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RECENT TRENDS IN MEASUREMENTS OF SPHERICITY

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Abstract: *Parameters relating to sphericity are not included in the standards of the Geometrical Product Specifications (GPS). The methods used for assessing sphericity involve measuring roundness profiles of a sphere in several cross-sections. However, such methods do not guarantee accurate qualitative and quantitative results, especially if the analyzed surface contains local irregularities. This paper presents the latest findings on the measurement of sphericity deviations and the fundamentals of the concept of combined measurement of sphericity.*
Key words: *sphericity, measurement, deviation, evaluation*

1. INTRODUCTION

In industrial practice, assessing the sphericity of an object requires measuring its roundness profiles in several selected cross-sections. Since the quantitative and qualitative information obtained in this way is generally not sufficiently accurate, specifically, if some local irregularities are present, manufacturers of spherical components used, for instance, by the rolling bearing or automotive industries, expect improvements in this field. It is vital that assessment be reliable and that the whole object measured be graphically represented.

The method developed by the authors, which is a method of combined measurement, meets these expectations. It involves first measuring roundness profiles of a spherical object placed on a measuring table in several equally spaced cross-sections, then rotating it by a right angle about the vertical axis, and measuring it in another several equally spaced cross-sections. Such measurement can be performed using radial measuring instruments equipped with a special unit for controlling the object rotation about at least two perpendicular axes. The concept requires developing a mathematical model of measurement strategy.

2. METHODS OF SPHERICITY MEASUREMENT

According to the existing industrial standards, the strategy for sphericity assessment consists in measuring roundness profiles in two or three mutually perpendicular planes (see Fig. 1). The results obtained for the individual cross-sections are represented graphically in polar coordinates, which makes it possible to determine sphericity deviations. This approach to sphericity measurement is very simplified because a significant part of the spherical surface is not measured.

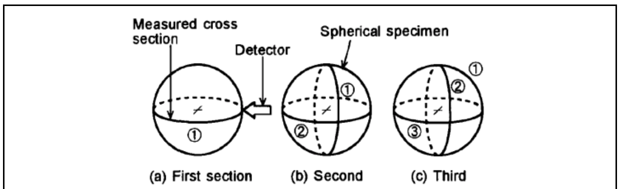

Fig. 1. The most popular industrial strategy for sphericity measurement (Kanada, 1997)

Most industrial standards state that the best reference in sphericity evaluation is the minimum circle circumscribed on a measured profile. Sphericity measurements are generally conducted using radial devices, i.e. ones determining changes in the radius. In radial measurement, the workpiece is placed on a table, which can be rotary or non-rotary, according to the design of the device. If the measuring table is non-rotary, the measuring sensor rotates. Figure 2 shows a schematic diagram of a typical radial device (Kanada, 1997).

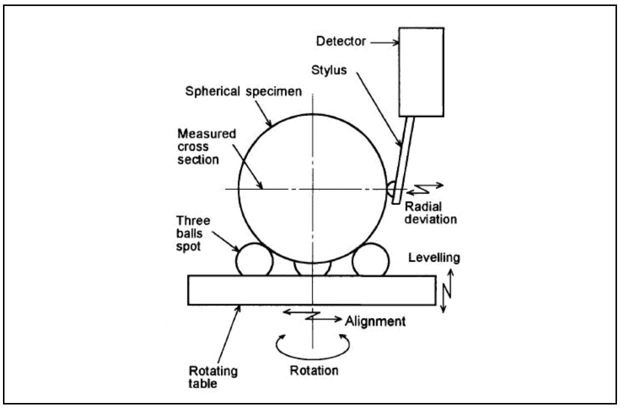

Fig. 2. Measurement of spherical element by the radius change instrument (Kanada, 1997)

Recent advances in metrology have caused that researchers are working on the development of other methods for sphericity measurement. A large number of institutions are investigating the use of coordinate measurement systems to assess sphericity deviations. As the accuracy of coordinate measuring machines is increasing, this technique may soon be applied not only to assess sphericity but also other form deviations. Nowadays, however, it is still the radial devices that provide the highest measurement accuracy. One of the most original methods proposed recently for measuring sphericity was that developed by Gleason & Schwenke (1998) (see Fig. 3).

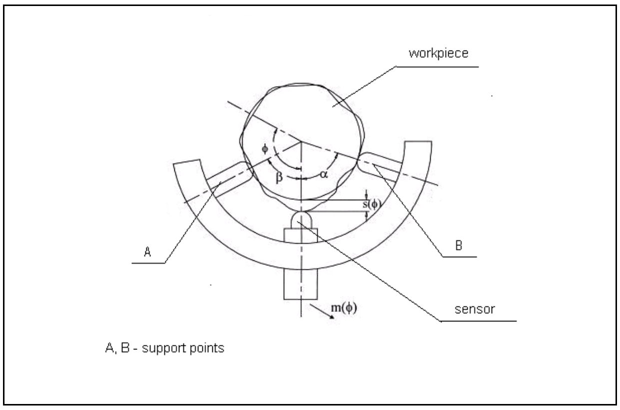

Fig. 3. Measurement of sphericity using the three-point method proposed by Gleason & Schwenke (1998)

This measurement strategy is called the three-point method. When the measurement is performed for a rotating workpiece, the measuring signal *m(ø)* is affected not only by the form deviation *s(ø)* but also by the mutual alignment of the support points and the location of the sensor. The best way to determine the relationship between the value of the measuring signal and the real deviation is to apply a Fourier transform (Adamczak et al., 2011). An advantage of the concept presented in Ref. [2] is that the measuring signal is not affected by the spindle errors. The most important drawback is that some harmonic components of the profile cannot be detected by the measuring system. Another interesting concept of measurement of spherical workpieces is the use of optical systems (Halkaci et al., 2007). Their accuracy, however, is still relatively low, when form deviations are measured. This suggests that optical methods are not suitable for accurate sphericity measurements.

3. EVALUATION OF SPHERICITY DEVIATIONS

A large number of academic and industrial research centres are engaged in developing and improving methods for the measurement of spherical surfaces as well as methods for the evaluation of sphericity deviations. Traditionally, the methods used for assessing deviations from an ideal sphere are similar to those used for analyzing out-of-roundness.

The research activities conducted in this area include calculation of reference sphericity parameters based on the measurement data. In order to solve this problem, different approaches can be applied. Numerical methods, for instance, seem to be suitable when the measurement is performed using a coordinate measuring machine (Samuel & Shunmugam, 2003). Another method of calculation of reference spheres is to apply computational geometry techniques, which frequently make use of the so-called Voronoi diagrams (see Samuel & Shunmugam, 2002, and Huang, 1999). Sphericity can also be evaluated using the method described by Fan & Lee (1999). They suggest that sphericity should be assessed with respect to the minimum zone reference sphere by applying the principle of minimum total potential energy. A completely different approach to the assessment of sphericity deviations was proposed by Kanada (1997), who suggests analyzing the statistical parameters.

4. A NOVEL APPROACH TO SPHERICITY MEASUREMENT

The concept of accurate measurement of sphericity deviations developed at the Kielce University of Technology is based on various solutions presented in the literature as well as the authors' experience concerning accurate measurement of roundness and cylindricity. The research project involving the development of the method was divided into two parts: theoretical (including computer simulations) and experimental. The theoretical investigations included: defining the spherical surface, selecting a relevant measurement strategy, generating and superimposing profiles, filtering the profiles, calculating the reference sphere and the sphericity parameters (Adamczak et al., 2009).

The authors assumed the following strategy of measurement. First, a selected sphere is measured on a measuring table to determine its roundness profiles in several equally-spaced cross-sections. Next, the object is rotated at a right angle about the vertical axis so that more cross-sections can be measured (see Fig. 4). The limitation of the approach proposed by authors is that the fixing unit may not rotate the workpiece accurately, which can influence measurement data.

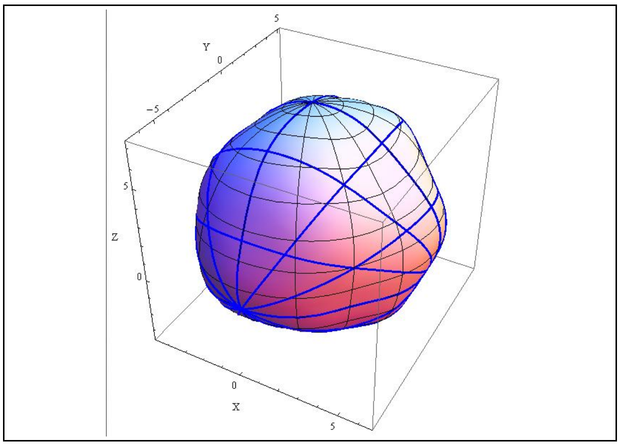

Fig. 4. Strategy for sphericity measurement proposed by the authors

5. SUMMARY

Since the existing measurement strategies applied to assess sphericity deviations are not sufficiently accurate, the authors developed a combined method, which involves measuring the changes in radius with radial devices. The measuring instrument is a computer-aided radial device for measuring radius changes in roundness profiles. It is equipped with a special-purpose fixing unit for accurate positioning of the measured element. The next stage of the research will be the experimental verification of the concept. It will be carried out at the Kielce University of Technology at the Laboratory of Computer-Aided Measurements of Geometrical Quantities.

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