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DETERMINING THE VALUES OF DIFFERENTIAL ACCURACY INDICATORS OF SPUR GEARS BASED ON THE RESULTS OF THE DOUBLE FLANK GEAR TEST

The Double Flank Gear Test is most commonly used method for quality control of gears. Researched experimentally the possibility of determining some differential indicators of accuracy on the results of the double flank gear test.

Keywords: *Double Flank Gear Test, Base Pitch Deviation, Total Profile Error, Base Circle Error, Profile Angle Deviation.*

Introduction

It is known that the double flank gear test (DFGT) is the only method which allows measuring indicators from all 4 accuracy norms for gears while performing these tests at a single setting of the measured gear. At the same time, it is possible to simultaneously measure four complex indicators of the norms for kinematic accuracy, smoothness (cyclic error of the gear $f_{zkr} = 0,3636\ f''_{ir}$), contact and backlash [1]. This unusual fact in gear metrology is an effect of the big amount of data, obtained from double flank measuring per revolution. This data is a significant base and a prerequisite for indirect assessment of the values of specific differential and set-up indicators for the accuracy of the controlled gear. The data correlates sufficiently to the results from the direct measurement of the indicators. This fact allows for significant widening of the possibilities of the most productive method for acceptance control, thus assigning to it a principally new place in the gear measurement process [2, 4, 5].

Discussion

There are opinions [1] and research [3, 4], showing that from one DFGT gearing there is a real possibility to obtain measurement information about the accuracy indicators base pitch error f_{pbr} and the misalignment error of the involute profile $f_{H\alpha}$ (respectively the error of the involute profile f_{fr}), as well as the errors F_{db} of the real value of the base diameter (set-up error) and f_{α} of the profile angle of the gear-cutting tool.

It is known that for cylindrical gears with straight teeth the deviation f_{pbr} provokes deterioration of the smoothness of operation of the gearing. When grinding gear-teeth, the deviation of the average value of the base pitch on both sides of the tooth is provoked by the pressure angle error $f_б$ of the grinding disk [1].

The involute form error f_{fr} is provoked by some characteristic errors of the technological process, including geometrical and kinematic eccentricities when machining, the radial deviations of the base circle F_{db} and the pressure angle when setting up the gear cutting machine tool, the radial run-out of the worm gear mill during tooth cutting, and the wear-out of the cutting edge of the cutting tool [1]. The index f_{fr} is formed by two components, one of which is systematic and is called profile angle error of the involute profile $f_{Hб}$ (Fig. 1). The deviation $f_{Hб}$ provides information on the condition of the profile angle of the machining tool, respectively its sharpening error or wear-out.

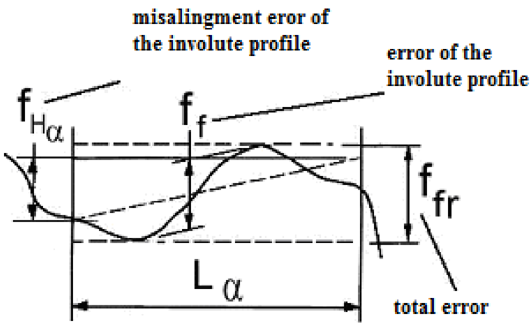

Fig. 1. Total error of the involute profile

Known are the following dependencies which relate the results from complex DFGT with differential and set-up indexes [1, 2]:

– base pitch error:

$$f_{pbr} = f_{pbm} = 2f''_{im}\sin\alpha_w\ ; \qquad (1)$$

– profile angle error of the tooth cutting tool:

$$f_{\alpha} = -\frac{2f''_{im}\sin\alpha_w}{\pi m\sin\alpha} \approx -\frac{2f''_{im}}{\pi m}\ ; \qquad (2)$$

- profile angle error $f_{Hб}$ (f_{fr}):

$$f_{H\alpha} = \frac{f''_{im}.z.\sin\alpha_w \mathrm{tg}\alpha}{\pi}\ ; \qquad (3)$$

– error of the real value of the base diameter:

$$F_{db} = \frac{2f''_{im}\sin\alpha_w.z}{\pi}\ . \qquad (4)$$

The article aims to present the results from an experimental research of the possibilities of the DFGT for technological control of cylindrical gears.

The research has been carried out using a center-distance gear-rolling tester МЦ-400 (MC-400), modernized as a result of a project of the Scientific Research Fund of the University of Ruse ‘Angel Kanchev’. The device is equipped with a circular and linear encoder transducers and a module for connection to a personal computer, and processing and visualization of signals, by National Instruments, operating in the software LabView.

The research aims to use standard gears to measure multiple times 30 experimental gears divided into 3 groups with different modules and number of teeth - 1.75 mm (z=60 teeth), 3 mm (z=48 teeth) and 4.5 mm (z=30 teeth). The obtained coefficients of overlapping are ε=1.78 for m=1.75 mm, ε=1.75-1.60 for m=3 mm and ε=1.65-1.49 for m=1.75 mm. Some of the gears are produced with deliberately specified base circle errors F_{db}, the sharpening angle of the grinding disk $f_б$ and with positive corrections with coefficients x=+1,1 and x=+1,0, as well as come combinations between them.

18 measurements have been carried out for each gear – three times in both rotation directions, with three starting points for taking into account the turning, offset by 90 degrees or 540 measurements in total.

The elementary measurement of the base pitch deviation f_{pbr} is done using a universal gear-tooth measuring device by Carl Zeis Jena with 0,001 mm interval of the indicating device. Three measurements have been made on the right and left hand side profile of each tooth, or 8316 measurements in total.

The elementary measurement of the profile form error of the tooth f_{fr} is done using a universal involute profile measuring machine КЭУ-М (KEU-M), class B, with a constant i =0,001 mm.

Performed are six-fold measurements of both profiles (right and left) of four teeth, offset from each other at 90 degrees on the gear crown - 1440 measurements.

The measurement results and the results from the calculations of dependencies (1), (2), (3) and (4), are processed statistically, summarized and presented in tables 1 and 2.

The analysis of the obtained experimental results yields the following general findings and conclusions:

- For gears with little or no deviations $\Delta б_w$ of the gearing angle $б_w$, there is a very good correlation between the directly measured values of the base pitch errors and the values determined using DFGT. In this case, the correlation coefficient between the deviation of individual gears is within the range 0.72-0.78, and its value for the respective average values from multiple repetitions is 0.88 - 0.99;

Table 1

Group of gears	fб, min		Uncertainty min
	specified	obtained $\bar{X}$	
m1,75 / z=60	-30	-11	±4,9
m 3 / z=48	-30	-22	±12,2
m4,5 / z=30 X=+1,0;	-30	-157	±9,9
Group of gears	Fdb, мм		Uncertainty мм
	specified	obtained $\bar{X}$	
m1,75 / z=60	50,4	87	±12,2
m 3 / z=48 X=+1,1	66	196	±5,2
m4,5 / z=30	80	67	±7,2

- For gears with significant deviations of the profile angle б, which also provoke big deviations of $б_w$, expectedly the variations of the measurement center-to-center distance per tooth f_{ir} also increase, as well as the respective deviations of the measured values of the base pitch. The presence of interference when measuring strongly distorts the measurement results;
- The method for determining the profile angle error of the gear tooth cutting tool $f_б$ is sensitive towards the presence of such an error and may be used for preventive control of its occurrence. It is sensitive even in the presence of big radial correction x. One should be warned for values bigger than 0,01 mm. The method yields better results for smaller number of teeth, respectively for smaller coefficient of overlapping ε. The big number of teeth, especially for smaller modules, as well as for lower degrees of accuracy, distort the measurement result. Similar results are obtained also when determining the error of the real value of the base diameter F_{db}- better results are obtained for gears with less teeth and a bigger module, regardless of the influencing factors, such as accuracy level, correction, etc. This means that in both cases for a longer active, respectively for a longer gearing line, the deviation of the obtained results is smaller;
- Since the average deviations f''_{im} are always positive (sign +), then the errors and the elementary indexes defined using these deviations should be used for preventive control of the technological process.

Summaries

The results from measuring cylindrical gears using double flank gear test can be used for preventive control of the technological production process while assuring a coefficient of overlapping of the measurement gear ε ≅ 1.05 and absence of measurement interference.

Table 2

m=1,75 z=60	Gear	left	right	middle	fpbr,мm						ffr,мm						
		f"im	f"im	f"im	Direct measurement, мm			Obtained,мm			Direct measurement, мm			Obtained,мm (fHб)			
		мm	мm	мm	left	right	middle	left	right	middle	left	right	middle	left	right	middle
norm	1,2,3	7	7	7	-12	-8	-10	5	5	5	-8	-7	-8	17	16	16
fб	4,5,6	9	8	8	20	17	19	6	6	6	12	11	12	21	19	20
Fdb	7,8,9	7	6	7	-16	-11	-14	5	4	5	-14	-13	-14	18	14	16
	x	8	7	7	-3	0	-2	5	5	5	-3	-3	-3	18	17	17
	Uncert.±	0,1	0,1	0,1	1,7	1,3	1,5	0,1	0,1	0,1	1,2	1,1	1,1	0,2	0,2	0,2
m=3 z=48	Gear	left	right	middle	fpbr,мm						ffr,мm						
		f"im	f"im	f"im	Direct measurement, мm			Obtained,мm			Direct measurement, мm			Obtained,мm (fHб)			
		мm	мm	мm	left	right	middle	left	right	middle	left	right	middle	left	right	middle
norm	10,11,12	14	15	15	-17	-10	-14	10	10	10	-30	-15	-23	27	29	28
fб	13,14,15	30	31	31	39	27	33	21	21	21	56	41	48	58	59	58
x=1,1	16,17,18	22	21	22	-26	-9	-17	17	17	17	-19	-7	-13	47	47	47
Fdb x=1,1	19,20,21	17	16	16	-24	-6	-15	13	13	13	-14	-10	-12	36	35	36
	x	20	20	20	-10	-1	-6	15	15	15	-4	0	-2	41	41	41
	Uncert.±	0,5	0,5	0,6	2,3	1,3	1,8	0,4	0,3	0,3	2,8	1,9	2,4	1,0	1,0	1,0
m=4,5 z=30	Gear	left	right	middle	fpbr,мm						ffr,мm						
		f"im	f"im	f"im	Direct measurement, мm			Obtained,мm			Direct measurement, мm			Obtained,мm (fHб)			
		мm	мm	мm	left	right	middle	left	right	middle	left	right	middle	left	right	middle
norm	22,23,24	16	12	14	-23	-11	-17	11	8	10	-41	-27	-34	20	14	17
Fdb	25,26,27	10	10	10	-12	-1	-7	7	7	7	-22	-15	-18	12	12	12
fб x=1,0	28,29,30	270	270	270	266	278	272	221	221	221	264	251	257	385	385	385
	x	142	140	141	124	136	130	115	114	115	116	115	116	200	199	200
	Uncert.±	10,2	10,4	10,3	11,2	11,3	11,3	8,5	8,6	8,5	11,8	11	11,3	14,7	14,8	14,8

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ОПРЕДЕЛЕНИЕ ЗНАЧЕНИЙ ДИФФЕРЕНЦИАЛЬНЫХ ПОКАЗАТЕЛЕЙ ТОЧНОСТИ ЦИЛИНДРИЧЕСКИХ ЗУБЧАТЫХ КОЛЕС ПО РЕЗУЛЬТАТАМ КОМПЛЕКСНОЙ ДВУХПРОФИЛЬНОЙ ПРОВЕРКИ

Б.Д. Сотиров, С.Г. Иванов, И.С. Железаров

Комплексная двухпрофильная проверка является наиболее распространенным методом контроля качества цилиндрических зубчатых колес. Экспериментально исследованы возможности определения численных значений некоторых дифференциальных показателей точности по результатам двухпрофильной проверки.

Ключевые слова: *комплексная двухпрофильная проверка, отклонение шага зацепления, погрешность профиля, погрешность основного диаметра, отклонение угла профиля/*

ВИЗНАЧЕННЯ ЗНАЧЕНЬ ДИФЕРЕНЦІАЛЬНИХ ПОКАЗНИКІВ ТОЧНОСТІ ЦИЛІНДРИЧНИХ ЗУБЧАСТИХ КОЛІС ЗА РЕЗУЛЬТАТАМИ КОМПЛЕКСНОЇ ДВУХПРОФІЛЬНОЇ ПЕРЕВІРКИ

Б.Д. Сотіров, С.Г.Іванов, І.С.Железаров

Комплексна перевірки є найбільш поширеним методом контролю якості циліндричних зубчастих коліс. Експериментально досліджено можливості визначення чисельних значень деяких диференціальних показників точності за результатами двухпрофільної перевірки.

Ключові слова: *комплексної перевірки, відхилення кроку зачеплення, похибка профілю, похибка основного діаметра, відхилення кута профілю.*