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THE INFLUENCE OF THE GEOMETRICAL PARAMETERS IN THE WORM-GEARS WITH ROLLING ELEMENTS EFFICIENCY

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Abstract: *Taking in account the lower values of classical worm-gears efficiency, the studies of the worm-gears with rolling elements is important. The paper presents theoretical and experimental results regard the values of efficiency in various function conditions and the influence of geometrical parameters variation.*
Key words: *worm-gears, efficiency, rolling.*

1. INTRODUCTION

The analysis on the performance of gears take in account a group of factors, each of these shows through a specific way the energy loses. These factors are: load, vibration, portant capacity, noise, heat of gear etc. All these show loses on different ways which are summed in the efficiency value, like a final conclusion on the behavior of gear.

2. GENERAL ASPECTS ABOUT WORM GEARS EFFICIENCY

The worm-gear's efficiency is defined by formula:

$$\eta_a = \frac{tg\gamma_0}{tg(\gamma_0 + \varphi')} \quad (1)$$

Where: γ_0 is reference helix angle (lead angle), φ' is angle of friction.

From (1) we can observe the dependence of the value of efficiency from reference helix angle (lead angle) and surface state helix angle.

Due technological reasons we know that the maximum reference helix angle is γ_0=max.(25°-30°). Above these values only a minor increase is possible to obtain. The angle of friction through the coefficient of friction has important implications in the efficiency value. If the angle of friction value decrease, the efficiency value increase.

The gear efficiency depends also, in the classic worm gears case, by the diametrical quotient (q) and also by the number of threads of worm (z_1).

When: the diametrical quotient (q) increase, the worm rigidity increase, the reference helix angle (lead angle) decrease, the peripheral speed increase and the efficiency decrease.

When: number of threads of worm (z_1) increase, the efficiency of the worm gears increase.

If the value of lead angleγ_0 increase, the efficiency value increase at the maxim value, obtained for $\gamma_0 = 45° - \varphi/2$. Above this value of the lead angle γ_0 the value of the worm gears efficiency decrease.

At the low value of the classical worm gears module (m<1), the factors which have influence on the transmitted torque are shown in the Figure 1.

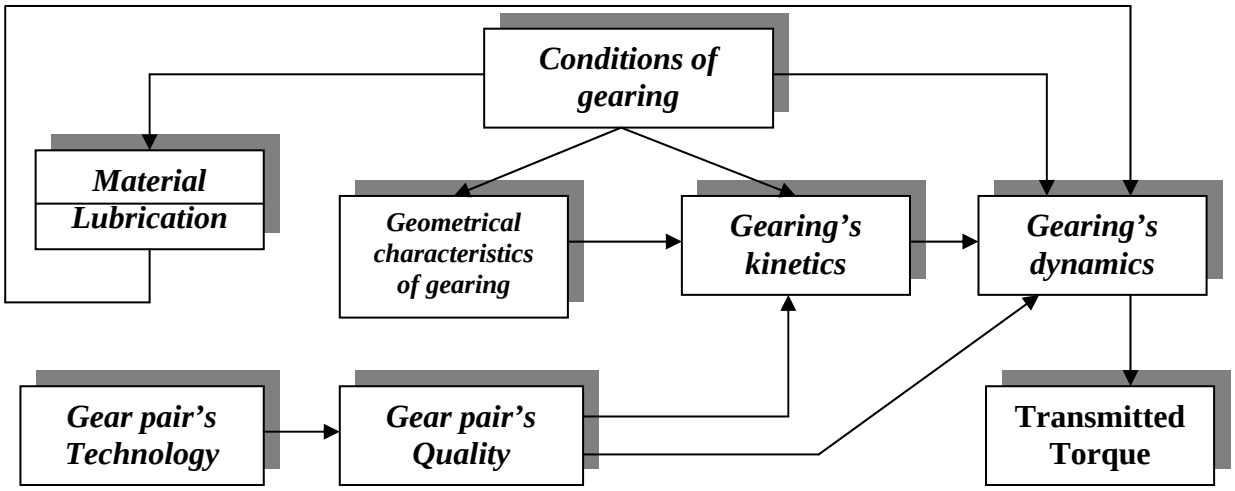


Fig. 1

The kinetics of the gearing depends by conditions of gearing, geometrical characteristics and the quality of the worm-gear, all of these, together with dynamical aspects, decides the value and the variation of the transmitted torque.

In [4] was studied and confirmed following:

a. The influence of the geometrical elements and of the friction coefficient on the value of the slide worm gears efficiency.

b. The efficiency is better for $\gamma_1 < 30°$.

c. The dependence of the efficiency with number of threads of worm.

d. Materials of gears, loading and revolutions per minute have influence on the efficiency.

e. Number of teeth of worm gear has a very little influence on efficiency value.

f. The increase of the error centre distance determined a drastically decrease of the efficiency.

3. STUDY ABOUT THE DOUBLE ENVELOPING WORM GEAR PAIR'S EFFICIENCY VALUE AND SOME GEOMETRICAL AND FUNCTION PARAMETERS VARIATION

The study about the double enveloping worm gear pair's efficiency value and some geometrical and function parameters variation started from relations (3) and (4) from [1], [5].

The formula for calculus of efficiency:

$$\eta = \frac{P_2}{P_1} = \frac{\left(\cos\gamma_0 - \frac{\mu}{\cos\alpha_n}\cdot\sin\gamma_0\right)\cdot d_2}{\left(\sin\gamma_0 + \frac{\mu}{\cos\alpha_n}\cdot\cos\gamma_0\right)\cdot d_1 i_{12}}$$

The formula for calculus of rolling friction coefficient:

$$\mu M1(T2) := \mu a2\cdot\phi(\lambda 21)\cdot\left[0.73\cdot\lambda 21(T2)^{-0.75} + \frac{E'\cdot\sigma\theta}{\sigma 0(T2)}\cdot 0.026\cdot(3-\lambda 21(T2))^{0.5}\right]$$

where was included the real conditions of function.

Base on these formulas, results the theoretical curves of the revolutions, loading values for the maximum/minimum diameter of double enveloping worm gear pairs, taking in account the lead angle variation.

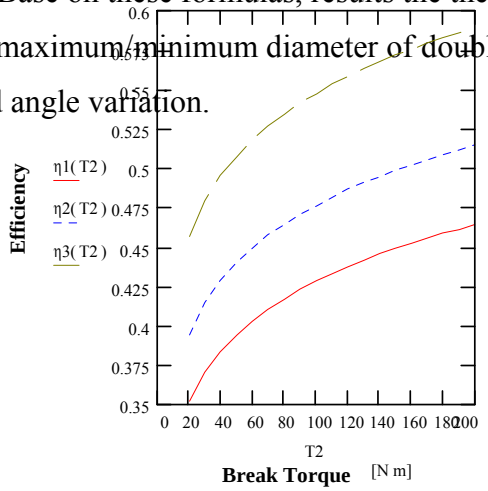


Fig. 2

The efficiency value variation with load increase and revolution value variation

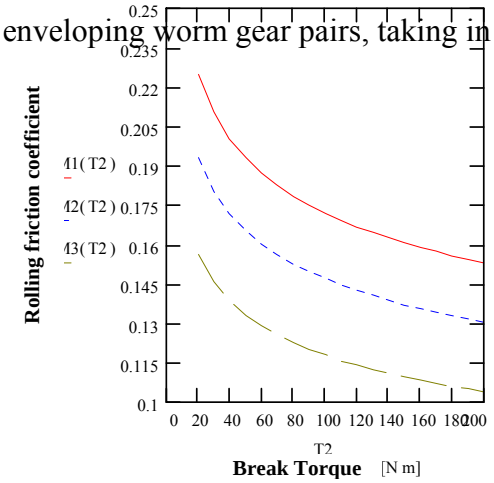


Fig. 3

The rolling friction coefficient value variation with increase of the load and revolution value

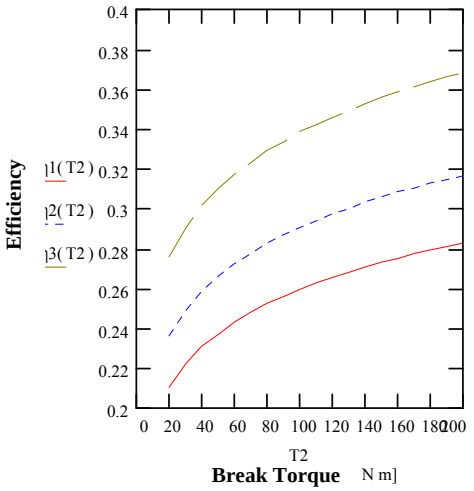


Fig. 4

Rolling worm gear pair efficiency for maximum diameter of worm

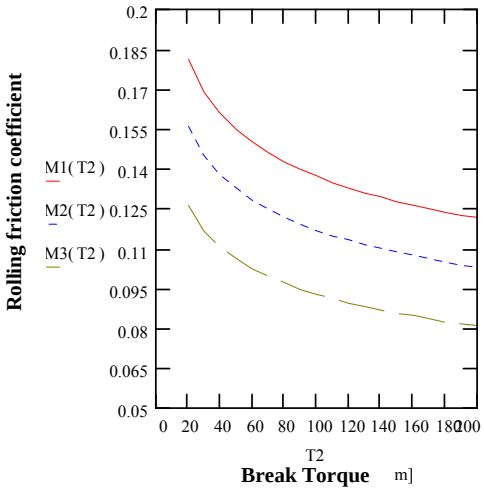


Fig. 5

Rolling friction coefficients efficiency for maximum diameter of worm

We studied the efficiency variation in different areas of rolling contact, with the influences from the lead angle, different values of worm diameter and different value of rolling speeds of rolling elements. Figure 2 presents the efficiency values for minim value of diameter. Figure 4 presents the efficiency values for maximum value of diameter. Figure 3 and 5 presents the rolling friction coefficient values for minim and maximum value of worm diameter. The differences which are between the two sections of the worm for efficiency and rolling friction coefficient values are presented in figures 6 and 7.

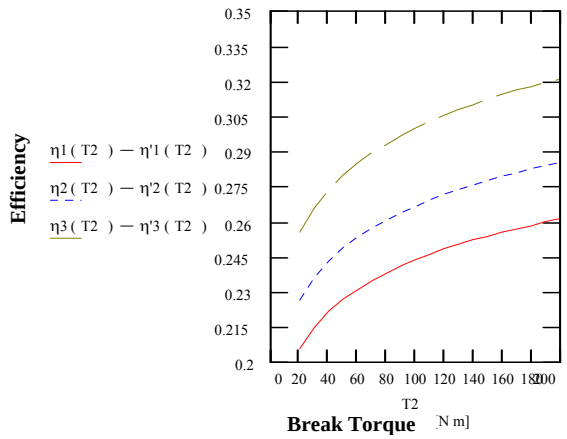


Fig. 6

Differences of the efficiency values at rolling worm gear pair for maximum and minimum worm diameter

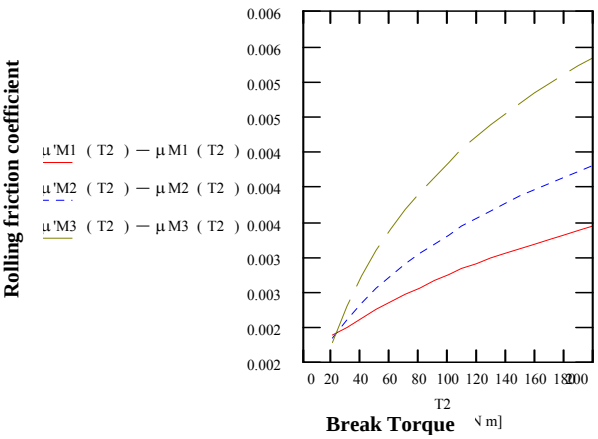
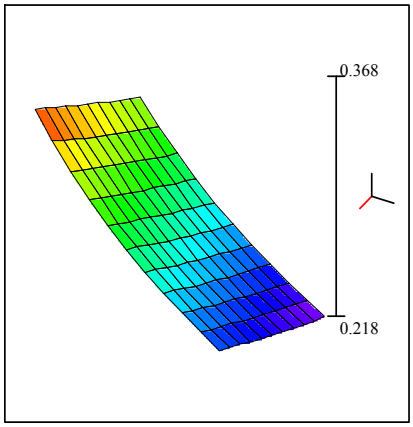
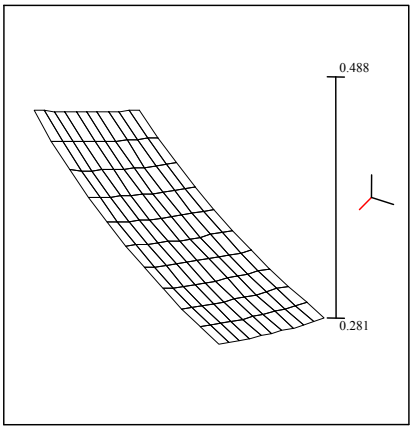


Fig. 7

Differences of the rolling friction coefficient values at rolling worm gear pair for max. and min. worm diameter



Rr1

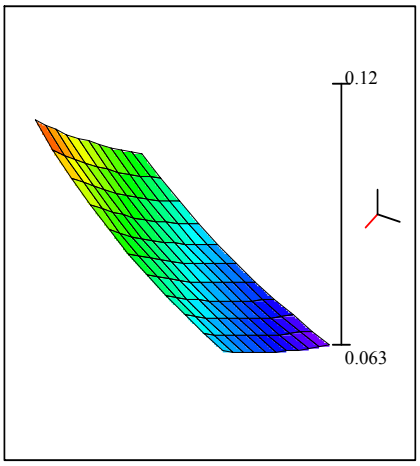


Rr3

a ***b***

Fig. 8

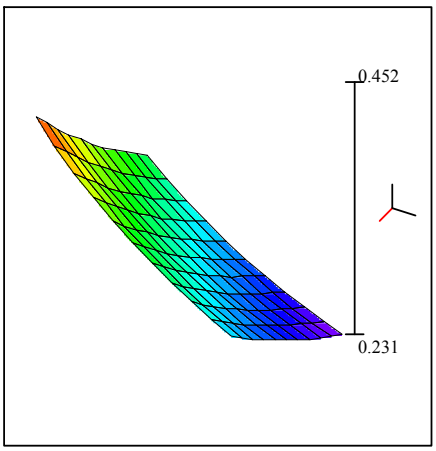
Rolling worm gear pair efficiency variation with worm diameter and lead angle values and maximum (a) and minimum (b) revolution per minute



Rr3– Rr1

Fig. 9

Differences of rolling worm gear pair efficiency for diameter and lead angle of worm variation for max. and min. revolution speed at rolling worm gears.



R

Fig. 10

Rolling worm gear pair efficiency with worm diameter and rolling friction coefficient values

5. CONCLUSIONS

Comparing the variation efficiency theoretical curves with the values of the lead angle and the double enveloping worm diameter we can observe the decrease tendency of these with the increase of diameter value and decrease of lead angle.

Also, the increasing of efficiency value is possible with the increase of revolution per minute and the increase of the loading. We have some reserve of the generalization of observation about the behavior of efficiency with loading value due the contradictions about this in scientific papers, someone confirming the increase, others infirming it, and confirming the decrease. Our position is to analyzing this aspect for each case, with specific materials couples, lubrication and functioning parameters.

The values periphery speed variation with double enveloping worm diameter value changing and the changed of the lead angle have like effect the changed of friction phenomena parameters, with important and complex effects on the values of efficiency and rolling friction coefficient.

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