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METHODS FOR EXPERIMENTAL RESEARCH OF WORM GEAR DRIVES [1]

Assoc. Prof. Vasko Dobrev, PhD
Department of Machine Science, Machine Elements and Engineering graphics,
University of Ruse, Bulgaria
Tel.: 00 359 82 888 492
E-mail: vdobrev@uni-ruse.bg

Yuliyan Dimitrov, PhD
Department of Machine Science, Machine Elements and Engineering graphics,
University of Ruse, Bulgaria
Tel.: 00 359 82 888 235
E-mail: ydimitrov@uni-ruse.bg

Abstract: *The paper reviews existing methods of experimental research of worm gear drives. It analyses the differences between the methods taken into consideration. Special attention is given to possible procedures for elaboration of new test machines for experimental investigation of power losses in worm gear meshing. The purpose of this procedure is to lead to experimental determination of the friction. Based on the theoretical research made, the authors derive conclusions about further work and investigations in the area of experimental research of power losses and possible efficiency increasing of worm gearboxes.*

Keywords: *Power losses, Worm gear drives, Efficiency, Experimental research.*

INTRODUCTION

A gear train would include a drive gear (input pinion), one or several intermediate gear sets and a final gear, connected to the output shaft. There is a variety of different gear tooth forms and layout designs. Each transmission design carries its own advantages and negative features and imposes different challenges to the tribology and design engineers.

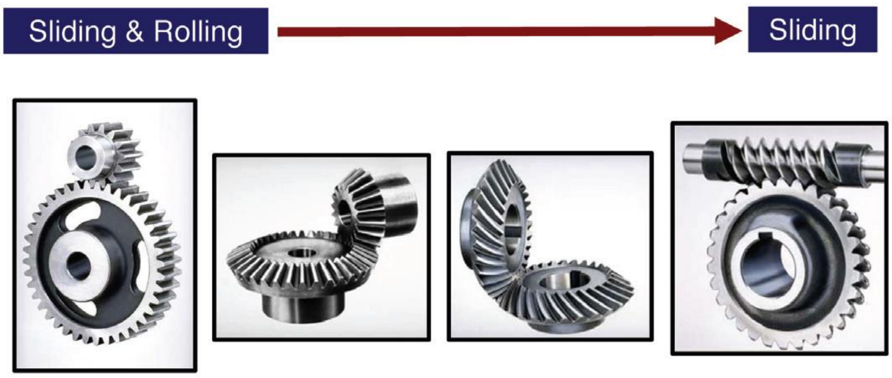

Fig. 1. Common Gear Types and their Frictional Characteristics, (Johnson, M., 2008).

Different kinds of gear trains, as noted in Fig. 1 and discussed in (Johnson, M., 2008), include – for example: a spur, bevel gears and a worm gear pair. The degree of sliding force increases as the degree of curvature of the gear tooth profile increases, with the worm gear set presenting an intensive sliding engagement.

Worm gear drives usually show lower overall efficiencies in comparison with other gear types due to this specific feature discussed: high sliding motion value. Their advantages concerning high

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ratios in one stage, low-vibration operation with low noise emission and possibility of self-locking make worm gear sets still irreplaceable components in transmission production.

CREATING TEST MACHINES IN THE AREA OF MACHINE SCIENCE

The authors' team had the opportunity to take an advantage of the experience accumulated working in team with representatives of academic staff having scientific achievements in the area of creating new test machines in the area of Machine Science, Machine elements, Automation and Measuring. These researchers work in a team within scientific contracts financed by the University of Ruse. Prerequisies for creating test machines for experimental research of gear trains are the acheivements of the research team mentioned in the field of innovative methods decribed in details in: (Dobreva, A. & Dobrev, V., 2007), (Stoyanov, S., Dobrev, V., Dobreva, A., 2017) and (Dobreva, A. & Dobrev, V., 2018).

The research team mentioned has solved successfully a relative great number of problems in the area of machine design. Some of these achievements are in the area of design of test machines for experimental research of energy efficiency in mechanical gear trains: (Dobrev, V., Stoyanov, S., Dobreva, A., 2015), (Dobreva, A., 2013), (Dobreva, A. & Dobrev, V., 1993) and (Dobreva, A., Dobrev, V, Stoyanov, S., Neykov, Y., 2009).

Creating new test machines requires knowledge and experience in the area of developing software programs for processing data and visualizing results. The members of the research team mentioned present their contributions in this area in: (Dobreva, A. & Haralanova, V., 2013), (Stoyanov, S. & Dobreva, A., 2010), (Stoyanov, S. & Dobreva, A., 2004) and (Kamenov, K., Dobreva, A., Ronkova, V., 2017).

The design layout of an automated test machine created for meaasuring energy efficiency of gear trains includes the following components: a frequency inverter; an asynchronous motor; a sensor for input torque; a reducer tested; a sensor for output torque; multiplier; couplings; a generator; components for ensuring load resistance; an unit of National instruments and a PC with LabVIEW installed. The test machine developed and produced is equipped with electronic measuring devices working in environment of LabVIEW. The authors' team present more details about the design and the experimental method applied in (Dobrev, V., Dimitrov, Y., Dobreva, A., Kamenov, K., Ronkova, V., 2016).

This test machine presented has a relative significant disadvantage. Intermediate experimental results for the changing values of the input and output torques are not available. This is the reason that such results cannot be vesualized.

Therefore, the same authors' team develop another new test machine with two opportunities for obtaining intermediate experimental results: signals from electronic as well as from mechanical measuring devices, (Dobrev, V., Dobreva, A., Ronkova, V., Dimitrov, Y., Kamenov, K., 2016).

METHODS FOR EXPERIMENTAL RESEARCH OF WORM GEAR DRIVES

There is a great variety of different test rigs designed and produced in order to measure efficiency, wear, friction, and some special features of transmission components. The authors (Hoskins, T. J., Dearn, K. D., Kukureka, S. N. & Walton, D., 2011) used a test machine in order to study the fundamental characteristics of the noise emission generated by separating its various components. These authors received important results showing the increasing surface roughness, wear and temperature influenced by significant sound levels.

Another authors' team (Dearn, K. D., Hoskins, T. J., Petrov, D. G., Reynolds, S. C. & Banks, R., 2013) described the application of a similar test machine in order to investigate the tribology properties of gears using dry film lubricants in the meshing.

A new test method of evaluating the energy efficiency of gear oils has been described in (Hargreaves, D. J. & Planitz, A., 2009). The approach involves measuring the power applying a specific test lubricant. The authors assert to achieve a 14.6% reduction in power. The oils of especially good performance run at reduced temperatures and they were more expensive in comparison with other products investigated.

The authors in (Yousef, S., Osman, T. A., Khattab, Bahr, A. A. & Youssef, A. M., 2015). present a universal test machine, designed to determine the wear characterization of worm and other gear drives. This test rig consists of motor, flexible coupling, metallic spur gear-set, worm gear couple, loading mechanism, etc. The results described in this reference concern the determination of the wear rate of worm gears in comparison to that of spur gears (produced from the same materials). According to the authors, its increasing is around 68%.

The test machine, shown on Fig. 2, has a clear and not quite complicated design layout. It is operating through the method of the open power flow circuit. It is suitable only for experimental testing of spur and worm gear sets made of plastic. The research of the influence of the lubrication is not possible. This method for experimental research of worm gear drives does not provides good modelling and simulation of the real contact in the meshing of the worm gear drives.

Fig. 2. Universal test machine presented in (Yousef, S. et al, 2015)

The reference (Mautner, E. M., Sigmund, W., Stemplinger, J. P. & Stahl, K., 2015) presents significant experimental investigations of large-sized worm gears. The gear couple is made of steel (worm) and bronze (worm wheel). The centre distance is relative large: 315 mm. The authors' objective is to measure and analyse wear, pitting behaviour and efficiency at different operating and lubrication conditions for worm gear drives with the size mentioned.

The photo on Fig. 3 presents the layout of a worm gear test machine. The gearbox tested is assembled to a reverse transfer gearbox (driven by worm wheel) with identical geometry. Therefore, a double joint coupling is applied. A hydrostatic torque motor ensures the necessary load, connected to a reverse transfer gearbox. A summation gearbox closed the cycle assembled. It is operating through the method of the closed power flow circuit.

The test machine shown on Fig. 3 is appropriate for evaluating a great number of different parameters having influence upon the operational capacity and the efficiency of worm gear drives. Some of them are: influence of contact pattern, roughness, input speed, output torque, oil viscosity, pitting, efficiency, gear ratio, etc.

The following experimental method is used: speeds and torques at input and output shafts are measured continuously (for the estimation of overall efficiency of the worm gear set tested); flank pictures of the worm wheel are made periodically (for estimating pitting load-carrying capacity); wear on worm wheel is measured (with transmission error measuring system). The researchers claim that an overall worm gearbox efficiency of up to 96% is measured.

The experimental methods applied within this are quite similar to the approaches described in (Michaelis, K., Höhn, B.-R. & Hinterstoißer, M., 2011). The researchers from (Mautner, E. M., Sigmund, W., Stemplinger, J. P. & Stahl, K., 2015) registered an increasing pitting damage (up to 45%). This pitting performance has no significant influence upon the efficiency of the wormgear tested (according to the authors mentioned).

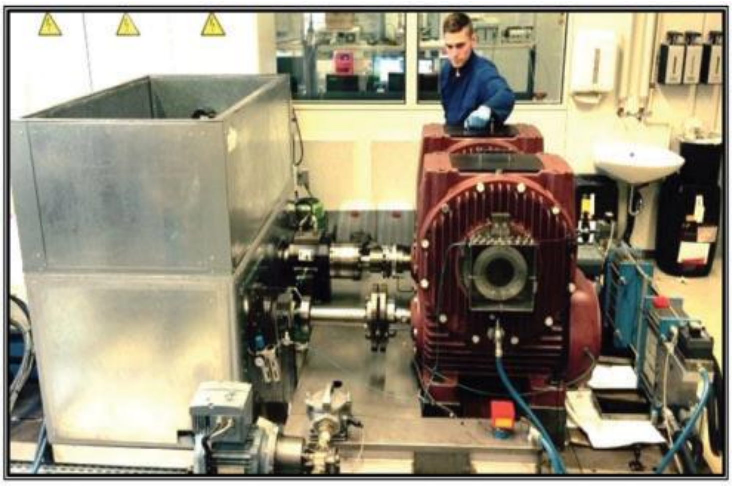

Fig. 3. Test machine for large-sized worm gears according to (Mautner, E. M. et al, 2015)

The test machine indicated on Fig. 3 posesses the following significant advantages: it is working based upon the closed power circuit and it gives the opportunity for experimentalresearch of worm gear drives with large dimentions.

CONCLUSIONS

Based upon the analysis of existing methods for experimental research of worm gear trains, the following conclusions can be derived:

The precise experimental measuring of the material wear of worm gears is especially important for the determination of the working capacity of these gear drives.

Designers can achieve a significant influence on the efficiency of worm gear trains making an optimal selection of geometry, material, type of lubrication, and operating conditions. The most important parameter for these gear drives is the type of lubricant. It has an impact upon the load capacity and upon the efficiency of the worm drives. The correct selection of the lubricant type can diminish the power losses with about 15 %.

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