



January 2012

COOMET Project 507/BY/10

Supplementary

COMPARISON OF LENGTH STANDARDS FOR MEASURING GEAR PARAMETERS

COOMET.L- S10

Final Report

Pilot laboratory:
Belarusian State Institute of Metrology (BelGIM)
Contact person:
Mr. V. Makarevich
BelGIM
Geometrical quantities measurement section
Starovilensky tract 93, Minsk, 220053, Belarus,
Fax +37517 2392338
E-mail: Makarevich@belgim.by

Contents

Contents	2
1 Participants	3
2 Organization of comparison	3
2.1 Principle of comparison.....	3
2.2 Time-schedule of comparison.....	3
3 Transfer standard	3
4 Measurement procedure	4
5 Environmental conditions	4
6 Measurement standards	5
6.1 Measurement standard of BelgIM.....	5
6.2 Measurement standard of VNIIMS.....	6
7 Measurement conditions for measuring the transfer standard	7
8 Uncertainty of measurement	7
9 Comparison results	7
10 Evaluation of measurement data	8
11 Conclusions	8
Bibliography	8

1 Participants

1.1 Participants of comparison are described in Table 1.

Table 1

NMI	Address	NMI acronym	Contact person	E-mail, phone, fax
Belarusian State Institute of Metrology	Starovilensky tract 93, Minsk, 220053, Belarus	BelGIM	Vladimir Makarevich	Tel: +375172392338 Fax: +375172880938 E-mail: Makarevich@belgim.by
All-Russian Scientific Research Institute of Metrological Service	46 Ozernaya st., Moscow, 119361, Russia	VNIIMS	Valery Lysenko	Tel: +495 437 34 29 Fax: +495 437 34 29 E-mail: lysenko@vniims.ru

2 Organization of comparison

2.1 Principle of comparison

2.1.1 Scheme of comparison: radial

2.1.2 Pilot laboratory: BelGIM

2.1.3 The aim of comparison is to:

- establish the degree of equivalence between the measurement standards;
- support the CMCs.

2.2 Time-schedule of comparison

2.2.1 Time-schedule of comparison is described in Table 2.

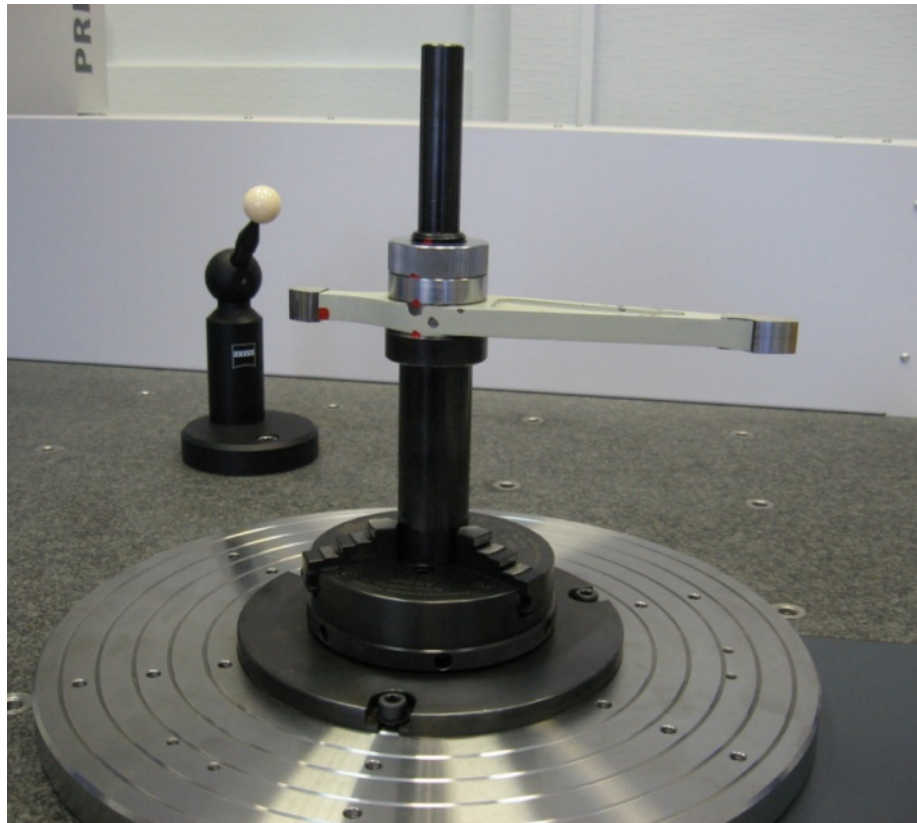
Table 2

NMI	Measurement time
BelGIM	September 2010
VNIIMS	April 2011
BelGIM	September 2011

3 Transfer standard

3.1 The transfer standard was a gear involute master No 5 provided by BelGIM.

3.2 This standard has two base circle radii, i.e. 150 and 60 mm, respectively, and corresponding profiles on the left and on the right (picture 1).



Picture 1 Transfer standard (gear involute master)

4 Measurement procedure

4.1 The involute profile was measured from root towards tip of the tooth . The scanning was performed in automatic mode along the mid-section of the base cylinder over the complete estimation range, with scanning speed of 2 mm/s.

The software program GEAR PRO involute was used to determine three parameters as follows: total profile deviation (F_{α}), profile form deviation ($f_{f\alpha}$) and profile slope deviation ($f_{H\alpha}$).

4.2 Each participant performed 10 measurements for each of two involute profiles with basic circle radius of 150 mm and 60 mm, respectively.

4.3 The measurement result for each parameter was calculated as a mean value from 10 measurements.

5 Environmental conditions

5.1 The environmental conditions are described in Table 3.

Table 3

Condition	Requirement
Ambient temperature, °C	$20 \pm 0,5$
Relative air humidity, %	from 40 to 60
Allowable deviation of ambient temperature, °C/day	1,0
Allowable deviation of ambient temperature, °C/hour	0,5
Allowable temperature gradient, °C/m ³	0,5

6 Measurement standards

6.1 Measurement standard of BelGIM

6.1.1 The measurement standard is shown in picture 2.



Picture 2 BelGIM measurement standard

6.1.2 Composition of the measurement standard

6.1.2.1 The measurement standard includes the following:

- Carl Zeiss PRISMO® ultra coordinate measuring machine (Germany) with rotary table;
- VAST gold® scanning probe;
- package of probes used to gage gear parameters;
- KMG-CHECK standards used to check the metrological characteristics of rotary table;
- rotary table accessories;
- material measures: gear involute master, reference gear wheel;
- software: CALIPSO 5.0 intended for all tasks , GEAR PRO 3.4 involute intended for measuring spur and helical gears, GEAR PRO 3.4 bevel intended for measuring bevel gears, CMM-Check intended for measuring KMG-CHECK standards.

6.2 Measurement standard of VNIIMS

6.2.1 The measurement standard is shown in picture 3.



Picture 3 VNIIMS measurement standard

6.2.2 Composition of the measurement standard

6.2.2.1 The measurement standard includes the following:

- interferometry measuring system for realization and dissemination of length for measuring form deviation of involute surfaces using special software;
- interferometry measuring system for realization and dissemination of length for measuring slope deviation of involute tooth using special software;
- interferometry measuring system for realization and dissemination of length for measuring kinematic error parameters;
- set of material measures: gear involute master, gear with reference tooth slope and reference gear wheel;
- auxiliary equipment including a rotary table with rotation angle sensor.

7 Measurement conditions for measuring the transfer standard

7.1 Measurement conditions for measuring the transfer standard are described in Table 4.

Table 4

Condition	Value	
Profile	Left	Right
Base circle radius, mm	150,030	60,140
Module m , mm	15,966	7,111
Profile slope α	20°	20°
Helix slope β	0°	0°
Evaluation range, mm	305,383 to 330,568	127,000 to 144,000
Probe diameter, mm	3,0	3,0
Filter λ_{light}	1	0,8
Scanning speed, mm/s	2	2

8 Uncertainty of measurement

8.1 Stated measurement uncertainties for gear involute measurements are given in Table 5 for BelGIM and VNIIMS, respectively.

Table 5

Laboratory	Standard uncertainty, μm		Combined standard uncertainty u_c , μm	Coverage factor, k	Expanded uncertainty, U , μm	Level of confidence, %
	u_A	u_B				
BelGIM	0,05	0,50	0,50	2	1,0	95
VNIIMS	0,20	0,15	0,25	2	0,5	95

9 Comparison results

9.1 Comparison results are given in Table 6.

Table 6

Nominal radius of basic circle, mm	Parameter	Result of measurement by VNIIMS, R_1 , μm	Result of measurement by BelGIM, R_2 , μm	Difference between measurement results of VNIIMS and BelGIM $ d_j $, μm	VNIIMS stated measurement uncertainty, u_{c1} , μm	BelGIM stated measurement uncertainty, u_{c2} , μm	$u(d_j)$, μm	$U(d_j)$, μm
60,140	$f_{f\alpha}$	1,818	1,669	0,15	0,25	0,50	0,56	1,12
	$f_{H\alpha}$	-1,643	-1,905	0,26				
	F_α	2,304	2,372	0,07				
150,030	$f_{f\alpha}$	0,55	0,472	0,08				
	$f_{H\alpha}$	0,484	0,234	0,25				
	F_α	0,792	0,593	0,20				

10 Evaluation of measurement data

10.1 The bilateral comparison establishes the degree of equivalence from the difference between the measurement results produced by measurement standards under comparison and from the associated expanded uncertainty with coverage factor $k=2$.

10.2 The degree of equivalence of the measurement standards is determined quantitatively using two quantities as follows (d_j , $U(d_j)$) i.e.:

- difference between measurement results, d_j ;
- expanded uncertainty $U(d_j)$ of this difference at 95 % confidence level:

$$d_j = R_2 - R_1, (1)$$

where R_1 means measurement result of VNIIMS;

R_2 means measurement result of BelGIM.

$$U(d_j) = 2u(d_j) (2)$$

$$u(d_j) = \sqrt{u_{c1}^2 + u_{c2}^2}, (3)$$

where u_{c1} and u_{c2} are stated combined standard uncertainties of VNIIMS and BelGIM, respectively.

The measurement standards under comparison are equivalent, if the following condition is met

$$|d_j| \leq 2u(d_j) \text{ or } |d_j| \leq U(d_j) (4)$$

11 Conclusions

11.1 Comparison results demonstrate that the actual measurement uncertainties are consistent with the stated values.

11.2 The measurement standards under comparison are equivalent.

11.3 Once have been published, the comparison results will support CMC entries classified under LENGTH - 5.3 Gear standards - 5.3.1 Spur gear and 5.3.5 Gear involute master.

Bibliography

- [1] ISO 1328-1:1996 Cylindrical gears. ISO system of accuracy . Part 1: Definitions and allowable values of deviations to corresponding flanks of gear teeth.
- [2] ISO/IEC Guide 98-3:2008 Uncertainty of Measurement – Part 3: Guide to the Expression of Uncertainty in Measurement (GUM:1995).
- [3] COOMET R/GM/11:2010 Regulations for comparison of measurement standards from the national metrological institutes of COOMET.