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The Comparative Study on the Behavior of the Speed Reducer With Worm Face Gear With Modified Geometry

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Abstract

The paper highlights the findings of the research on the thermal limits of a speed reducer equipped with a worm face gear with modified geometry made of hardened steel 42MoCr11x by nitrocarburizing (cylindrical worm) and improved steel OLC 45 (worm face wheel). This type of gear is a worm face gear variant where of the worm flanks are executed with equal pressure angles to simplify the geometry tools and execution technology. The paper made a comparison with thermal limit values for other types of worm face gears obtained by the authors

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Keywords: worm face gear; spiroid gear; modified geometry; speed reducer; thermal limit

1. Introduction

The designers of mechanical transmissions are available at the moment, a lot of constructive solutions. The choice between them depends on several factors: the transmitted power, input speed, position and spacing of the shafts, working conditions etc. A parameter that is taken into account is the cost, which is usually correlated with the equipment to be included in the mechanical transmission in question.

For these reasons scientists are continually finding new technical solutions to ensure, under conditions of low cost, technical performance as high. One of the solutions which in recent years is researched different aspects worm face gear transmission is known as spiroid gear Formed in the 50 years [17,18] this transmission can be achieved in

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various constructive versions which provide different performance obviously related costs [1,4,12,13,14,15,16,20,21,22,23].

A variant of this is the most economical worm face gear uses the modified geometry profile axial symmetrical sides have equal pressure angles [19,2,9]. For applications, less demanding worm face gears were designed in combination hardened steel materials (worm) steel heat treatment improvements (worm wheel) and hardened steel (worm) – gray cast iron (worm wheel).

It is well known that the worm gear generally a specific technical requirement is the thermal limit at which it can be loaded. It generally depends largely on the thermal limit of the specific design of gear elements, the precision of execution, the torque of materials, type of lubricant used and the construction of the housing in which they are included (geometry, material, volume). There are standards that set detailed rules for defining such features [24].

In [3] shows the results of an investigation into the thermal limit of a reducer equipped with such a the worm face gear with modified geometry in the combination of materials made of hardened steel (worm)-gray cast iron (worm wheel). This paper presents the results of an experiment made for the same type gear reducer mounted the same but the combination of hardened steel materials (worm) - steel heat treatment improvements (worm wheel). Making this experiment led to a comparison in acceptable conditions which allowed issue conclusions with a strong practical.

2. Experimental research

Worm face gears of the research (Fig. 1) presented following kinematic and geometric features: the gear ratio i = 1: 47; the axial distance A = 56 [mm]; sidewall angles $\alpha 1 = \alpha 2 = 20°$; ZA type cylindrical worm; number of worm's beginnings Z1 = 1; number of wheel teeth Z2 = 47; axial modulus = 2,5 mm.

a

b

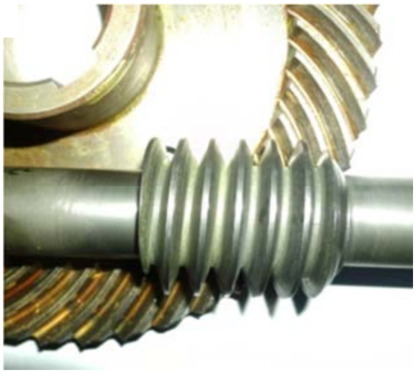

Fig. 1. Worm face gear with modified geometry; a) Overview; b) Detail.

This gear was included in the structure of a speed reducer with a cast iron housing (Fig.2.) which allows the use of a bath oil with a volume of around 2000 cm^3.

The worm was made of steel 42MoCr11x is hardened to 620 HV by nitrocarburizing.A nitrocarburat coating layer consists of a combination of 10 to 12 μm, and a diffusion layer of about 300 μm with a coarser structure (Fig. 3). Its flanks had a roughness Ra of (3.4 to 4.2) μm measured with Taylor Hobson SURTRON 25.

Worm face wheel with modified geometry was made of steel OLC 45 improved and was hobbing by flying cutter on the machine FD 500 UM Cugir.[6] (Fig. 4) having teeth flanks with a roughness of 6.3 μm measured on the initial Taylor Hobson device SURTRON 25 (Fig. 5). After a load operating flanks roughness Ra values reached (0.4-0.8) μm

Was used for lubricating gear oil 80W90 CEPSA Transmisiones EP which is a high performance oil ensuring a good flow at low temperatures, resulting in reduced wear, high loads and shock enables high load. This type of oil is used to lubricate complex transmissions with very good anti-wear properties, where they develop gear for extreme pressures. Its main features are: Grade SAE 80W90; 150^0C density D-4052 at 150 kg / l 0.904; flash point (COC) D-

92 ^{0}C 214, viscosity at 100ºC D-445 cSt 14.6; viscosity at 40° C 134 cSt D-445; Brookfield viscosity at -26° C D-2983 cP <15000.

Fig. 2. Speed reducer unit- worm face gear with modified geometry

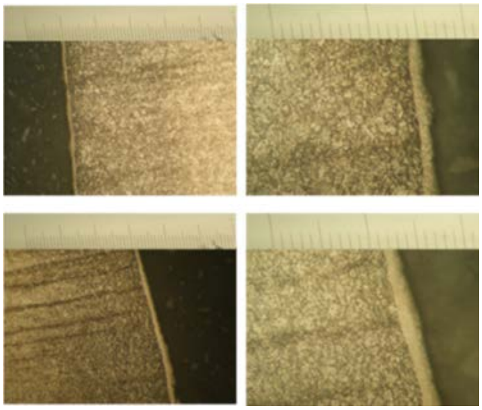

Fig.3. The resulting hard layer by the worm nitrocarburizing treatment

Fig. 4. Hobbing the worm face wheel

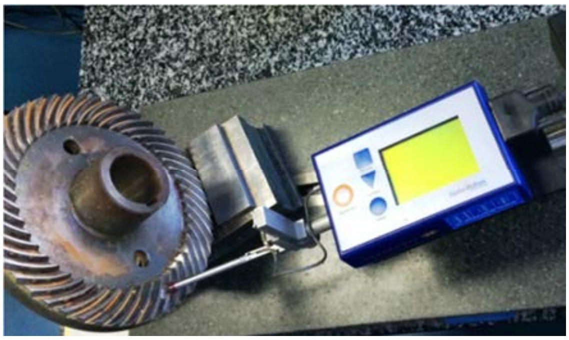

Fig. 5. Determination the worm face wheel flanks roughness

The program of experimental determination of thermal limit for worm gear reducer equipped with worm face gear modified geometry was performed on the test bench in the TAPFA Research Center of the Petru Maior University Tirgu Mures. The construction of the stand was presented in detail in [3,10,11].

An attempt were conducted gradually increasing the torque resistant (Table 1.) out of gear with a powder-type brakes. Mobac FRAT 3500.

Table 1. Loading torque steps

Step	Grind	1	2	3	4	5	6	7	8	9
Value[Nm]	0	12	23	36	58	66	70	75	89	100

Charging for each step was done over a period of time until the oil sump temperature stabilizes. After this time to go to the next step unloaders experiment was stopped at reaching a temperature of 80^{0} C. The test program was made for both directions taking into account that driving the wheels is on a convex flank sense and for the other on a concave flank which changes in working conditions that form frictional torque. The time between two temperature readings from temperature sensors permit the stand was 30 seconds values are taken through a data acquisition boards and transmitted to a computer for recording.

3. Analysis of the experimental data

Based on the values recorded in both directions of rotation were able to build diagrams in Fig. 6. concave flank of the tooth wheel in Fig. 7 the convex side of the tooth wheel.

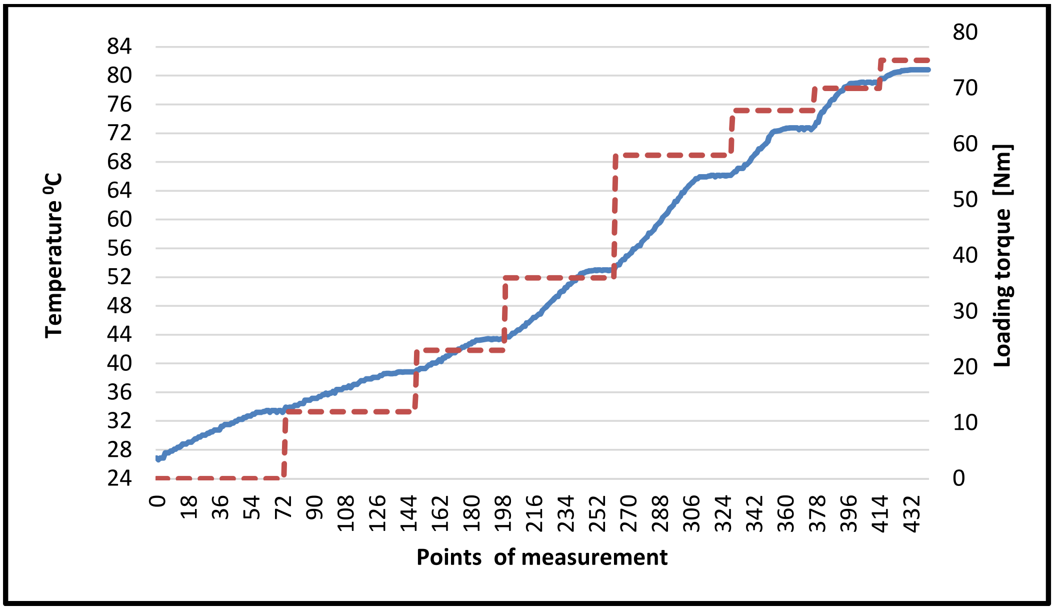

Fig.6. Temperature variation depending on the load on the concave side of the wheel tooth

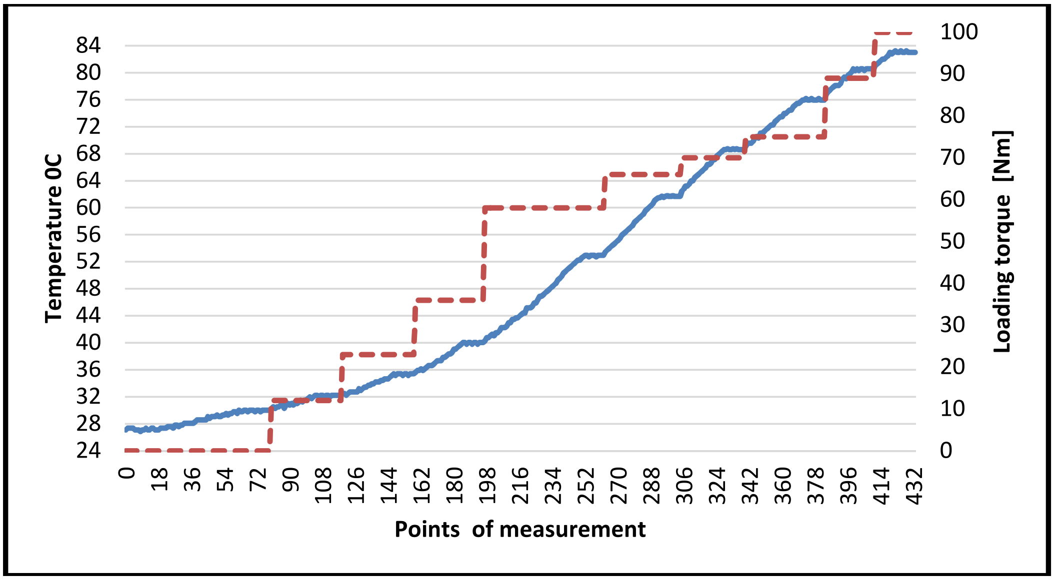

Fig.7. Temperature variation depending on the load on the convex side of the wheel tooth

Given these results, obtained for worm face gears with modified geometry, making a comparison with experimental results obtained in research conducted and presented in [3, 5,7,8,11] on a worm face with cylindrical worm flanks of the tooth wheel 10^0, 30^0, experiments conducted under similar conditions results in considerable differences of behavior as regards thermal limits, these differences being highlighted tabulated.

Table 2. - Comparison to 80^0C thermal limit

<table>
<tr><td rowspan="6">Materials couple</td><td colspan="2">Worm face gear with cylindrical worm</td><td colspan="2">Worm face gear with cylindrical worm (modified geometry)</td></tr>
<tr><td colspan="4">Heat treatment worm</td></tr>
<tr><td colspan="2">Ionic nitriding</td><td colspan="2">Nitrocarburizing</td></tr>
<tr><td colspan="4">Loading flank of the tooth wheel</td></tr>
<tr><td>convex
10^0</td><td>concave
30^0</td><td>convex
20^0</td><td>concave
20^0</td></tr>
<tr><td colspan="4">Loading torque [Nm]</td></tr>
<tr><td>Steel (42MoCr11x)-Worm / Cast iron (Fc250)- Worm-wheel</td><td>-</td><td>-</td><td>73</td><td>71</td></tr>
<tr><td>Steel (42MoCr11x)-Worm / Steel (OLC45)- Worm-wheel</td><td>-</td><td>-</td><td>89</td><td>74</td></tr>
<tr><td>Ionic nitrided steel-Worm / Nodular cast iron-Worm-wheel</td><td>202</td><td>162</td><td></td><td></td></tr>
<tr><td>Ionic nitrided steel-Worm / Ionic nitrided steel -Worm-wheel</td><td>213</td><td>205</td><td></td><td></td></tr>
</table>

4. Conclusion

Experiments with the reducer equipped with worm face gear with modified geometry executed in materials combination steel materials (42MoCr11x- worm) / steel materials (OLC45-worm wheel), which intended to establish thermal limit is reached during operation, it was performed in conditions identical to that fitted. Worm face gear with geometry modified executed in combination steel materials (42MoCr11x- worm) / cast iron (Fc250- worm wheel) to make a comparison of the results.

The results of the performed experimental nature lead to the following conclusions:

- Thermal limit torque of materials 42MoCr11x steel / steel OLC45 have significantly different values to drive the two sides, which is higher convex side towards training concave flank;
- Thermal limit for driving on the convex side for both couples is more favorable material situation convex tooth flank drive wheel;
- Operation worm face gear with modified geometry when worm 42MoCr11x steel hardened steel and wheel OLC45 improved torque which are not usually used in practical applications with high load factor, in this case ensured an acceptable operating conditions without producing phenomena of gripping. Reason for this is in close touch with lubrication conditions very special worm gear units is achieved front where a wedge hydrodynamic lubrication, which allows a type lubricating fluid;
- Thermal limit of the reducers equipped with worm face gear with asymmetric flanks is about 50% higher than the worm face gear with cylindrical worm symmetrical flanks.

Industrial use of worm face gear with modified geometry whose cost price is lower, it is recommended only for low load situations and arrangements easy.

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References

[1] Anferov V. N., Kovalkov A. A**.** Test data for the efficiency of the spiroid spur gearing, Journal of Mining Science, Vol. 42, No. 6, 2006, p 617-621;

[2] Boantă I. C., Boloş V., The Mathematical Model of Generating Kinematic for the Worm Face Gear with Modified Geometry. Elsevier, Procedia technology, 2014, 12, ISSN 2212- 0173, pag.442-447;

[3] Boantă C., Boloş V., The study on the behavior of the gear box with worm face gear with modified geometry, Scientific Bulletin of the „Petru Maior" University of Tîrgu Mureş, 2014, Vol. 11 (XXVIII) no. 2, ISSN-L 1841-9267 (Print), ISSN 2285-438X (Online),ISSN 2286-3184,p. 5-8;

[4] Bodzas S., Dudas I., Horvath R., Dudas S. I., Mandy Z., Measuring and analysis of noise level of a new geometric, arched profile conical worm gear drive in axial section , Machine design, Vol.5(2013) No.2, ISSN 1821-1259 pp. 75-78;

[5] Boloş C., Boloş, V**.**, Experimental determination of the thermal limit of a speed reducer on spiroid gearing, In: MicroCAD 98 International Computer Science Conference, Miskolc (Hungary), 1998 Section J, pag. 113-116;

[6] Boloş V.**,** Spiroid worm gearings. The hobbing of the plane wheels (In Romanian language), Editura Universităţii Petru Maior Tg.Mureş, pp 264, ISBN 973-99054-9-8;

[7] Boloş V., Boloş, C.,Experimental research regarding the use of alloy steel 41 Mo Cr 11 in making the spiroid worm gearing . În Proceeding The 27th Annual American Romanian Academy of Arts and Sciences, - ARA Congress, Oradea, May 29 – June 2, 2002, Polytechnic International Press Montreal, ISBN 2-553-01024-9, pag 606-609;

[8] Boloş V., Boloş C., Experimental research on the use of nodular graphite cast iron in making spiroid worm gears,The International meeting of the carpathian region specialists in the field of worm gears,Volume XVI,serie C (ISSN 1224-3264), North University of Baia Mare, June 2002, pag.35-38;

[9] Boloş V., Boantă I.C., The Mathematical and numerical model of the spiroid gearing. The International Scientific Conference Inter-Ing 2007 "Petru Maior" University Faculty of Engineering, Tg. Mureş, 15 – 16 November 2007, ISSN 1843-780X, Editura Universităţii Petru maior din Tîrgu Mureş; pag 1-44-1- I_44_4 ;

[10] Bucur, B., Bolos V., Study of the Thermal Limit of the Gearbox Worm Face – Gear with Reverse Tapered Pinion – The Experimental Bases, Annals of MTeM for 2009& Proceedings of the 9th International Conference Modern Technologies in Manufacturing MTeM 2009,.ISBN 973-7937-07-04, pag.33-36;

[11] Bucur B., Boloş V., Experimental study of the thermal limit for the gearbox worm face-gear with reverse tapered pinion, Publication: In: Anals of MTeM for 2011 & Proceedings of the 10th International Conference Modern Technologies in Manufacturing 6nd-8nd October, 2011, Cluj-Napoca, Volume number: vol 1, ISBN 978-606-8372-02-0, pag. 53-56, 6-8 October 2011 Cluj-Napoca, Romania;

[12] Dudás I**.**, Designing Of Worm Gear Drives, In Manufacturing System, Journal of Production Processes and Systems, Volume 6. No. 1. (2012) pp. 9-18;

[13] Dudás, L., Modelling and simulation of a new worm gear drive having point-like contact, Engineering with Computers (2013), 29, pp251–272;

[14] Georgiev A., Samigullin R., Kotova I., Разработка усовершенствованных конструкций спироидных и цилиндро–спироидных редукторов (Development of the improved designs of spiroid and helical–spiroid gear units), International Conference Power Transmission 2003;

[15] Goldfarb V.I., Makarov V.V., Trubachev E.S., Kuznetsov A.S., New perspective application of spiroid gears, 12th IFToMM World Congress, Besançon (France), June18-21, 2007;

[16] Mudrik J., Riečičiarova Eva, Load Application Of The Spiroid Gears Using Dynamic Dynamometer, ADEKO, Faculty of Technical Sciences Novi Sad May 18th 2008, 48 Anniversary of the Faculty Machine Design;

[17] Oliver E.Saari, US 2696125, 1954, Speed reduction gearing;

[18] Oliver E.Saari, US 2731886, 1956, Method of making speed reduction gearing;

[19] Schrempp E., Skew axis gearing, 1972, US 3645148;

[20] Spiroid Application –Guide (2011) http://www.itwheartland.com/spiroid-gearing/ ;

[21] Spiradrive Brochure (2013), http://www.davall.co.uk;

[22] Spiroplane right-angle gears motors W37 W47 (2014), http://www.seweurodrive.com/news/xml_images/d_1329774560.pdf;

[23] Spiroid gearboxes for pipeline valve drives- Production Catalog, http://www.mechanik.udmnet.ru/images/stories/ctlg_2013.pdf;

[24] AGMA ISO 14179- 1, Gear Reducers - Thermal Capacity Based on ISO/TR 14179- 1.