:

For the determination of the contact curves belonging to the flanks of worm and worm gear for a given angular displacement φ_1, a computer program based on the kinematics method has been developed. The program for a given worm geometry calculates the theoretical contact curves and fits on them an envelope surface.

The relations between bearing pattern localisation and the geometrical parameters can be examined, as well as the bearing surface. These were explored on the basis of the prescribed connection conditions.

The limit curves of the bearing pattern were given by a line of points, thus rendering the entire bearing pattern suitable for being handled analytically.

The design and geometrical parameters of the worm drive were established for achieving the right connection.

REFERENCES:

[1] ALTMANN, F. G.: **Determination of tooth surfaces in worm driving** (in German), VDI Forschung aus dem Gebiet des Ingenieurwesens, Berlin, No.5, 209–225, 1937.

[2] BALAJTI, ZSUZSA, ILLÉS, DUDÁS: **Error Analysis of Geometrical Dimensioningin Production of Cylindrical Worm Having Concave Arched Profile**, microCAD 2010. International Scientific Conference, Section N: Production Engineering and Manufacturing Systems, Miskolc, 18-20. March 2010., pp. 7-14., ISBN 978-963-661-925-1 Ö, 978-963-661-918-3.

[3] DUDÁS, I.: **Reduced manufacturing and qualification of arced profiled worm driving pair**, Doctoral dissertation. First draft, Miskolc, 1972.

[4] DUDÁS, I.: The **Theory and Practice of Worm Gear Drives**, Penton Press, London, ISBN 1 8571 8027 5, 2000.

[5] DUDÁS, I.: **Theory and manufacturing of worm gear driving** (in Hungarian), Technical Publisher, Budapest, ISBN 978-963-16-6047-0, 2007.

[6] LÉVAI, I.: **Contact cylindrical Worms- internal face and their Meshing** (in Hungarian), GÉP LIX. VOL. No. 10–11. , 69–85, Miskolc, 2008.

[7] KRIVENKO, I. SZ.: **Up to date type worm driving pairs in ship** (in Russian), Izd. Szudoszrovenie, Leningrad, 1967.

[8] LITVIN, F. L., FUENTES, A.: **Gear Geometry and Applied Theory**, Cambridge University Press, ISBN 0-521-81517-7, 2001.

[9]ÓVÁRINÉ DR. BALAJTI, ZSUZSANNA: **Development of production geometry of kinematics drive pairs** (in Hungarian), PhD. dissertation, First draft, Miskolc, 2007.