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GEOMETRICAL STUDY OF GUIDE-CHAIN CONTACT, FOR GENERAL CHAIN TRANSMISSION

Radu PAPUC[1*], Radu VELICU[2], Catalin C. GAVRILA[3]
[1] Transilvania University of Brasov, radu.papuc@unitbv.ro
[2] Transilvania University of Brasov, rvelicu@unitbv.ro
[3]Transilvania University of Brasov, cgavrila@unitbv.ro

***Abstract*—** The friction complexity between guide and chain is generated by a large number of factors acting simultaneously, of which wear has a significant share**.** During transmission functioning, guide and chain are subjected to normal forces in their contact surfaces**.** An analysis of the guide position can be described by a mathematical model. This paper presents a synthesis on the geometry of the contact between a guide and chain drive transmission. In the first part of the paper are established mathematical relationships underlying the extent of chain drives with a chain guide. Then, based on the mathematical model are traced a number of variation diagrams of geometric and kinematic parameters.

***Keywords*—** chain, guide, transmission.

I. INTRODUCTION

CHAINS are flexible kinematic elements consisting of articulated links. The chain drive functioning is based on the engagement of the chain with chain guides. Due to chain engagement on the chain guide, an average constant transmission ratio is achieved. Chain transmissions are preferred when the system demands high torques with constant transmission ratio [1]-[3].

The kinematic and dynamic functioning of the chain drives highlights the possibilities of vibrations. There can be mentioned transversal, longitudinal and twist vibrations. Chain functioning in vibration conditions reduces the durability performances due to specific dynamics. From this reason the presence of chain guide on the driven branch of the chain and of a chain guide tensioner on the driving branch is needed. The chain guide profile can be circular (studied in the paper) or complex, composed by multiple circular segments or spline. Chain tensioning is also useful in compensating the initial pitch errors and wear effects leading to extension of the length of the chain [4]-[7].

II. TRANSMISSION GEOMETRY

The main geometrical parameters of the chain transmission are:

- chain pitch, p
- center distance, A
- chain sprockets pitch diameters, $D_{d1,2}$

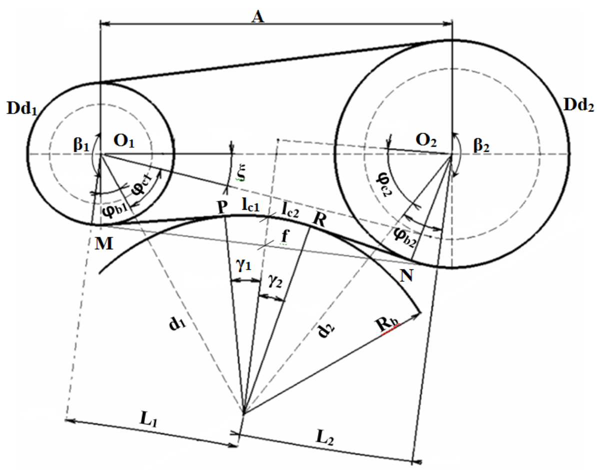

Fig.1. General scheme of chain transmission with guide.

Applying the chain tensioning by guide, the transmission geometry is changing as it is shown in Fig. 1. Also, in Fig. 1., are represented the geometry and functional parameters at the contact between guide and chain as follows:

- $L_{1,2}$- the distance from the driving respectively driven gear center to the chain guide profile center;
- $O_{1,2}$- the driving and driven sprocket center;
- $\varphi_{b1,2}$- the angle between the axis from driving respectively driven sprocket center and chain guide profile center;
- $\varphi_{c1,2}$- the angle between the chain guide profile center and center axis;
- ξ- the angle between the chain sides;

- $\beta_{1,2}$- the chain rolling angle on the driving, respectively the driven sprocket;
- $\gamma_{1,2}$- the angle corresponding to the chain pitch, on the chain guide profile radius R_b;
- $l_{c1,2}$- the circle string corresponding to the chain pitch;
- f- the interference between the chain normal side and the guide profile;

The guide profile radius R_b was considered as a result of the relation

$$\mathbf{R_b = R + h_e} \tag{1}$$

where:
R- represent the guide profile real radius,
h_e- is the distance between the chain bolt center and the link edge which is in contact with the guide profile.

Taking account of relation (1) result that the guide profile radius R_b depends by the real chain guide profile radius and the chain link shape. For a given chain guide profile real radius R, the radius R_b depend by the chain link shape.

In Fig. 2., a, is presented a chain link detail with planar edge on the guide profile. Similar, in Fig. 2., b is presented a chain link detail with curve edge on the guide profile.

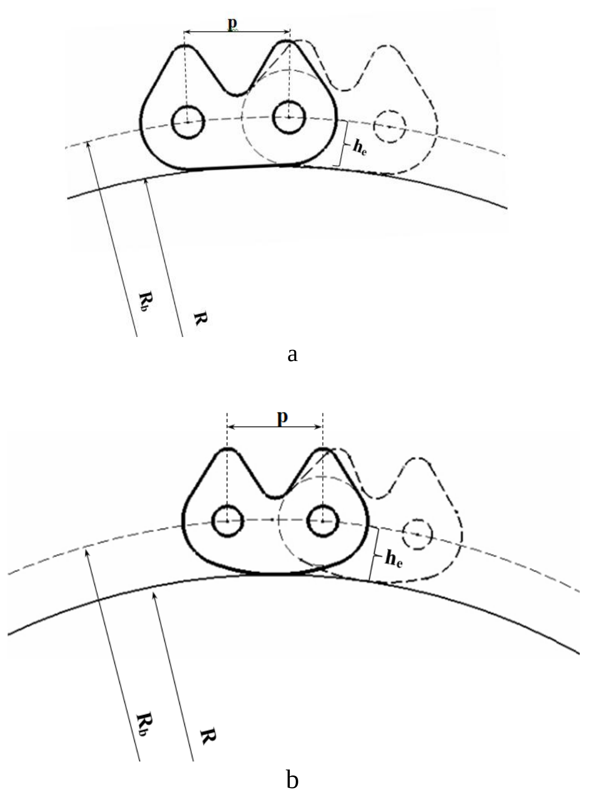

Fig.2. Chain link contact on guide profile.

For the case presented in Fig. 2., a, in plane, the contact can be considered as line on the circle. Also, for the case presented in Fig. 2., b, in plane, the contact can be considered as circle on the circle.

For a chain transmission, the relation between the chain pitch and chain gear diameter split is given by

$$\mathbf{\frac{Dd_{1,2}}{p} = \frac{1}{\sin\frac{\pi}{z_{1,2}}}}, \tag{2}$$

where $D_{d1,2}$ are chain sprockets pitch diameters and $z_{1,2}$ represent the teeth number of chain sprockets.

Taking account by Fig. 1, for the distance between the gear center and guide profile center d_1, respectively d_2 are:

$$\mathbf{d_{1,2} = \sqrt{L_{1,2}^2 + \left(R_b + \frac{Dd_{1,2}}{2} - f\right)^2}}, \tag{3}$$

where, the relation between the distances from the driving respectively driven gear center to the chain guide profile center, L_1 respectively L_2, are given by

$$\mathbf{L_1 + L_2 = A\cos\xi}. \tag{4}$$

Chain transmission ratio is given by relation [8]

$$\mathbf{i = \frac{Dd_2}{Dd_1}}. \tag{5}$$

The angle between the chain sides is given by [8]

$$\mathbf{\xi = \arcsin\frac{Dd_2 - Dd_1}{2 \cdot A}}. \tag{6}$$

For chain transmission ratio values closed to 1, relation (6) led to

$$\mathbf{\xi \approx \frac{Dd_2 - Dd_1}{2 \cdot A}}. \tag{7}$$

The angle between the axis from driving respectively driven gear center and chain guide profile center, φ_{c1} respectively φ_{c2} are given by relation

$$\mathbf{\varphi_{c1,2} = \arccos\frac{L_{1,2}}{d}}. \tag{8}$$

The angle between the chain guide profile center and center axis, φ_{b1} respectively φ_{b2}, are given by relation

$$\mathbf{\varphi_{b1,2} = \arccos\frac{R_b + \frac{Dd_{1,2}}{2}}{d_{1,2}}}. \tag{9}$$

The angle corresponding to the chain pitch, on the chain guide profile radius R_b result

$$\mathbf{\gamma_{1,2} = 90^o - \varphi_{c1,2} - \varphi_{b1,2}}. \tag{10}$$

The circle string corresponding to the chain pitch l_{c1} respectively l_{c2} are given by relation

$$\mathbf{l_{c1,2} = \gamma_{1,2}\frac{\pi}{180^0}R_b}. \tag{11}$$

The number of links n_z in contact with the chain guide profile is given by relation

$$\mathbf{n_z = \frac{l_{c1}}{p} + \frac{l_{c2}}{p}}\ . \quad (12)$$

III. NUMERICAL RESULTS

The main problem of the chain-guide contact is to calculate the number of links n_z in contact with the chain guide profile. The number of links is useful for future virtual modeling and simulation of the chain transmission. The main assumption is that the chain-guide contact is based on an inscripted regulate polygon, into the guide circle profile R_b, with the side length equal with the chain step (see Fig. 3).

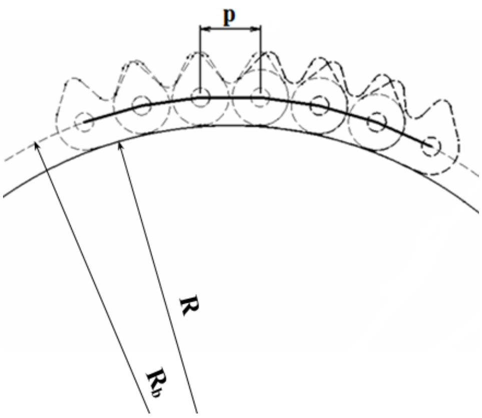

Fig.3. Chain contact to the guide profile.

Taking account by previous relations and the chain transmission geometric particularities will be determined the number of chain kinks in contact with the guide profile, depending by several input as:

- the chain pitch *p*;
- the chain guide profile $R_{b;}$
- the interference between the chain normal side and the guide profile *f*;
- the center distance *A*;
- the sprockets pitch diameters, $D_{d1,2}$;
- the chain ratio *i*.

For general use of the results, all the analysis were based on variables related to the pitch of the chain *A/p*, R_b/p, *f/p* or ratios like L_1/L_2. The main purpose of the calculus is to determine the number of links n_z of the chain, in contact with the guide. This parameter is very important in defining the contact pressure and friction losses between chain and guide.

The results are presented in Fig. 4-7.

Figure 4 presents the variation of link number depending by the ratio *f/p*, for a given values of the ratio *A/p* between 20…80. From this diagram, can be observed that for small values of *f/p* ratio, the number of links n_z is low (zero for *f* equal zero), for all values of *A/p* ratio. Also, for *A/p*=20 (case of reduced center distance), the guide profile intersect the gears profile for *f* values increased.

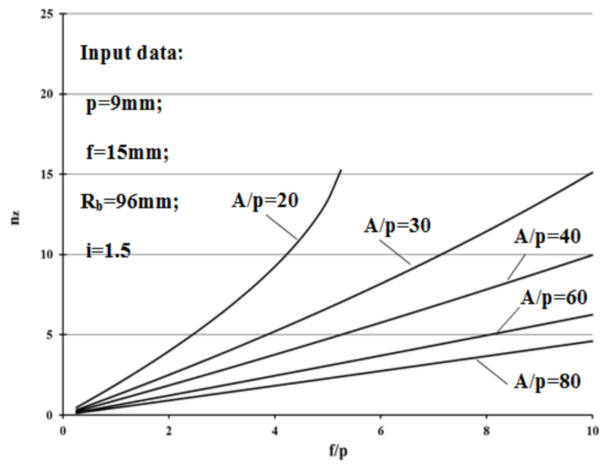

Fig.4. Variation of link number n_z depending by the ratio *f/p*, for given values of the ratio *A/p*.

Figure 5 presents the variation of link number depending by the ratio *f/p*, for a given values of the ratio R_b/p between 10…50. From this diagram, it can be observed that for small values of *f/p* ratio, the number of links n_z is low, for all values of R_b/p ratio. In this case, for R_b/p up to 30 (case of increased guide profile radius), the guide profile intersect the gears profile for *f* values increased.

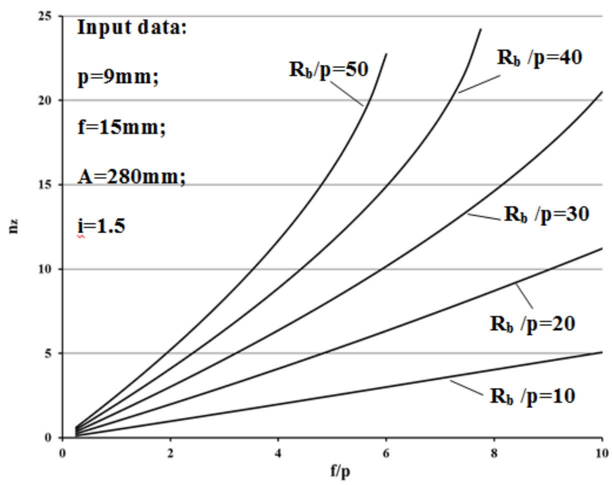

Fig.5. Variation of link number n_z depending by the ratio *f/p*, for given values of the ratio R_b/p.

In Fig. 6., is presented the variation of link number depending by the ratio *f/p*, for a given values of the ratio L_1/L_2 between 0.2…1. The diagram, shows that for small values of *f/p* ratio, the number of links n_z is low (zero for *f*=0, similar with previous cases), for all values of L_1/L_2 ratio. In this case, for L_1/L_2 closed to 1, the number of links n_z is increased in comparison with other values for L_1/L_2.

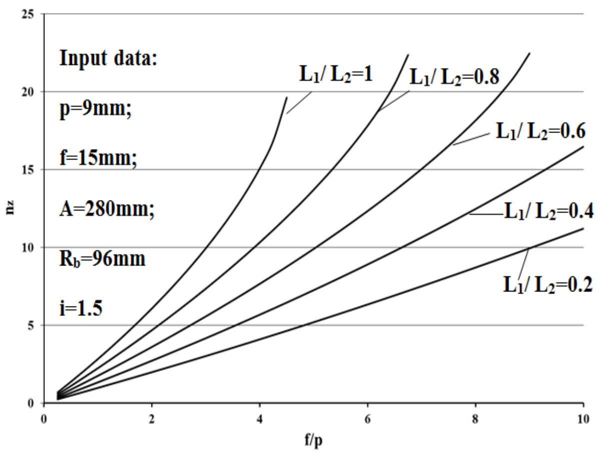

Fig.6. Variation of link number n_z depending by the ratio *f/p*, for given values of the ratio L_1/L_2.

Finally, Fig. 7., present the variation of number of links n_z depending by the ratio *f/p*, for different chain transmission ratio, *i*=1.5…3, and the same given values of center distance *A*, chain pitch *p*, guide profile radius R_b. The diagram shows that for this chain transmission ratio, the values are much closed and the results led to the same diagram.

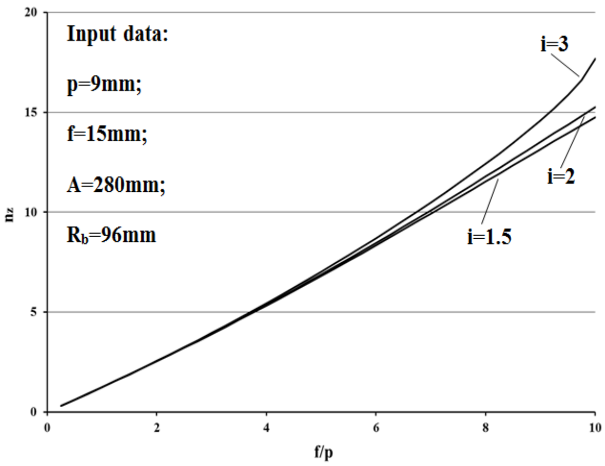

Fig.7. Variation of link number n_z depending by the ratio *f/p*, for given values of the chain ratio *i*.

IV. Conclusion

The number of links n_z in contact with the guide profile is important in the chain transmission with guide geometry optimization. Also, the link number n_z is necessary to be known in virtual modeling of this transmission.

The number of links n_z depends by various chain transmissions geometrical parameters, as it was shown in the paper.

The diagrams from Fig. 4…7., are relevant to observe the interdependence between the chain number of links in contact with the guide profile, and ratio *f/p* for different geometrical parameters.

From Fig. 4 …6., can be observed that for small values of *f/p* ratio, the number of links n_z is low. For reduced center distance *A*, respectively increased guide profile radius R_b combined by an increased value for the interference between the chain normal side and the guide profile, the guide profile intersect the gears profile.

From Fig. 7., results that, for different chain transmission ratio, the variation curves for number of links n_z depending by the ratio *f/p*, are much closed for the same values of center distance, chain pitch, and guide profile radius.

As it was shown in the paper, the calculus of link number n_z in contact with guide profile is important in chain transmission optimization and virtual modeling of this transmission.

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