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EXPERIMENTAL RESEARCH CONCERNING THE CONTACT PATCH OF THE WORM FACE GEAR WITH MODIFIED GEOMETRY

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Abstract

This paper presents the contact patch resulting during the engagement in the worm face gears with modified geometry. The worm face gears, a gear known as spiroid, which was the subject of research is composed of a cylindrical worm flank with equal pressure angles which drives a wormgear face plane. The study of the contact between gear teeth was done for two combinations of materials: a hardened steel worm gear and the wormgear of cast iron and the other case a hardened steel worm and wormgear of steel in improved condition. The gears mounted in two gears have undergone a test upload and then the contact stains that occurred on teeth flanks wormgears were analyzed. This element highlights the mode of transmission of the load during operation an indicator of the quality of this gear in terms of loading. The tests have been made for the worm drive highlighting the behavior on both flanks of the wormgear face plane.

Key words: worm face gear; spiroid gear; modified geometry, speed reducer, contact patch

1. Introduction

The family of worm face gears, known as spiroid gears, which has developed in the last half century [15],[16],[26],[27],[28],[32], contains a significant number of variants made following constructive research which proposed to solve constructive solutions suitable for the requirements of machine manufacturers and equipment from different fields [17],[18],[30],[31],[33],[34],[35],[36].

The worm face gear with modified geometry first proposed by the patent [29] is a constructive solution which keeps most of the favorable characteristics of this type of gear with crossed axis (reduced axial distance, high torque capability, to maintain more tooth surface to be in contact at any time) and attempts to reduce the complexity and costs involved in the constructive execution.

It is well known that in the case of gears with crossed axes the transmission of important torque is strictly related to the size and position of the contact patch resulting from the process of engagement between their components. This problem lies in the attention of the producers of mechanical transmissions which include such gear where contact patch size and position is influenced both by the precision of execution of the elements of the gear components and precision mounting and adjustment of the gear backlash.

The theoretical and experimental analysis of this issue has a high degree of complexity given the multitude of factors to be taken into account among which an important role has the elastic properties of the worm and wormgear material hardness flanks [1],[9],[10],[11],[12],[13],[14],[18],[19],[20],[21], [22],[23],[24],[25].

In this paper we present the results of an experiment conducted with two speed reducers equipped with worm face gear modified geometry manufactured in two materials: steel gray cast iron and hardened steel on improved steel. In this experiment we mainly aimed to examine the thermal behavior of load reduction gears for different tasks [3] at the same time to pursue and contact patch size and position products. The results of experimental research have enabled us to make practical conclusions useful for users of mechanical transmission.

2. Experimental research and results

To carry out the experimental program of this research we prepared two worm face gears with modified geometry, both having the same geometrical parameters, but made with wormgear made of different materials (cast iron Fc250 or steel OLC45 condition improved), worms being run out 42MoCr11x hardened steel.

The geometric parameters of the gears used are shown in Table 1.

Table 1: Principal gear geometric parameters

Axial module	m_a	2,5
Number of threads in worm	Z_1	1
Axial profile worm	Form ZA	Archimedic
Axial distance	A	56 mm
Lead angle of the worm	grade	$5^0 42'37''$
Pressure angle	grade	20^0
Helix tilt direction	-	left
Diameter pitch	d_0	43,5039
Coefficient equivalent diameter	q	3,4843
Worm axial pitch	P_E	7,854 +/- 0,030
Accuracy class		7C – STAS 6461-81
Number of teeth in the wormgear	Z_2	47

For worm teeth flanks hardening we chose heat treatment, nitrocarburizing treatment.

Table 2: Worm hardness

Material worm	Measuring system	The measured value		
		1	**2**	**3**
42MoCr11x [STAS 791-88]	HV 0,5	619,8	621,4	620,1
	HV 1	585,5	591,3	594,4
	HV 0,5	611,0	620,6	609,7
	HV 1	586,0	581,2	579,3

Nitrocarburetings is a thermochemical treatment which is widely known as one of the best thermochemical treatments today. This process has an advantage in that deformation and dimensional changes are very small, so that costly auxiliary operations can be avoided. This is why the cylindrical worm was chosen for the realization of a steel which permits this treatment. Table 2 presents the measured values of worm flanks hardness.

In making the wormgear we used a blank gray iron Fc250 according to STAS 568-82. The first wormgear, OLC45 a blank respectively steel improved condition for the second wormgear. In Table 3 are shown the measured values of the wormgear loaders used in the experiment.

Tabelul 3: Hardness wormgear

Material wormgear	Hardness
Cast iron Fc250	229 HB
Steel OLC 45 improved	355,7 VH ≈ 33 HRC

For the wormgear face plane modified geometry toothing the tool chosen was a kinematic machining milling machine that can be applied to the gear FD 500 UM Cugir existing at TAPFA Research Centre Petru Maior University of Tîrgu Mures [5],[6],[2],[8].

Fig. 1: Hobbing of cast iron wormgear

Fig. 2: Hobbing of steel wormgear

The tool used in an operation for gear hobbing worm drive gear on FD 500 UM Cugir is usually a hob worm reference materializing or worm generator. Taking into account the technological complexity of executing a hob to materialize worm generator of worm face gear with modified geometry it was decided to use a flying cutter tool (Figure1 and Figure2) [7].

The roughness of the sidewall Fc250 was machined with a flying cutter around Ra 6.3 micron, both convex flank and concave flank steel wormgear OLC45 condition improved, processed under the same conditions, have roughness Ra12,5 values microns. The causes of this difference are in close connection with the processability of the two materials, that is the processing regime used.

Fig. 3: Worm face gear with frontal speed reducer combination of materials hardened steel hardened / cast iron

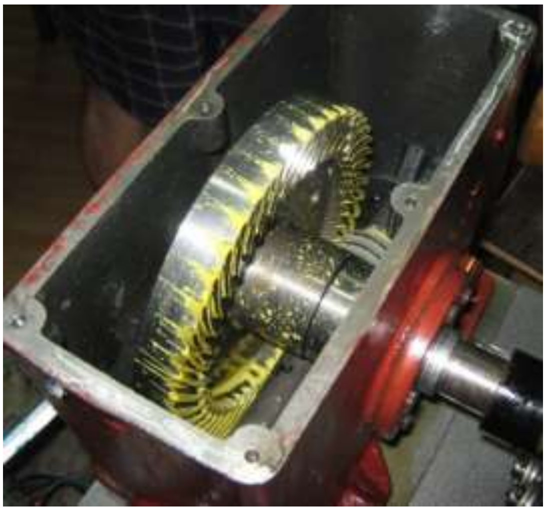

Fig. 4: Worm face gear with frontal speed reducer combination of materials hardened steel / steel improved

It is noted that for both cases we used the same cutting state, due to safety considerations regarding tool life, mode of processing which is suitable to Fc250 gray cast iron wormgear processing. [4].

Teeth flanks roughness thus obtained in the experiment could be regarded as acceptable for a gear with a special purpose use and also in terms of economic value. The gears processed in the above-mentioned conditions ware installed in the structure of the two speed reducers (Fig.3 and Fig.4).

The speed reducers were installed on the existing test stand at the Centre for Research TAPFA Petru Maior University of Tirgu Mures. [3].

3. Discussion

Given that in the case of the gear with crossed axes the contact patch is a complex indicator of how transmission load occurs between the components we checked the contact patch in gear mounted in the housing, using the lowest stage charging stand (1 Nm) and leaving a running of approx. 3 minutes for each flank individually.

Fig. 5: Contact patch on the convex side gear in the combination of materials hardened steel/cast iron

Fig. 6: Contact patch on the concave side gear in the combination of materials hardened steel / cast iron

The size of the contact patch was established by measuring with the admitted approximation of one-tenth, using a digital caliper.

Figures 5, 6, 7 and 8 present images of contact patch resulting from operation under those conditions.

The percentage values of the contact patch obtained are shown in Table 4.

There is a sensible difference between contact patches on both sides, providing a contact convex flank to flank superior concave, the pair of worm steel materials 42MoCr11x / wormgear Fc250 of cast iron. The pair worm steel 42MoCr11x /

wormgear steel OLC45 condition improved there is a size contact patch.

Fig. 7: Contact patch on the convex side gear in the combination of materials hardened steel / improved steel

Fig. 8: Contact patch on the concave side gear in the combination of materials hardened steel / improved steel

Tabel 4

The combination of materials (worm/wormgear)	The size of the contact patch with the size flank
Hardened steel / Cast iron	flank convex –. 80%
	flank concave – 35-40%
Hardened steel / Improved steel	flank convex - 33-35%
	flank concave – 33-35%

about equal on both sides, convex and concave, but positioning symmetrical on top tooth flank convex and the bottom flank concave.

Clearly this operating parameter is contact patch is strongly influenced by the dimensional accuracy of the worm and the positioning accuracy at the nominal rate of reduction housing axial distance. Contact stain can be improved by adjustment of the position of the worm along its axis, but measurements have not made such adjustments.

It can be assumed that higher values contact patch of gear consisting of worm steel 42MoCr11x hard / wormgear gray iron Fc 250 can be explained by the fact that the greater hardness of the worm caused a slight mating surface flank wormgear surface Flank worm phenomenon that is much less likely to worm torque 42MoCr11x hardened steel / steel wormgear OLC45 condition improved.

A lapping the flanks gear ensure improved contact patch, as confirmed by other studies [13],[14].

It should be emphasized that the accuracy of the contact patch made in the research could be greatly enhanced through the use of specialized equipment, but that was not accessible during the experiment.

4. Conclusions

The experimental research presented above allows the termination of a set of conclusions among which the following should be mentioned:

- the contact patch of the worm face gear with modified geometry for the material couple steel / cast iron Fc250 proved to be superior to that of gear formed by materials couple steel on steel, capability, determined by the superior hardness of the worm compared to the worm face wheel, to produce a slight conjugation of the flank surfaces of the worm face wheel tooth with the flank of the worm tooth, incomparably less common phenomenon to the combination steel / steel
- the size of the contact patch worm face gear modified geometry units can be greatly enhanced by increasing processing accuracy flank milling gear teeth using a hob;
- kinematic chain accuracies of hobbing machine and gear cutting tool will be included in the final accuracy of the gear teeth in a similar way as the usual worm face gears;
- worm face gears with modified geometry by working conditions insured can be recommended to be used for low and middle load situations.

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