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Four-point technique development for measuring spherical surfaces of machine parts

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Four-point technique development for measuring spherical surfaces of machine parts

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Abstract. The article presents the theoretical foundations of the four-point measurements of spherical surfaces of parts method, allowing to increase the efficiency of spherical structural elements of ball tips of various sizes control. Compared to the measurement method on the coordinate measuring machine, the developed technique can be used at workplaces of forming spherical elements. The technique ensures the efficiency of measurements and increases the efficiency of carrying out the cutting tool settings.

1. Introduction.

Traction is considered to be the most important knot of the car from the viewpoint of its safety, when being driven. Traction are a mandatory element of the steering system, it can also be included in the vehicle suspension. The behavior of the vehicle during maneuvering and cornering depends on its technical condition. It ensures the transmission of forces and the prescribed laws of displacement between the various connecting levers. Spherical mates are the main elements that allow this class of parts to perform the function of assignment. Structurally, they are made in the form of a spherical support and a spherical finger. One of the most important key characteristics of a spherical finger is the diameter of the sphere. The correctness and durability of the operation of a spherical coupling depends on the value of this indicator determined as a result of simulating operational loads by the size of the gap in a spherical mate [1]. As a rule, the parameters of the spherical surface of these parts are measured on coordinate measuring machines. Measurements on the coordinate machines are distinguished by high accuracy, but low efficiency and high labor intensity.

As a rule, at workplaces, instead of CMM measurements, measurement of a spherical surface radius by the two-point method (micrometer) is used, these values differ from the values of the diameter of a spherical surface measured by the coordinate method. Since there is an error associated with the position of the measuring tips of the device during the two-point measurements. The difference can be up to 0.02 mm. from the actual size of the spherical surface. Generally accepted tolerances on spherical surfaces allow 0.05 mm, this value can reach up to 1/3 of the tolerance field. Using the two-point method instead of measuring the diametral size of a spherical surface can make the process of timely amending a CNC lathe program dependent on the qualifications of a controller or adjuster, and can potentially lead to the appearance of inappropriate products for the diametrical size of a spherical surface, an excessive gap in the pairing and, as a consequence, increased wear on the whole pairing.

At present, the radius of the spherical surface of the ball pin and the position of its center in an enterprise is measured only in the laboratory on the IOTA 2204 coordinate measuring machine (Figure 1 b).
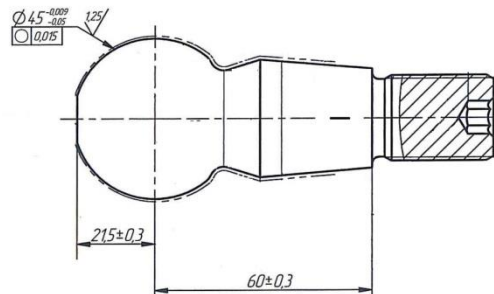

Fig. 1 a) the key indicators of the ball pin, affecting the performance of the function of official purpose, b) the IOTA 2204 measuring machine in the process of measurement. This is a rather complicated and time-consuming procedure. According to internal regulatory documents of an enterprise, 1-2 out of 100 manufactured parts are exposed to measurement. As a consequence, the rapid assessment of values for the management of these indicators in the process is impossible [2, 3].

2. Theoretical part

The task was set to improve the performance of measurements of these indicators, with the organization of measurements near workplaces of forming a spherical surface. This problem can be solved by applying the four-point method of measuring a spherical surface coordinates. To find the diametrical size of a sphere, it is necessary to know the position coordinates of any four points lying on the sphere. To obtain such information it is necessary to apply to the following measurement scheme: the finger is installed on a special support before contact with four recording devices (indicators), registering the size value along the Z coordinate with the previously known position coordinates of the measuring tips along the X and Y axis $(X_1, Y_1, X_2, Y_2, X_3, Y_3, X_4, Y_4)$ - figure 2. The values of the coordinates along the
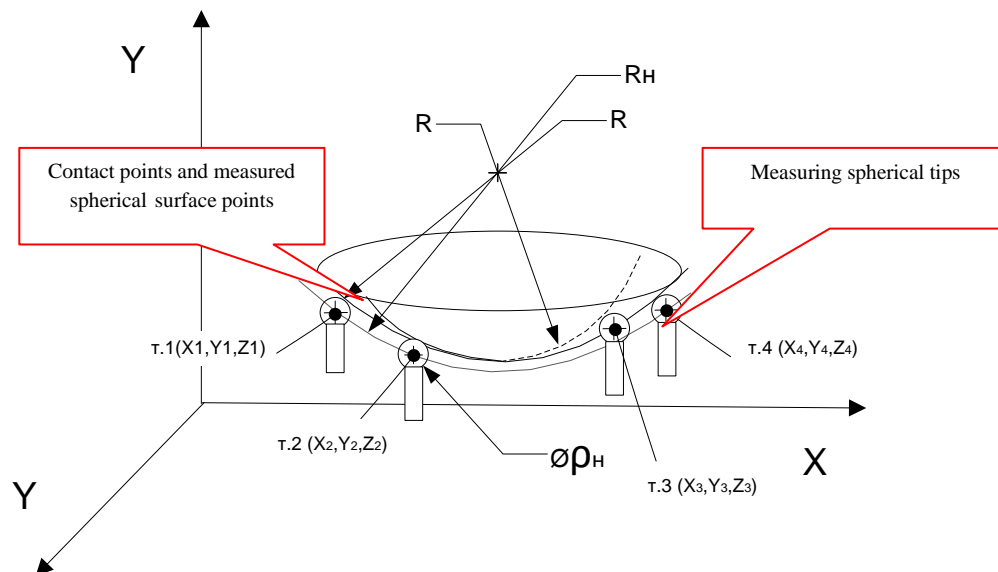
axis Z - (Z_1, Z_2, Z_3, Z_4) obtained in the process of measurement must be inserted into a system of four equations with four unknown parameters of a spherical surface (1).
Fig. 2 Diagram of four-point measurements of the radius and coordinates of its center.

In this case, the system of equations will have one solution, in the form of the coordinates of the position X_0, Y_0, Z_0, R_H, the center of the spherical element of the tip of the measuring indicator and the radius of the spherical surface tangent to the measurement points.

$$\begin{cases} (X_1 - X_0)^2 + (Y_1 - Y_0)^2 + (Z_1 - Z_0)^2 = R_H^2 \\ (X_2 - X_0)^2 + (Y_2 - Y_0)^2 + (Z_2 - Z_0)^2 = R_H^2 \\ (X_3 - X_0)^2 + (Y_3 - Y_0)^2 + (Z_3 - Z_0)^2 = R_H^2 \\ (X_4 - X_0)^2 + (Y_4 - Y_0)^2 + (Z_4 - Z_0)^2 = R_H^2 \end{cases} \quad (1)$$

The found values of the coordinates of the sphere center of the measuring tips X_0, Y_0, Z_0 are the desired coordinates of the center of the measured spherical surface of the ball pin X_, Y_, Z _.

To find the value of the radius of the spherical surface R, it is necessary to subtract from the found radius R_H the value of the known diameter of the spherical tip ρ_H (2).

R = R_H − ρ_H (2)

To use the methodology, it is necessary to automate calculations for finding solutions to the system of equations. The simplest method of finding a solution to a system of equations is to use the built-in search for solutions add-in in the standard Excel package. To test the methodology, the above formulas of the equations were entered into the program cells. The actual values of the coordinates are obtained by measuring the spherical surface of a known diametrical size. The measurements were carried out when installing the part in the universal globes vice with the single-coordinate altimeter of the MahrDigimahr 817 L firm, similar to the method of finding the diametrical size in [4-8]. The measured values of the indicators are highlighted in red in table 1.

3. Practical results

The main condition for successful solution of the equation is that the coordinates of all four points should not lie in the same plane (this condition must be taken into account when making the body of a special measuring device). After that, a solution was found to the system of equations.

Table1.Table of search results for a system of equations by a superstructure
"Search for solutions" package Excel

c notation	conventional	Diameter of measuring tip, mm.			
Ppoint number		1	2	3	4
x	xi	-10,000	9,000	10,000	-9,000
y	yi	10,000	9,000	-10,000	-9,000
z	zi	10,001	9,000	10,003	9,002
		The results of solving the equation - the coordinates of the radius of the measured sphere, mm			
x	x0	0,000000	0,000000	0,000000	0,000000
y	y0	0,000000	0,000000	0,000000	0,000000
z	z0	28,500000	28,500000	28,500000	28,500000
RН		23,286262	23,286262	23,286262	23,286262
		The square of the radius of the sphere center points			
RН ^2		542,25	542,25	542,25	542,25
		Sphere radius, mm			
R		20,286262			

The obtained values of the radius of the sphere and the coordinates of the position of its centers coincided with their theoretical values.

Thus, it has been established that the developed four-point measurement technique is suitable for finding characteristics of the accuracy of a spherical surface provided that a special measuring device is developed, for example, using inductive linear displacement sensors, and measurement data processing instrumentation.

References

 [1]   Safarov D T and Kondrashov A G 2018 *Stand for monitoring the operational parameters of conjugations "ball support - Body of the tie-rod end" of automotive components* IOP Conference Series: Materials Science and Engineering Vol 289 **012018**

 [2]   VasilievV A, Odinokov S A and Serov M M 2016 *Modern methods for the quality management of high-rate melt solidification Russian Metallurgy* Metally Issue 13 pp 1321-24

 [3]   Safarov D T, Fedorova K A and Ilyasova A I 2016 *Algorithms development of making special techniques in APQP manufacturing process of automotive components* Vol 134 Issue 1 8 **012036**

 [4]   Kondrashov A G, Safarov D T and Kas'yanov S V 2013 *Diagnosticheskie izmereniya geometricheskih parametrov prostranstvenno-slozhnyh detalej avtokomponentov odnokoordinatnym vysotomerom* Kontrol'. Diagnostika No 8 pp 60-64

 [5]   Kondrashov A G, Safarov D T and Kas'yanov S V 2013 *Izmerenie otnositel'nogo polozheniya i radiusa cilindricheskih ehlementov detali priborom dlya izmereniya vysot* Promyshlennye ASU i kontrollery No 3 pp 18-24

 [6]   Safarov D T, Kasyanov S V, Kondrashov A G 2019 *Informative value of measurements for quality management of auto parts* Lecture Notes in Mechanical Engineering pp 1657-66

 [7]   Safarov D T, Kondrashov A G and Khafizov I I 2018 *The method of diagnosing machine systems by measuring the accuracy of manufactured parts* IOP Conference Series: Materials Science and Engineering Vol 412 No 1 **012065**

 [8]   Kasjanov S V, Kondrashov A G and Safarov D T 2017 *Regulation of Geometrical Parameters Deviations of Automotive Components Parts through Diagnostic Measurements Organization* Procedia Engineering V 206 pp 1508-14