

A Study on Evaluation of Sphericity and Related features of Shaft with Spherical End Faces

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Introduction

Recently, for introducing the G.P.S. (Geometrical product specification) to the technical drawings and the machining, the assessment of the related features (position, concentricity, symmetry) is getting more important. For example, this paper describes assessing of spherical parts that have the shaft and spherical end face. For assessing this part, it is very important not only measuring a form of the sphere, but also estimating a related feature between sphere and shaft.

The authors have developed the spherical coordinate instrument. Using with this system, the form deviation of the specimen is obtained in the spherical coordinates. Furthermore, the technique is presented to assess the related feature between the straight shaft and the sphere of end faces .

Measuring System

As shown in Fig.1 , the instrument has a vertical and a horizontal high accuracy air spindles. These two spindle axes cross perpendicularly to each other. The spherical specimen is set on the vertical spindle. And the measuring probe is mounted on the horizontal spindle. By rotating these two spindles, the probe generates a sphere datum. The form deviation of specimen surface from an accurate sphere form is obtained.

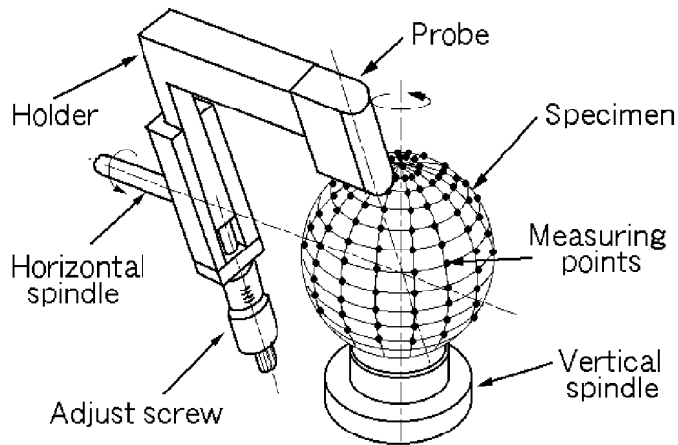


Fig.1 Measuring system

an accurate sphere form is obtained.

In this system, it is possible to use the sensor which has a very high resolution with short measurement range. In this paper, the laser type sensor with $0.005\mu\text{m}$ (max.) resolution is used. For the experiment, the measurement range is set to $+30\mu\text{m}\sim-30\mu\text{m}$.

In this system, the measuring area covers the whole sphere except holding part of the spindle. Also, it is possible to measure the form of asphere within a limited range of the probe.

Specimen

As mentioned above, for introducing the G.P.S. (Geometrical product specification) to the technical drawings and the machining, the assessment of the related features (position, concentricity, symmetry) is getting more important. A typical example of this problem, the assessment of spherical parts that have the shaft and spherical end faces (Fig.2) is selected. It is very important not only measuring a form of the sphere, but also estimating a related feature between sphere and shaft.

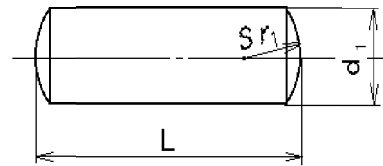


Fig.2 Specimen

Measurement setup

It is necessary for assessing the form of the sphere and the related feature to measure the sphere and shaft at the same time. For this purpose, the measuring system is arranged as shown in Figure 3. The specimen is mounted to the vertical spindle. For measuring the spherical end face, the probe rotates around the horizontal spindle and the specimen rotates around the vertical spindle. For assessing the related feature between sphere and shaft, the probe is set to the horizontal direction. Then the measurement data of shaft is obtained by rotating the vertical spindle. If exceed sensor range, the probe is adjusted by the adjust screw (Fig.1).

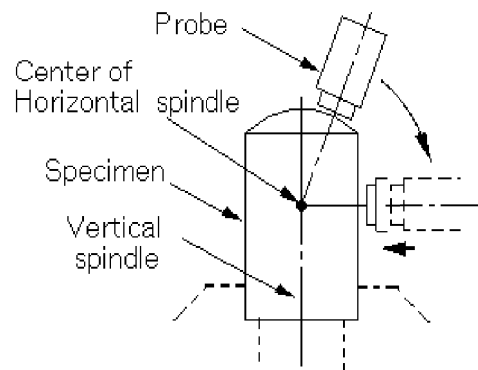


Fig.3 Measuring probe and specimen

Analysis

For the measurement and evaluation of sphericity, a best fit sphere by the least square method is applied. The data close to pole are not situated in equi-distance when the data measured by the spherical coordinate instrument. Then , we introduced weight function related to region of a data point area.[1]

For the estimation of a related feature between the sphere and the shaft, it is necessary to get a position of sphere center and a position of the shaft center . From the former data of sphericity measurement, the sphere center is obtained. From the latter data of the shaft measurement, the shaft center is defined. The roundness of shaft part of specimen is measured and calculate the position of the shaft center using a best fit circle by the least square method.

Result of experiments

Table 1 shows the specification of shaft for experiments. This specimens has been ground with center-less grinder and specially provided grinder.

The measuring data of the end faces of the sphere have gotten 200 point (interval 1.8 degree) during a one revolution of the vertical spindle. And the horizontal spindle have been positioning from pole($\theta = 0$ degree) to $\theta = 24.3$ (S1), 35.1 (S2) degree (interval 0.9 degree).

Figure 4 shows the contour map of form errors of spherical end face. The error of local sphere form assessed by means of least square method fitting a sphere form to measured data.

Table 2 shows the result of experiments. P.D.S.(Profile deviation of Any surface) shows the form errors of spherical end face. The data of position deviation shows the related feature between sphere and shaft.

Figure 5 shows the cross-section form through the pole in Figure 4. Figure 6 shows the cross-section form measured with Form talysuf for the same specimen. It shows good similarity.

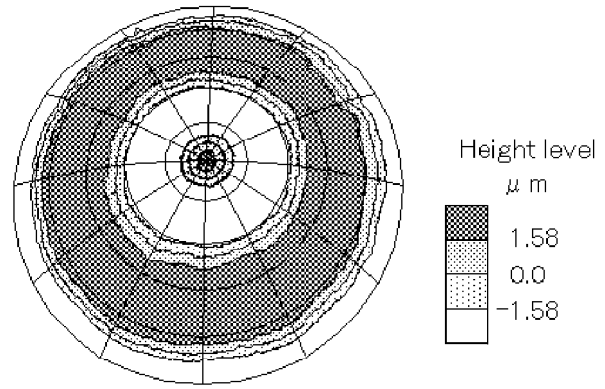


Fig.4 Contour map for S1

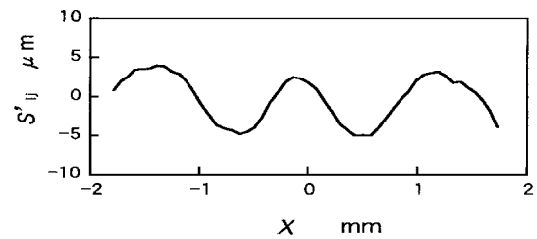


Fig.5 Cross-sectioned form through the pole in Fig.4

Tab.1 Specimens

Specimens No.	d1 mm	L mm	r1 mm
S 1	ϕ 5	71	4.5
S 2	ϕ 4	17	2.8

Tab.2 Result of experiments

Specimens No.	Profile deviation of Any surface(P.D.S.)		Position deviation e s mm
	PV μ m	rms	
S 1	13.0	1.58	0.79
S 2	6.5	0.70	1.48

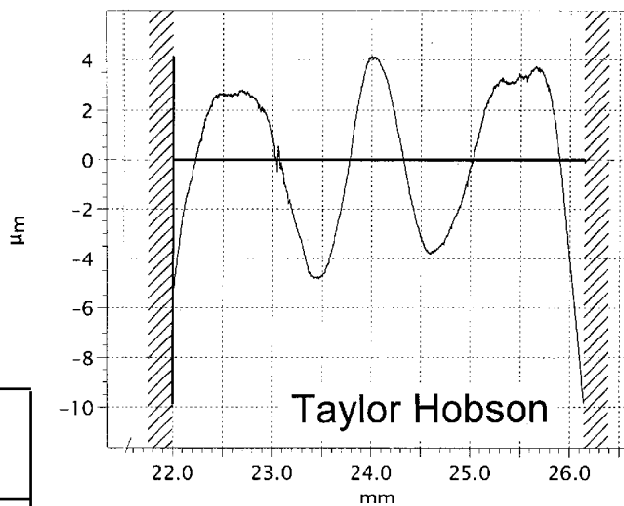


Fig.6 Cross-sectioned form through the pole with the Form talysuf

Effect of shaft's form error

Getting data from experiment setup as shown as Figure 3, it is expected the measuring error of shaft's center. To consider of this effect, the form error of shaft is assessed. Using with cylindricity measuring instrument with a air rotating table (Rondcom 50A-150: Tokyo Seimitu), the form data of the shaft of the specimen is measured. For every section data, it is fitting circle by least square method as shown in Figure 7.

Figure 8 show the experimental result for shaft S1. The center of position error is smaller than $0.03\mu\text{m}$. From this study, it is obvious that effect of the form error of shaft is small, in this case.

Conclusion

This paper presented the study on the evaluation of spherical part that have the shaft and spherical end face. A new measuring technique using with spherical coordinate system is presented.

Acknowledgment

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1. Masaaki Takahashi, Tadao Tsukada, Kazuyuki Sasajima, Measurement of Partial Sphere by Spherical Coordinate System (3rd Report) Journal of Japan Society for Design Engineering, 34(6), 196(1999) (in Japanese)

Keyword: Sphere, form, measuring, related features

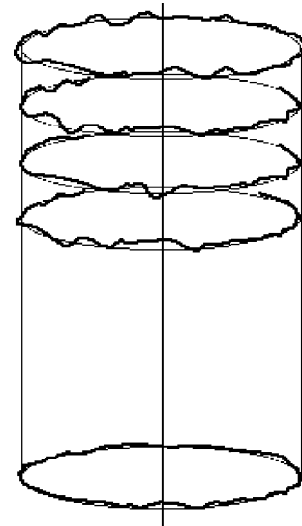


Fig.7 Fitting circle for section

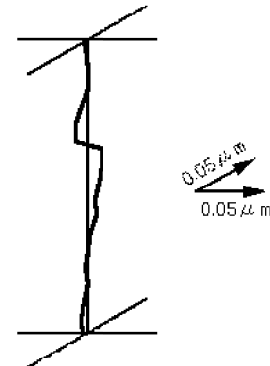


Fig.8 Center line of shaft