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CONTRIBUTION TO INFLUENCE LOADING OF EFFICIENCY AND OPERATION TEMPERATURE OF SPIROID-GEARS

Eva RIEČIČIAROVÁ

SLOVAK UNIVERSITY OF TECHNOLOGY, FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY, DEPARTMENT OF APPLIED MECHANICS, TRNAVA, SLOVAK REPUBLIC

ABSTRACT:
The contribution paper deals with experimental determination of mechanical efficiency of the spiroid – gears. The efficiencies obtained by experiment are confronted with results obtained by conventional calculation procedure, which is usually used for the worm – gears.
KEYWORDS:
spiroid – gears, mechanical efficiency, temperature experimental determination, dynamical dynamometer

1. INTRODUCTION

Gearbox is an important component of energy transmission chain within technical equipments. Dynamic properties of gearing influence behaviour of a machine aggregate as the complete unit and technological process quality as well to a large degree. They depend mainly on kinematical and geometrical deviations of the gearing. The gearbox with spiroid gearing (Fig. 1) is tested as a component of the machine aggregates containing a drive and loading machine.


Figure 1. Spiroid - Gear

The spiroid gearing is an intermediate gearing type between hypoid and worm gearing pertaining to gearing group with skew line axes. It consists of spiroid worm with its cylindrical or cone shape and spiroid disk gear with teeth of arc shape.

In comparison with the worm gearings, the spiroid gearings feature by smaller slips of the meshing gear surfaces, further by better conditions for formation of liquid friction and more favourable spreading of contact lines. Fundamental difference between classical and spiroid worms lies in profile asymmetry of the spiroid worm [1] (Figure 2).

The asymmetrical profile is needed so as to ensure approximately equal conditions for mesh and relief of the components being in mesh from both sides. The spiroid gearings are cheaper in comparison with hypoid gears, which have to be produced on expensive machine tools. The hypoid gears feature by great sensibility on assembly accuracy and on the other side for the worm of the spiroid gearing with constant gear ratio insensibility concerning accuracy in axis direction of the worm [2] can be found out. Within the international project “Drives and transmissions in task of method for analysis and synthesis of the rotating machine aggregates with gearings”, which is solved by Department of Applied Mechanics, the questions regarding dynamics of the machine aggregates with gearings – spiroid gearings – are studied.

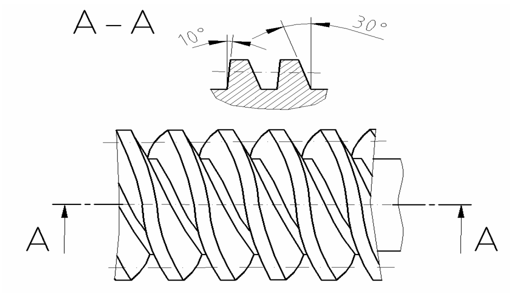

Figure 2. Cylindrical worm with profile asymmetry

The goal of this contribution is to complete information on field of the spiroid gear static loading and of torque size influence on its efficiency within formation of various type of friction, measured by dynamical dynamometer.

2. EXPERIMENTAL MEASUREMENT

The experimental measurements have been carried out using the dynamical dynamometer, which allowed to follow influence of the aggregate parameters on irregularity of angular velocity *ω(t)* and driving moment *M(t)* or to obtain dynamical characteristic of the machine aggregate in its stable and passage state in the form *M(ω)*. It makes possible to assess machine suitability with regard to its operational reliability, accuracy and its performance within various loading effects [3].

An asynchronous motor (under frequency control) drove the tested gearbox. On the gearbox output side was located direct-current motor and controlled rectifier working in inverted mode ensuring to return energy back into electrical network. Current controller controls the rectifier when on the controller input is located generator of elective formed control voltage. Its form corresponds with shape of the transmission mechanism loading torque.

Contemporary discrete programmable control makes possible to improve pre-project documentation by means of the dynamical experimental simulations using mathematic-physical model. By the same way can be also improved testing quality. The dynamical experiments utilising the new generation dynamometers are new testing elements. The dynamical dynamometer makes possible confrontation of the measured results with the results obtained by means of CAMS.

Losses of mechanism in stationary state run are characterized by efficiency coefficient *η*. Gear efficiency is defined by portion of output power to input power.

$$\eta_{12} = \frac{M_{ka}\omega_{ka}}{M_{kj}\omega_{kj}},$$

where: - M_{ka} means output torque, - ω_{ka} means output angular speed
- M_{kj} means input torque, - ω_{kj} means input angular speed.

The testing equipment has the limited torque value from 30 up to 50 Nm what allows measuring the transmission intended only for small loading torques directly. In the Table 1 can be found the measured and calculated values connected with spiroid gearing. The measurements have been carried out with dry friction, further with oil friction using the lubrication means type - MADIT OT-HP 32 and MADIT PP 80. The spiroid transmission was loaded by various loading types starting with lowest and ending with maximum torque in both rotation directions. The measured temperatures are given in the Table 2.

Table 1: Parameters of the spiroid gears

No	DRY OPERATION			OIL MADIT OT HP 80			OIL MADIT PP 80		
	M_{ka} [Nm]	M_{kj} [Nm]	η [%]	M_{ka} [Nm]	M_{kj} [Nm]	η [%]	M_{ka} [Nm]	M_{kj} [Nm]	η [%]
1	1,55	7,45	9,78	1,27	7,47	12,04	0,42	7,39	35,72
2	1,66	10,07	12,35	1,37	10,76	15,98	0,44	10,21	47,84
3	1,87	12,67	13,86	1,48	12,74	17,52	0,54	12,82	48,76
4	1,96	15,40	16,08	1,59	15,37	19,67	0,59	15,49	53,50
5	2,13	18,08	17,36	1,70	18,09	21,77	0,65	18,17	56,89
6	2,50	20,28	16,58	1,80	20,30	23,04	0,72	20,19	57,46
7	2,82	22,38	16,23	1,90	22,42	24,07	0,82	22,16	55,29
8	3,15	24,74	16,02	1,93	24,53	25,93	0,90	24,46	55,47
9	3,51	26,96	15,66	1,91	26,64	28,53	1,02	26,88	53,78
10	3,70	28,43	15,68	1,97	28,96	30,05	1,15	28,80	50,13

Table 2: Parameters of the spiroid gears

OIL OT HP 80	Temperature T [°C] speed n [min-1]										
LOADING	T_0	T_{300}		T_{600}		T_{900}		T_{1200}		T_{1500}	
		+n	-n	+n	-n	+n	-n	+n	-n	+n	-n
Static	20,0	22,3	23,1	27,4	25,4	29,3	29,7	35,3	34,2	37,4	36,5
Saw-shape	20,3	22,9	23,7	26,9	25,8	28,6	30,3	33,8	33,1	38,4	36,4
Rectangular	20,0	20,7	21,0	22,9	23,1	24,4	25,7	28,7	28,1	32,2	31,7
Sinusoidal	20,9	22,9	22,6	25,7	25,6	30,0	27,4	33,9	32,5	37,2	35,4
Triangular	20,0	22,5	22,7	25,8	24,9	30,5	29,8	35,1	32,3	37,8	36,4

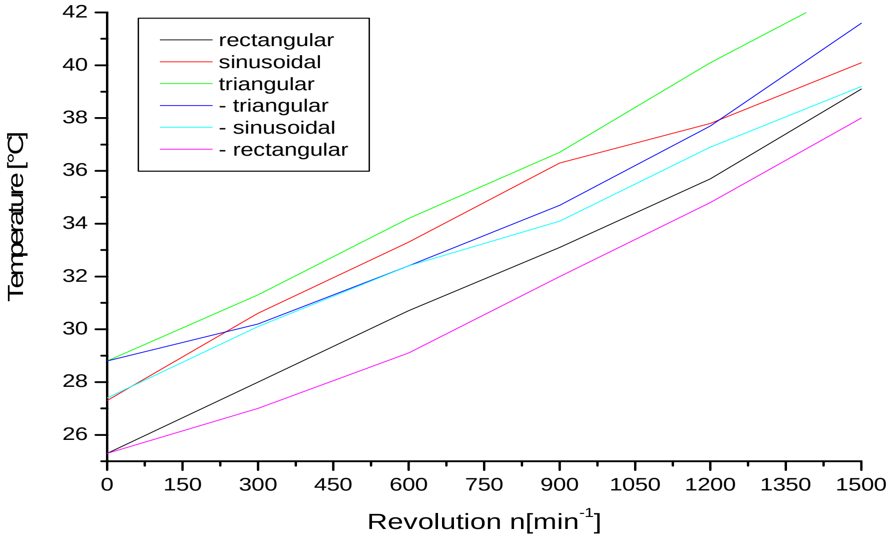

Figure 3. Graph of loading - rectangular, sinusoidal and triangular

Particular measurements are evaluated using diagrams. The temperatures obtained with loading pattern – rectangular, sinusoidal, and triangular – are shown in Figure 3, where:

- rectangular, sinusoidal, triangular means revolution in positive direction of rectangular, sinusoidal or triangular loading
- -rectangular, -sinusoidal, -triangular, minus sign means revolutions in opposite direction.

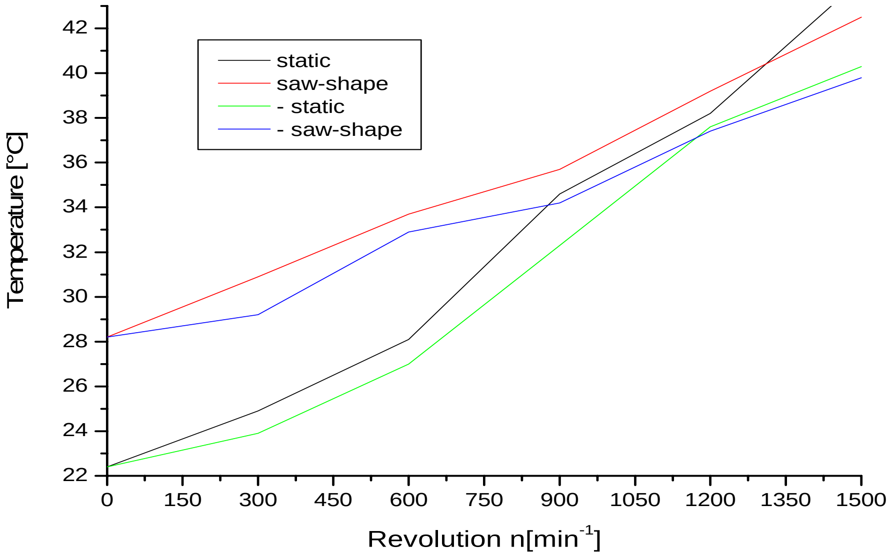

Figure 4. Graph of loading - static and saw-shape

The value of loading corresponds with lowest up to highest torque in both shaft rotation directions.

The temperatures obtained with static and saw-shape are shown in Figure 4. The value of loading corresponds with this in Figure 3 for both shaft rotation directions.

- static, saw-shape means revolution in positive direction of static or saw-shape loading
- -static, -saw-shape, minus sign means revolutions in opposite direction.

The obtained relations between revolutions and temperature assign generation of temperature spectrum in dependence on loading type and value of torque. Temperatures within gear contact depend strongly on transmission loading. Measurement of temperatures shows different temperature values for one and another rotation direction. It is supposed the reason is in asymmetry of tees.

3. CONCLUSION

Utilization of the testing equipment for dynamical loading of the machine aggregates and mechanisms can be used for creation of dynamic loads with defined static and dynamic parameters within a technological process [4]. Further the said equipment can be utilised for laboratory, production and input tests and for service life tests of any subsystem of a mechatronical systems under given dynamic loads.

The goal of this contribution is to bring closer the problematic of static load influence on the spiroid gears and influence of torque value on gear efficiency within creation of various type of friction, when carrying out measurements using dynamical dynamometer. The tested single-stage gearbox is the gearbox with gear ratio i = 49 and gearing module m = 1,75 mm, when pinion material is steel and gear wheel is made of bronze. It has been found out from the measured and calculated values that the lowest efficiency is within dry friction run. Influence of loading increase, i.e. of torque increase is the increase of gear efficiency, which increases up to its maximum value reached. Being the maximum efficiency reached, the efficiency is decreasing while the further loading still increases – it can be seen in Figure 5.

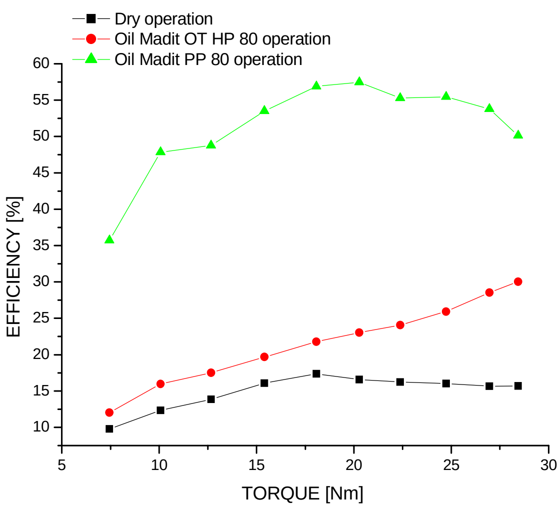

Figure 5. The influence of static loading on the efficiency of spiroid-gears

The measurement results show on gear efficiency dependence on teeth surface temperature. With temperature raising the efficiency decreases. Some differences against usual behaviour can be noted. It means it is necessary to continue in research of the spiroid gearings with verification of the competent parameters under further various conditions. It will be done within mentioned international project.

Acknowledgements

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