Scientific Bulletin of the „Petru Maior" University of Tîrgu Mureş
Vol. 11 (XXVIII) no. 2, 2014
ISSN-L 1841-9267 (Print), ISSN 2285-438X (Online), ISSN 2286-3184 (CD-ROM)

THE STUDY ON THE BEHAVIOR OF THE GEARBOX WITH WORM FACE GEAR WITH MODIFIED GEOMETRY

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Abstract
This paper present the result of the research concerning the behavior, from the thermal point of view, of the gearbox equipped with worm face gear with modified geometry. The worm face gear with modified geometry, known also as modified spiroid gear, consist of a cylindrical worm, which has equal pressure angle for the flanks of the tooth, conjugated to a planar worm wheel. During the experiment the thermal limit has been determined for the gearbox where the cylindrical worm was made from of alloy steel 42MoCr11x and hardened by nitro-carburizing, and the planar worm wheel made from gray iron Fc250.

Keywords: worm face gear; spiroid gearing; modified geometry, speed reducer, gearbox, thermal limit, wear

1. Introduction

The gearboxes are the object of extensive scientific concerns, given their wide spread in machine building and equipment. The group of the gearboxes having worm gears with crossed axis enjoy the property to provide high transmission ratios (1:30 to 1:75) in a single gear. The main limitation of the use of worm gear gearboxes is related to the so-called thermal limit. Its significance is the torque for that the gearbox can operate on a long term where the temperature for the oil sump is stabilized to 80^0C. Obviously gears behavior is important also from the point of view of the contact pressure solicitation, respectively cyclical bend, but thermal stress determines the load limit accepted for safe operation on a long term.

A new category of gearboxes having worm gears is researched to be introduced into industrial exploitation, is one that use worm face gears having conical or cylindrical worm [5], [6], [9], [10], [11], [12], [15], [16], [17], [18]. A particular constructive variant of worm face gear are the gears which have the defining element a cylindrical worm with symmetrical flanks meshes with the planar worm face wheel [14], [2], [6]. This category is not subject to any standard and is less known, is called for now "worm face gear with modified geometry" [2]. In fig. 1 is presented such a gear.

This paper aims to present the result of an experiment in terms of determining the thermal limit for a gearbox equipped with such a gear made by a combination of materials hardened steel / gray cast iron.


Fig. 1: Worm face gear with modified geometry

In [1], [3], [4], [7], [8], [13] are made known results of experiments on the thermal limit of gearboxes equipped with conventional worm face gears with different material combinations. The experimental conditions in which the values of this parameter were determined were not always identical, which makes the comparison of results to involve a degree of approximation. The companies that produce this type of gearboxes do not specify this parameter into their documentation, but it is assumed that the catalog's value for the power and speed covers this functional condition also.

2. Experimental research

In order to perform the experiment, was proceeded to equip the gearbox consist to a worm face gear with modified geometry (fig.2).

Fig.2: Gearbox - worm face gear with modified geometry

Its specific constructive values are shown in table 1.

Table 1: Geometric elements of gear

The gear ratio	i	1:47
Axial distance	A	56 [mm]
Sidewall angles	α_1, α_2	α_1=α_2=20°
Cylindrical worm type		ZA
Number of worm’s beginnings	z_1	1
Number of wheel teeth	z_2	47
Module axial		2,5 [mm]

The materials used and the characteristics of hardness of tooth flanks are presented in table 2.

Table 2: Materials: worm and worm face wheel

Component	**Material**	**Hardness**
Worm	42MoCr11x	620 HV
Worm face wheel	Fc250	229 HB

For gearbox lubrication during the experiment for determining the thermal limit was used mineral oil CEPSA TRANSMISIONES EP 80W90, whose physico-chemical characteristics are presented in table 3.

The experiment was conducted on the test stand for gearboxes in TAPFA Research Center of the Petru Maior University, Tirgu Mures [7], [8]. The stand uses an electromagnetic brake with particles: Mobac FRAT-3500.

The gearbox casing is a cast-iron structure and is not provided with multiple fins for cooling.

Table 3: The physico-chemical properties of the oil

Specification	**ASTM Standard**	**UM**	**Values**
SAE Grade			80W90
Density at 15^{0}C	D-4052	Kg/l	0,904
Flash point (COC)	D-92	^{0}C	214
Viscosity at 100 ºC	D-445	cSt	14,6
Viscosity at 40 ºC	D-445	cSt	134
Brookfield Viscosity at -26°C	D-2983	cP	<150000

3. Determination of the thermal limit and analysis of the experimental data

The experiment was intended to determine the temperature (thermal limit) reached by the gearbox, based on loading, the torque was applied sequential in steps. Table 4 highlights the braking torque applied by the brake Mobac FRAT 3500 to the gearbox during the experiment.

The gearbox was tested for both directions of rotation.

Table 4: Loading steps

Step	**Current (A)**	**Value (Nm)**
Grind	0	0
1	0,1	12
2	0,2	23
3	0,3	36
4	0,4	58
5	0,45	66
6	0,47	70
7	0,5	75
8	0,55	89
9	0,57	100

Reading interval for the temperature in the sump was set at 30 seconds (t_0-t_1), the shift to a the uppermost step of loading was determined by reading the same value at least 10 times in a row or if the variation in temperature recorded in the last 300 seconds becomes insignificant (±0,01^{0}C). Record of the data was done in two stages, depending on the direction of rotation of the motor.

Values indicated by the temperature sensor were transmitted via a data acquisition boards to a computer for storage and then for processing.

4. Evaluation of the experiment

Based on the recorded measured data, in fig. 3 is showed the temperature variation in sump for the gearbox with worm face gear with modified geometry for the material combination for cylindrical worm from alloy steel 42MoCr11x and the worm face wheel made from gray cast-iron Fc250, during gearing on the concave flank.

The experiment, conducted for worm face gear with modified geometry with cast-iron Fc250 on concave flank, lasted 201 minutes, the maximum temperature reached in the sump being 83,74 ^{0}C.

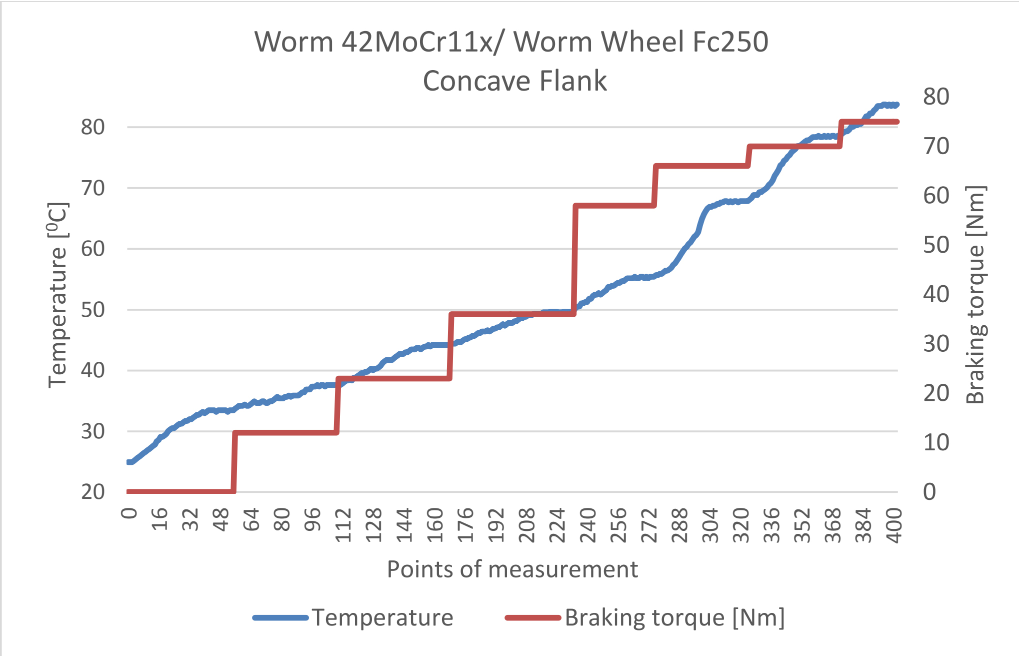

Fig.3: Temperature variation depending on the load on the concave side of the wheel tooth

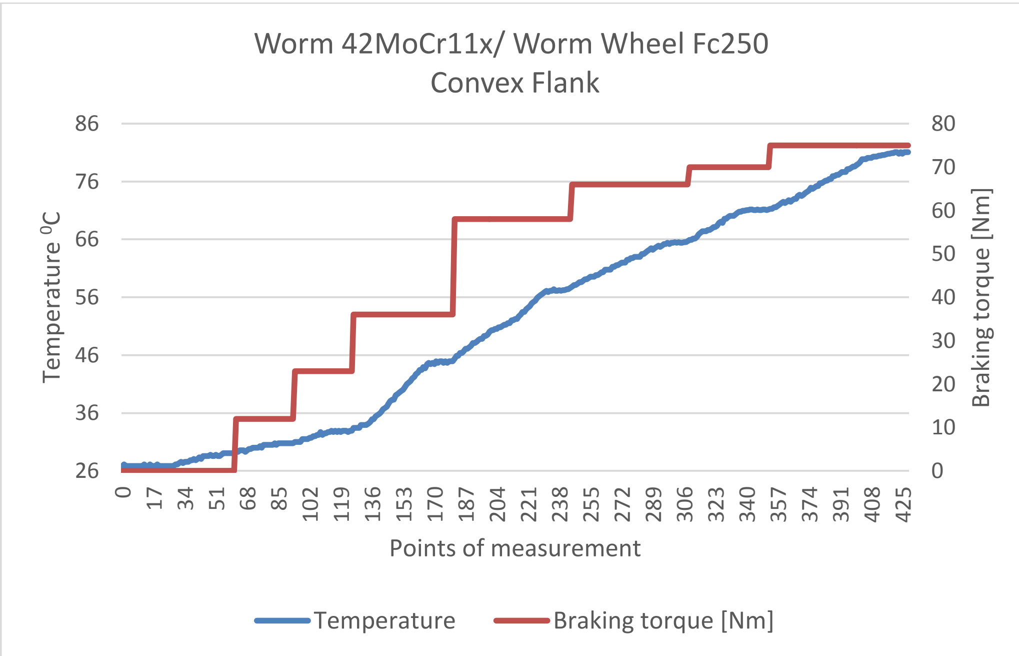

Fig.4: Temperature variation depending on the load on the convex side of the wheel tooth

In fig. 4 is presented the temperature variation in sump for the gearbox with worm face gear with modified geometry for the material combination for cylindrical worm from alloy steel 42MoCr11x and the worm face wheel made from gray cast-iron Fc250, during gearing on the convex flank.

For convex flank the experiment lasted 214 minutes, the maximum temperature reached in the sump being 81,054^{0}C.

5. Conclusion

Analysis of the recorded data and processed as diagrams allow an assertion of conclusions that can be considered of interest in terms of using this type of gear. As follows:

- Thermal limit for the pair of materials: steel 42MoCr11x / cast-iron Fc250 for both flanks is slightly closer, with a difference in favor of gearing on the convex side. Unlike conventional worm face gear to which the thermal limit for gearing on the smaller pressure angle (10^0) is far superior to the gearing on the flank having greater pressure angle (25^0-30^0).
- Making a comparison with the thermal behavior of the gearboxes fitted with asymmetrical flanks worm face gears, showed an extremely large difference to the detriment of the worm face gear having modified geometry (symmetrical flanks).
- This experiment reveals unequivocally that in terms of thermal limit, these gears are lower in terms of quality compared to worm face gears heaving asymmetric flanks, which largely explains their absence into significant industrial applications.

ACKNOWLEDGEMENT: This paper is supported by the Sectoral Operational Programme Human Resources Development POSDRU/159/1.5/S/137516 financed from the European Social Fund and by the Romanian Government.

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