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Two dimensional measuring methods of geometrical adjectives of cylindrical pins

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Abstract. Both instrumental errors and method errors of measuring tools, depending on reference values deviation, should be taken into account in measurement accuracy tolerance calculation. Uncorrected form deviations of measuring surfaces originate from dimensions procedural errors. A geometrical representation of a smooth cylindrical pin specifying primary errors, coordinate systems and bases is developed. The measuring methods of cylindrical pin form deviation in longitudinal and cross sections are developed based on this model. According to the measurement data realistic pin surfaces are constructed. The form deviation measurement rules are proposed. The mentioned measurement methods reveal procedural errors of measurement that depend on the kind of form deviation and error values.

1. Introduction

Operating standards specify many geometrical adjectives reference systems such as spacing and form deviation, linear and angular dimensions, so that geometry precision of components and goods cannot be normalized in complex. This is resulted in quality deterioration of machine and instrument-making production still at the stage of the design process. Both Russian and foreign specialists conduct researches of smooth cylindrical surface mating behavior. Little attention is paid to geometrical representations and measurement methods development of pin geometrical adjectives.

Geometry precision of components and goods in the manufacturing process should be controlled by the measurement technique (measurement methods) defined in Standards being the principle metrological document. A measurement method is specific and developed for a particular measuring object. It should include specific bases, systems of reference, geometrical adjectives composition of every component, a measuring object model, measurement design and certificate conforming measurement data authenticity based on measurement error estimation of each value. Hence, the method of measurement is to be indicated in an operational procedure.

2. Problem statement

Paper [1] describes the technique of linear and angular elemental and coordinates dimensions, component parts spacing and form deviation formed by plane and cylindrical surfaces. The technique is represented by the specific examples of pin connections. The deviations of spacing and form are shown to affect the fit class and assemblability of compound assembly units based on geometrical models of pin connections. The exclusion methods of locating redundancy with parts mating relative to one another (cover and shell joining) using two pins are proposed.

The precision of components and goods is formed and revealed at all stages of a product life cycle: design – manufacture – control – operation.

The metrology provision of components geometrical adjectives measurement should be coupled with the metrology provision of a design process and manufacturing technology. It should be supported by proper regulation of value tolerances in coordinate systems generated by set of bases taking into account their informativeness based on static location definability.

Thus, a special emphasis should be made on the measurement error estimation as the primary component of a procedural error, which estimates specifically for a particular measurement and is not included into the structure of measurement permissible errors.

3. Theory

A measurement method should correspond to the standard term of deviation and be developed based on the construction of the measuring object geometrical model. The measuring object geometrical model should include all dimensional and geometric initial errors of the measuring object and two sets of bases. They are a generalized coordinate system of a component and an auxiliary coordinate system where an examined element fulfills its operational function. Based on the pin geometrical model (Figure 1), the measurement methods of a smooth cylindrical pin are developed [2].

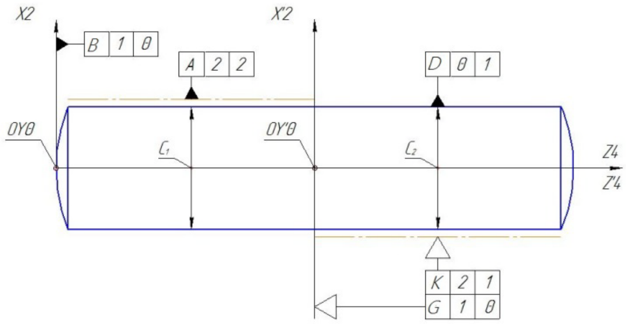

Figure 1. Smooth cylindrical pin: bases and coordinate system.

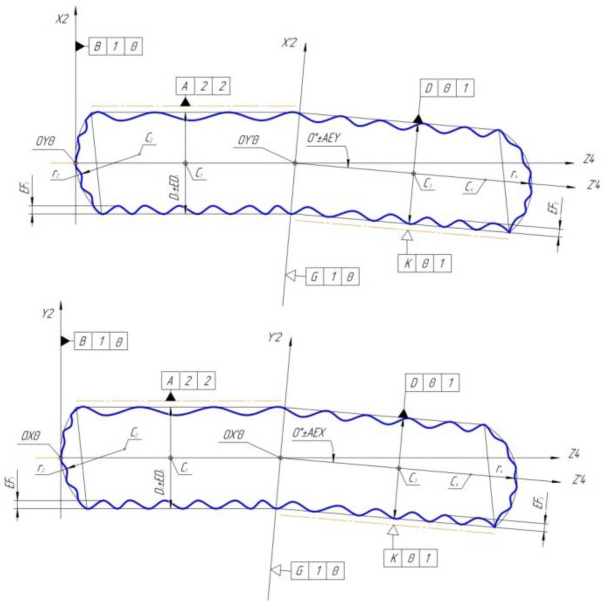

Figure 2. Smooth cylindrical pin: geometrical model.

IOP Conf. Series: Journal of Physics: Conf. Series **858** (2017) 012029 doi:10.1088/1742-6596/858/1/012029

All actual surfaces have form deviations, these surfaces having proper dimensions and tolerances of AUSS (GOST) P 53442-2009 (IOS 1101:2004). Form deviations are the deviations from a proper geometrical form of a surface in longitudinal and cross sections. More accurate measurement can be made in measuring statically definable components due to error of locating exclusion.
The primary errors of pin elements should be taken into account for a component geometrical model to be developed and for all deviations to be recorded. Measurement data derived through cylindrical pin measurements are required for the provision of components and goods quality. The measuring surfaces themselves are the measuring form deviations measurement bases. The deviation readout takes place on adjacent (actual) surfaces. Surface undulation and irregularity should be excluded by selecting the radius of a gaging tip in measuring form deviation. The above said allows the procedural errors of measurement to be excluded or significantly reduced.
The pin form deviation measurement schemes include the roundness measuring diagram (Figure 3), cross section measuring diagram (cylindricity deviation) (Figure 4) and pin diameter measuring diagram (pin axis straightness) for diameters minimum (L) and maximum (M) materials to be found (Figure 5).

4. Experimental results

The crossing profile form deviation measuring diagram (cylindricity deviation) is shown in Figure 3. The nature of the crossing profile form deviation is determined by selecting the measuring scheme. The two-point measuring scheme can detect out-of-roundness, and faceting can be detected exclusively by three-point measuring scheme.
Figure 3 shows the three-point measuring diagram. A narrow prism gives two points of contact with the pin surface. A plunger of the dial gage gives the third contact point with the pin surface. All three points are located in one cross section plane, which is perpendicular to the pin base axis (base A, Figure 1).

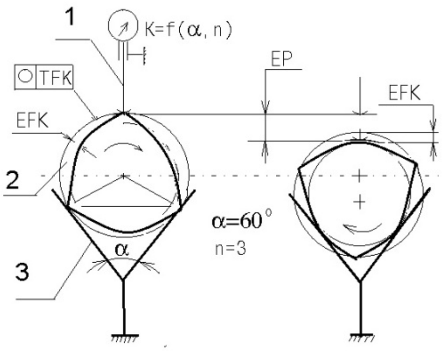

Figure 3. Measuring diagram of pin crossing profile deviation (cylindricity deviation): 1 – measuring transducer; 2 – unit under test (pin); 3 – prism.

The prism angle depends on the number of pin surface faces (n). As a rule the measurement line coincides with the prism bisector. Depending on the prism angle and the number of faces, the calibration constant of diagram K is selected and the form deviation value is calculated as the difference between the biggest and the least readout in one section in a single pin revolution: EFfacet=(Pmax-Pmin)/K=EP/K.
The procedure of the pin crossing profile form deviation measurement (cylindricity deviation):

- a pin is set on the two narrow prisms with the angle α;
- a digital indicator is mounted on a rack and the instrument is tuned for measuring (the tuning reference is a cylindrical measure);
- measurements on six or seven points at three cross sections are carried out, two of them being boundary and one being central, within the mating surface;

The boundary values of the pin diameter and the faceting with n number of faces are determined by the results obtained.

- the results of measurement are entered into the report.

The five point scheme is required for the cross section pin form deviation to be measured (Figure 4). Five points are measured, the four are formed with the two narrow prisms and the fifth is formed with the plunger of the dial gage. The prisms are spaced at the extreme pin sections as far as the mating length is the length of the pin. All three points of the measuring scheme should be spaced in the cross section plane and be contacted with the one generator cylindrical surface for the cylindrical deviation (cylindrical part axis straightness) to be measured. The cylindrical deviation values are calculated by the difference method as the semidifference of the biggest and the least values: EFcyl=0.5EFPP. The measurement treatment can be simplified if the measuring transducer is tuned for zero on one of the sections, although the measurement time increases in this case.

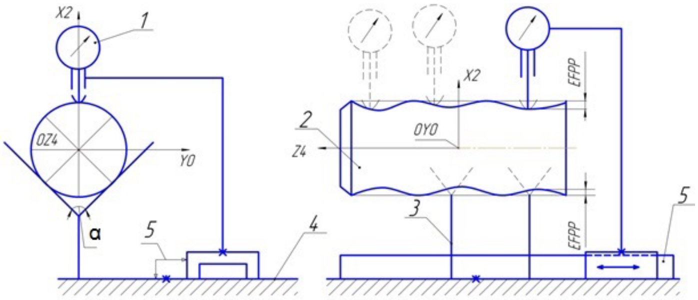

Figure 4. Pin crossing profile measuring diagram (straightness deviation): 1– indicator; 2 – unit under test (pin); 3 – prism; 4 – testing plate; 5 – toolmaker's straightedge.

The procedure of longitudinal section pin form deviation measurement:

- a pin is set in the prism on the angle α;
- a measuring transducer is mounted on a rack and the instrument is tuned for measuring;
- measurements on three points, at three cross sections are carried out, measurement is carried out by a workpiece rotation;
- the results of measurement are entered into the report.

In such schemes the measuring surface of testing plate is the degree of rectilinearity, its strain making force measurement error contribution affected by the workpiece and rack gravity, and that should be taken into account.
A pin is a workpiece with an external cylindrical base having informativeness which equals to four. It is based on two narrow prisms reifying four base points for rotation.
The diameter measuring procedure of minimum (L) and maximum (M) pin materials is described schematically (Figure 5):

- a pin is set in the prism on the angle 90°;
- a measuring transducer is mounted on a rack and the instrument is tuned for measuring;
- measurements on three points, at three cross sections are carried out;
- the results of measurement are entered into the report.

The biggest and the least cylindrical pin diameters are located on the two regular cylinders encircling actual pin surface. In this case the base axis is the axis of an external (maximum d M) cylinder which participates in components mating (with an aperture in a plane workpiece) with its exposed points.

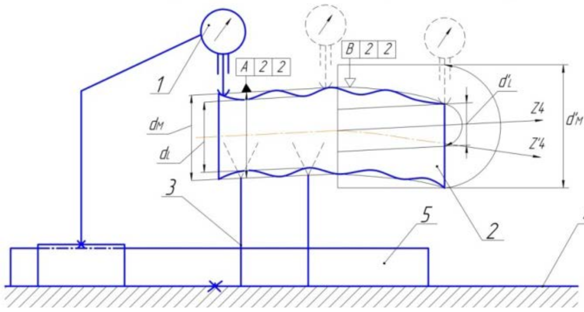

Figure 5. Pin actual diameter measuring diagram. 1– measuring transducer; 2 – unit under test (pin); 3 – prism; 4 – plate.

Rectangular coordinates are exclusively used for defining geometrical adjectives of a smooth cylindrical pin. Measurements of cross section prolife and rounding-off radii in two sections are used for defining smooth cylindrical pin geometric adjectives.

The pin longitudinal section profile coordinates and graphical representation of realistic longitudinal section profile and rounding-off radii according to the measurement results obtained, are shown in Figure 6.

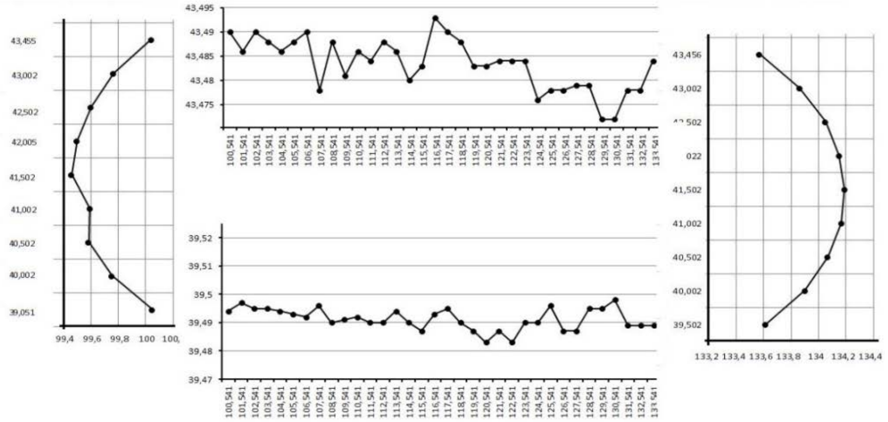

Figure 6. Graphs of longitudinal section actual profile and rounding-off radii of the left and the right pin radius.

Similar measurements were performed after turning the pin through 90° about axis Z, the results are shown in Figure 7.

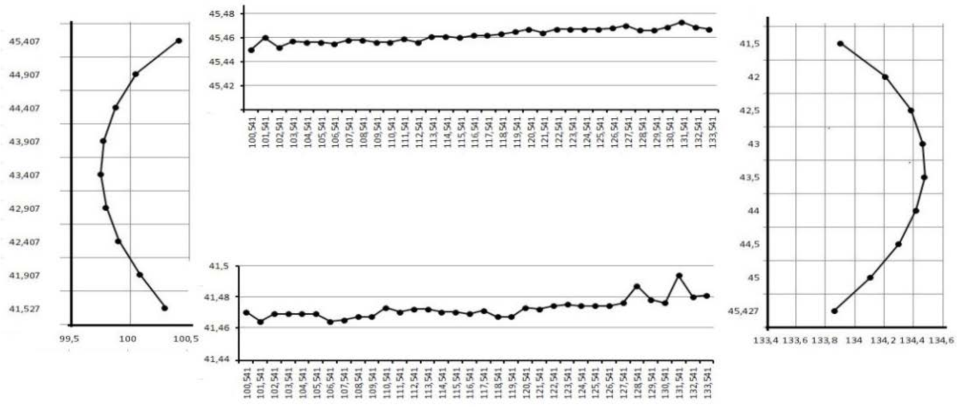

Figure 7. Graphs of longitudinal section actual profile and rounding-off radii of the left and the right pin radius after turning through 90 °.

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5. Experimental result discussion

In the view of the foregoing the rules of the form deviation measurement are brought up for discussion:

- the schemes of form deviation measurement should strictly correspond to standardized definitions;
- the form deviation measurement means finding its maximum value within the limits of a normalized range, a mating length;
- the measurement schemes are developed based on the geometrical model of the measuring object;
- the main assembly bases should provide orientation of the measuring object in space of the measuring instrument the same way as the workpiece is used in operation;
- measuring bases are measuring surfaces and readout deviation bases are the adjacent surfaces;
- surface undulation and irregularity should be excluded by selecting the radius of a gaging tip.

6. Summary and conclusion

A realistic pin model differs from its nominal prototype by the dimensions deviation, the element surface form deviation from the proper geometrical form and these elements deviation relative to workpiece bases due to inevitable manufacturing process errors. Measuring forms of deviation using different measuring schemes will produce different results. Thus, measuring schemes with standardized instruments allow two actual dimensions to be found – the biggest and the least pin diameter, but they produce measuring procedural errors that depend on the forms deviation kind and their values. Hence, in searching for cross section pin smooth cylindrical surface deviation we should take the number of faceting faces into account and in terms of this one should select the adjusting prism angle and the calibration constant of the measuring method. The mating length and measuring error force component should be taken into account in measuring cross section pin form deviation. A measuring scheme error arises if the geometrical model of the measuring object is not considered, incorrect measuring scheme (to use two point circuit instead of the three point, and not to take into account the mating surface of a workpiece) is used, as well as when the sensing element form of the instrument is incorrectly selected.

Following certain rules in measuring cylindrical surfaces form deviations allows measuring procedural errors to be excluded or substantially reduced. A procedural error can be excluded by introducing a correction, the pin surface form deviation having been preliminary measured.

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