Analysis of abilities of multi-sensor CMM to measurements of rolling bearing components

Analiza możliwości zastosowania wielosensorowej CMM do pomiarów elementów łożysk tocznych

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The paper presents the abilities of multi-sensor coordinate technique to measurements of selected components of rolling bearings.
The results of spherical cap of conical roller radius and angle between the main and auxiliary track of the conical bearing inner ring measurements are also presented.
KEYWORDS: multi-sensor coordinate measuring machine, rolling bearings, confocal sensor

Measurement of rolling bearing components due to their specificity and tolerances requires to use appropriate measuring devices to ensure sufficient value of the measurement uncertainty

The development of multi-sensor coordinate measuring devices in recent years makes it possible to use them to measure rolling bearings components. Measurement of these parts using methods that are applied in hitherto practice can be difficult or troublesome [1, 3].

The paper presents abilities of multi-sensor coordinate measuring technique to measure the radius of the spherical cap of conical roller and the angle between the primary running track and the auxiliary running track of the inner ring of conical bearing.

Examined components

Following components were measured:
- rollers of conical bearing (fig. 1)
- inner ring of conical bearing (fig. 2).

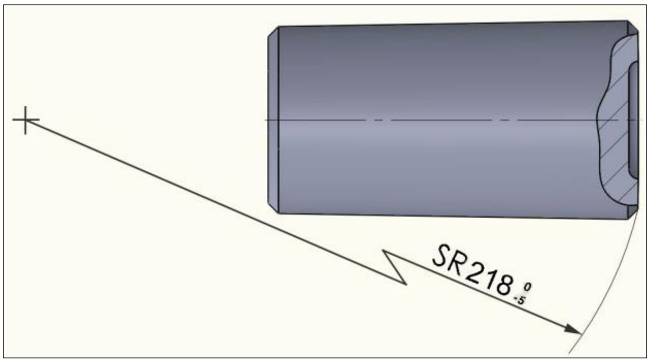

Fig. 1. Roller of conical bearing

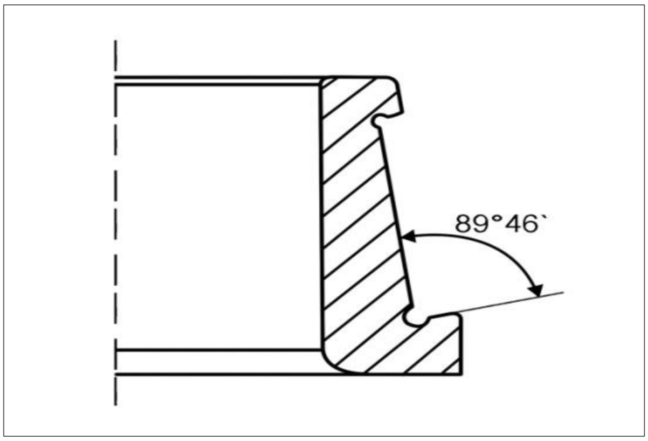

Fig. 2. Inner ring of conical bearing

Measuring instruments

Measurements were performed with the use of the ZEISS O-Inspect 422 multi-sensor measuring machine. This device makes it possible to make contact and optical measurements, because it is equipped with three types of sensors:
- tactile head VAST XXT,
- optical head equipped with Discovery V12 lens,
- confocal white light sensor.

In order to verify obtained results, comparative measurements were made using:
- contact profilometer FormTalysurf PGI 1230,
- scanning coherent interferometer Talysurf CCI [2, 4].

Measurement of conical roller spherical cap

The measurement results of the spherical cap of conical bearing were compared using the contact profilometer FormTalysurf, scanning coherent interferometer Talysurf CCI and the white light sensor of the O-Inspect 422 system. In the case of a contact profilometer, there is a risk of collision due to the geometry of the roller cap (the central cavity) and difficulty in positioning the measuring element, so that the measurement is performed along the meridian. The influence of inaccurate roller positioning during measurements on obtained radius value results can be described with the use of following equation:

$$R_x = \sqrt[2]{R^2 - x^2}$$

where: R_x, mm – measured radius of the cap; *R,* mm – radius of the cap; *x*, mm – value of the displacement of the measurement outline relative to the sphere pole.

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Since $R >> x$, the effect of inaccurate positioning of the roller during the measurement of the cap radius on the measurement error is small.

TalyMap Platinium software was used to analyze measured profile. Fig. 3 shows the isometric image of the conical roller cap based on the measurement on the Talysurf CCI optical profilometer [2, 4].

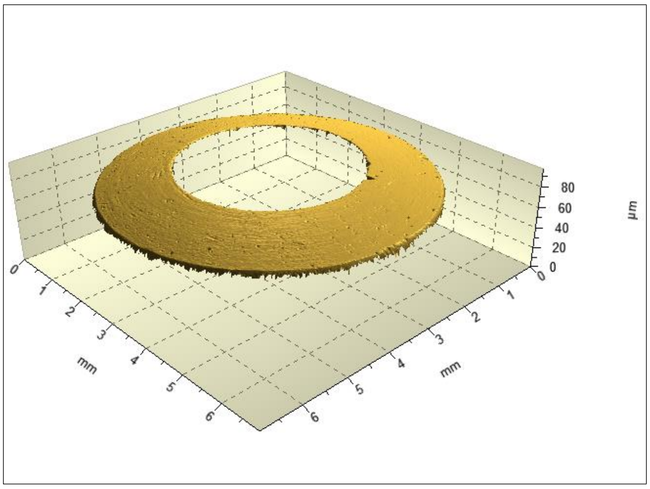

Fig. 3. Isometric image of spherical cap surface of roller

The radius of the spherical cap is determined on the basis of different number of random points and on the basis of all measured points [5]. The procedure for determining the radius of the roller cap is shown in Fig. 4, and results are given in Table I.

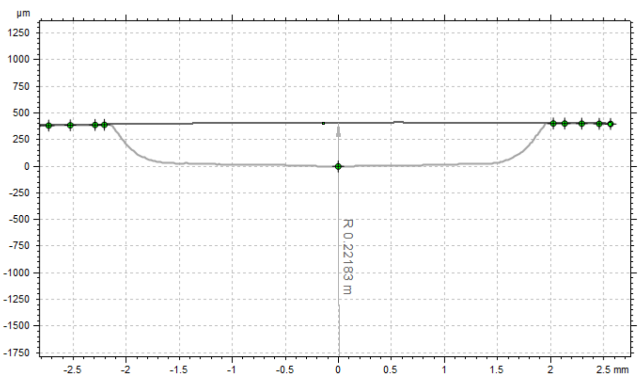

Fig. 4. Procedure for determining the radius of conical roller cap

TABLE I. Measurements of the radius of conical roller cap

Number of points for determination of the roller cap radius	Roller cap radius *R*, mm		
	FormTalysurf PGI	Talysurf CCI	O-Inspect
4	218.4	215.0	211.8
6	217.9	214.6	195.3
8	217.7	214.8	202.0
10	217.5	215.8	208.9
All points	216.7	217.9	170.4
Average	217.6	215.6	197.7
Standard deviation	0.6	1.4	16.5

The measurement results obtained by the white light sensor are characterized by significant dispersion and differ from the results obtained by the contact profilometer and the optical device.

Following standards were used to analyze the reliability of the conical roller cap radius measurement:

- step standard consisting of 2 K-class reference plates with a center lengths of 3 and 4 mm, U = 0.049 µm (k = 2), bonded to interference glass plate of class I with a maximum flatness of less than 30 nm,
- ceramic satin reference sphere with radius R = 15.00125 mm, determined with uncertainty U = 0.3 µm (k = 2), roundness deviation $RONt$ = 0.074 µm,
- roller standard – cylinder with base radius R = 40.1024 mm, determined with uncertainty U = 0.9 µm (k = 2), $RONt$ = 0.3 µm.

TABLE II. Measurement results of a step standard using confocal white light sensor

Average	0.9988
Standard deviation, µm	0.89
Mean square error, µm	0.28

By using the interference glass and reference plates, a step standard of height h = 1 mm was developed. There were N = 10 measurements of the step standard made using the white light sensor. The measurement results are shown in Table II.

The maximum permissible length measurement error for the white light sensor according to VDI/VDE 2617 6.2 is MPE E(OT) 3.90 + L/250 µm. Achieved results confirmed the fulfillment of the specifications for the white light sensor.

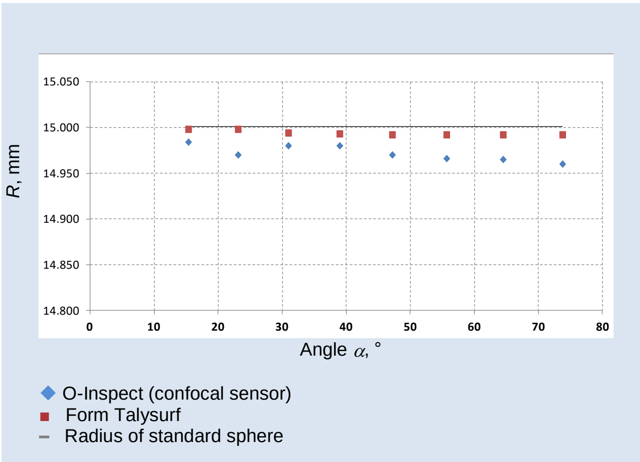

Fig. 5. Measurement results of the standard sphere step pattern

Measurements of the ceramic profile of the standard sphere were carried out in the cross-section through the pole. The length of the measured circle arc corresponds to the chord length c = 18 mm and the center angle α = 73.7°. White light sensor and FormTalysurf PGI contact probe equipped with a 2 mm diameter ball tip, was applied. The radius of the sphere was determined by several arc lengths symmetrical to the pole, using advanced contour analysis software. The results of the measurements are illustrated in Fig. 5.

The measurement results obtained with the contact profilometer are less error-prone. The accuracy of the measurement conducted with the white light sensor decreases as the angle of the arc is increased that is used to determine the radius of the cap.

Less accurate measurement with a white light sensor results from a much higher noise value for this measurement than with a contact profilometer. A comparison of obtained sphere profiles after removal of the nominal shape is shown in Fig. 6.

a)

b)

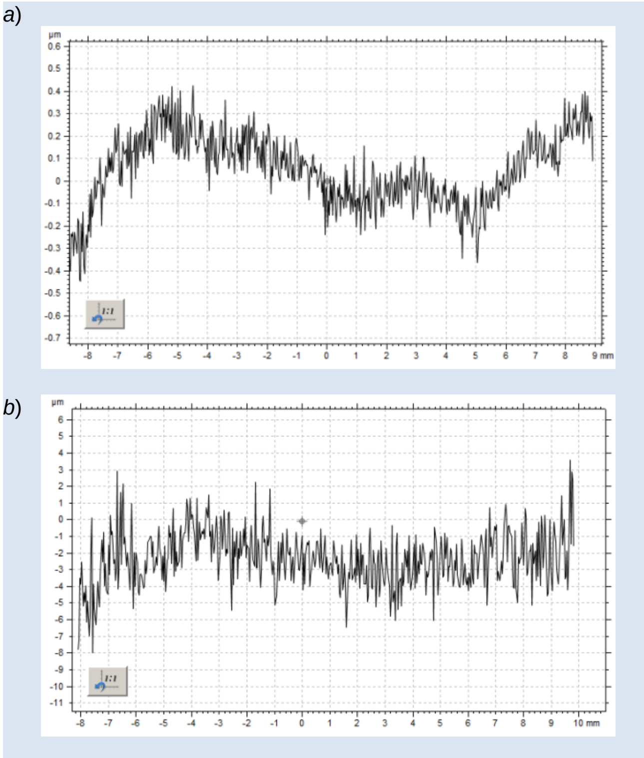

Fig. 6. Sphere profile determined using: *a*) FormTalysurf PGI, *b*) confocal white light sensor

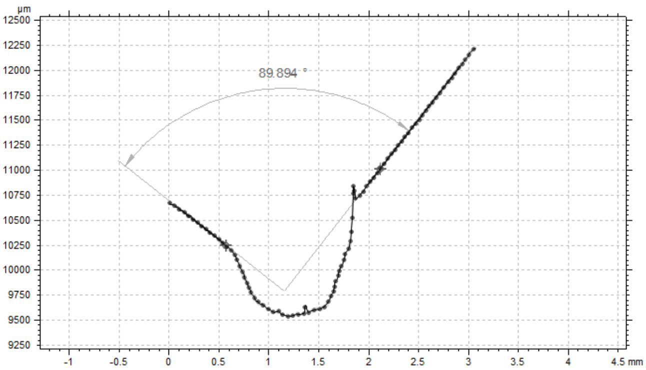

Fig. 7. Profile between the primary running track and the auxiliary running track

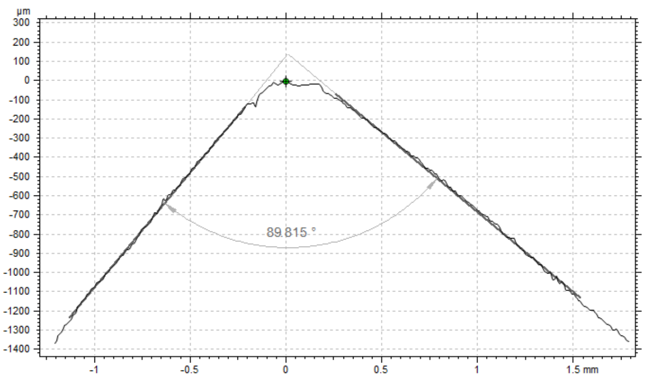

Fig. 8. Profile of a right angle standard

Angle measurement

A confocal white light sensor was used to measure the angle between the primary running track and the auxiliary running track of the inner ring of the conical bearing. The difficulty of this measurement is that the width of the track is about 2 mm, and there is an undercut between the running tracks, which may cause damage to the instrument during contact measurements.

The measured profile of the inner ring of the conical bearing is shown in Fig. 7.

For the purpose of measuring reliability, the measurement of the standard angle was conducted, whose measurement surfaces had similar reflectivity as the running track surface of the bearing ring. The result is shown in Fig. 8.

Conclusions

Measurement results do not justify unequivocally the use of multi-sensor coordinate measuring technology to measure selected roller bearing components.

The results of the measurements using the white light sensor for the applied standards show the high accuracy of the measurement of the distance in the case of surfaces perpendicular to the direction of the light beam. In the case of spherical and cylindrical surfaces with high reflection for points, where the angle of incidence of the beam is not perpendicular to the surface to be measured, there is a noise with a high value for the results. This phenomenon was confirmed during the measurement of radius of the conical roller and resulted in a significant dispersion of the results depending on the number of points taken to determine the radius of the cap.

Results of the angular measurements between the primary running track and the auxiliary running track of the inner ring of the bearing obtained by the white light sensor can be considered as reliable, taking into account the results obtained for the angle standard.

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