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METHODS FOR CALCULATING POWER LOSSES IN WORM GEAR DRIVES [1]

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Abstract: *The paper reviews existing methods of calculating power losses in worm gear drives. It analyses the differences between the methods taken into consideration. Special attention is given to calculation procedure for estimation friction coefficients of worm gear meshing. The purpose of this procedure was to determine the coefficients based upon boundary and hydrodynamic lubrication. A short summary of the existing information about values of power losses for worm gear drives in standards and catalogues is made. Based on the theoretical research made, conclusions are derived about further work and investigations in the area of research of power losses and possible efficiency increasing of worm gearboxes.*

Keywords: *Power losses, Worm gear drives, Efficiency, Calculation methods.*

INTRODUCTION

The function of the worm gear drives is transmitting power at high velocity ratios between non-intersecting shafts at right angles (usually). An advantage of these drives is their high velocity ratio, which can reach the value of 300 and even more in 1 stage within relative small overall dimensions.

A great disadvantage of worm gear drives is their low efficiency. The main compenents of worm gearing are a worm, which is the driving member and a worm wheel or gear (the driven member). The worm wheel or gear is similar to a helical gear with a face curved to conform to the shape of the worm. The worm material is steel while the material of the worm wheel is quite often: bronze or cast iron.

Because of the high gear ratios realized, the sliding velocity between the components in the worm gear meshing is also significant. Therefore, the friction in the meshing area and the meshing power losses for worm gear drives are higher in comparison with spur gear trains. There is a calculation method for determination of the efficiency of worm drives described in DIN 3996, which is unfortunately not valid for all gear ratios.

The power flow in worm gear drives begins from the input shaft, and then it goes to the worm gear meshing and to the output shaft. The simplicity of this power flow is due to the compact worm gear unit. It includes only two shafts, a worm and a worm wheel in meshing, bearing, seals and oil sump.

Therefore, the power losses in worm drives are four main parameters: meshing losses, oil churning losses, bearing and shaft seal losses.

The objective of the investigation is to analyse the differences between the calculation methods for power losses in worm gear drives and to derive conclusion and recommendations about further

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work and investigations in the area of research of power losses and possible efficiency increasing of worm gearboxes.

METHODS FOR CALCULATING POWER LOSSES IN WORM GEAR DRIVES

The method described in (Michaelis et al., 2011) presents a study of bearing and gear tooth friction losses. According to this research, there are two kinds of losses: load-independent losses and load-dependent losses. The authors made experiments with different types of bearings at various conditions. A great number of publications emphasize that friction losses in meshing are the most significant source of losses in gear drives according to: (Anderson, N. E. & Loewenthal, S. H., 1981) and (Velex, P. & Cahouet, V., 2000).

The research made is based also upon previous achievements of scientists at the department of Machine science, machine elements and engineering graphics in Ruse. A solution for a transmission with increased efficiency for a heavy vehicle has been done. The design components, materials applied and some special features of this product are presented in details in (Orzech, K., Khoshaba, S. & Dobreva, A., 2009) and (Dobreva, A. et al., 2010).

Another important investigation is the approach for improving the tribology indicators for gear trains with internal meshing and small difference between the teeth number described in (Dobreva, A. & Stoyanov, S, 2012).

The evaluation of the friction losses in the meshing depends significantly upon the determination of the losses of the specific sliding in the internal gear trains. Some publications taken into consideration deal with an evaluation of possible options for increasing the estimated efficiency of gear trains, (Dobreva, A., 2013), (Dobreva, A. & Dobrev, V., 2007) and (Dobreva, A. & Dobrev, V., 2018).

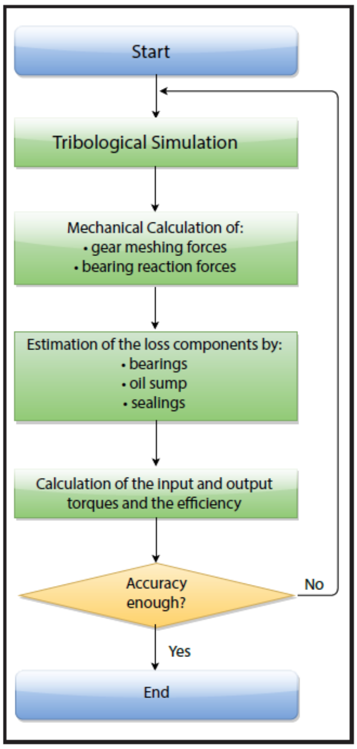

Fig. 1. Flow chart of calculating of worm gearbox efficiency, (Magyar, B. & Sauer, B., 2012)

The authors in (Magyar, B. & Sauer, B., 2012) describe a very univocal and summarizing calculation procedure. During the first stage of this procedure the friction coefficients of the worm gear meshing are calculate based upon boundary lubrication and hydrodynamic lubrication.

The second stage includes the calculation of the average tooth friction coefficient based upon the local tooth coefficients. The exact values of the friction coefficients are important for the determination of the gear meshing forces and the bearing reaction forces through the static equilibrium equations. The next stage of the method includes the calculation of the bearing losses, oil churning power losses and shaft seals power losses. The flow chart on Fig.1 shows the calculation procedure described.

The method presented possesses a significant advantage in comparison to conventional empirical equations. These traditional methods make a difference mainly between the load – dependant and load - independant losses. The method of the authors (Magyar, B. & Sauer, B., 2012) separates also between the power loss sources. This make the method more appropriate for optimizing the gear geometry and decreasing of power gearbox losses.

POWER LOSSES INFORMATION FOR WORM DRIVES IN STANDARDS AND CATALOGUES

Standards concerning measurement methods and energy efficiency of electrical motors give information about motor efficiency. These data are visible by means of efficiency maps, (Dereyne, S. et al., 2011) and (Stockman, K. et al., 2010). In contrast to this, the available information on gearboxes is extremely limited. Some data on the mechanical and/or hydraulic losses of a single gear wheel pair is available in, for example: (Höhn, B.R., Michaelis K. & Wimmer, A., 2007) and (Yenti, C., Phongsupasamit, S., & Ratanasumawong, C., 2013). It is very important that a complete gearbox consists of several gear pairs and other parts. As already mentioned, the total losses are a combination of bearing losses, seal losses, churning losses, etc. as illustrated in Fig 2.

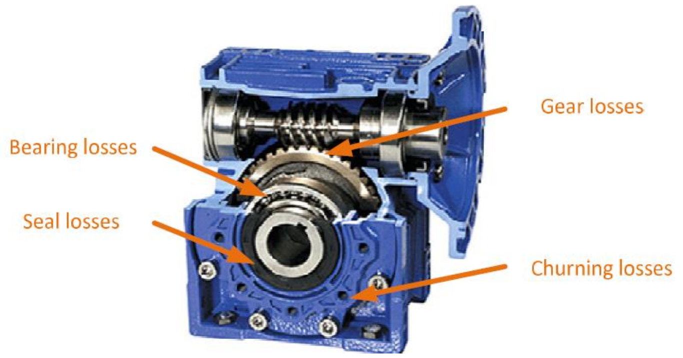

Fig. 2. Typical worm gearbox losses,
(Dereyne et al., 2016)

A small number of publications treats the total gearbox efficiency. Moreover, the gearbox catalogues provide also insufficient information. The manufacturers generally give the efficiency value as a function of the number of gear stages in these catalogues. Therefore, one efficiency value corresponds to a whole range of gearboxes. There is no enough information on the influence of the ratio or the power transmitted on the efficiency of the gearbox. Only worm gearboxes form an exception as their nominal efficiency depends to a certain extent to the values of the power transmitted and the ratio according to the manufacturers' catalogues. However, even for these gearboxes, the influence of the torque and speed on the gearbox efficiency is not sufficient.

CONCLUSIONS

The paper reviews existing methods of calculating power losses in worm gear drives. The authors analyse the advantages and some negative features of famous methods for calculating power losses in worm gear trains. This theoretical research indicates the most appropriate approach for future analytical and simulation investigations. Based on the theoretical research made, the authors derive the following conclusions:

1. It is necessary to implement further work and investigations in the area of research and calculation of power losses.

2. A very important objective of a future PhD work will be to find possible solutions for efficiency increasing of worm gearboxes.

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