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EXAMINATION OF SYSTEMATIC ERRORS OF A ROUNDNESS MEASUREMENT EQUIPMENT

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Abstract

The profile in the frontal section of a solid of revolution forms a perfect circle if all of its points are at an equal distance from the center line. The value of the deviation from circularity is very important and it is measured with a dedicated measuring device. This paper examines the systematic errors in a measuring device in which the measured workpiece is supported and rotated between two live centers, while a dial indicator detects the deviations. Regarding the structure, this paper proposes a model consisting of five systematic error measurements which considers the eccentricity of the live centers and the tilt of the dial indicator axis.

Keywords: *roundness, systematic error, coaxiality.*

1. Introduction

Circular features are the most common in machined parts which are three dimensional solids of revolution. The profile in the frontal section of a solid of revolution forms a perfect circle if all of its points are at an equal distance from the center line

According to the standard [1, 2] in every section perpendicular to the main axis, the effective profile must fall within two concentric circles. The tolerance is the radial distance between the two concentric circles.

The deviation can manifest in ovality or polygonal features [3, 4]. In practice, this deviation can even be seen with the naked eye: the shape of the part is not circular; however, this is impossible to measure with conventional measuring devices. Therefore, the construction of a measuring device was required, one which allows us to determine the amount of circular deviation.

2. The construction of the circularity measuring device

Measuring circularity requires a dedicated measuring device, which allows the user to measure the circular profile in every cross-section of the part. There are two different methods for such devices [4]. The first method consists of positioning the workpiece in a clamping device horizontally held up by either one or multiple points of contact. During the measuring process, it revolves around its axis and is swept by an indicator. This is the method recommended by the authors of study [5]. In the second method, the workpiece is positioned vertically with a precision bearing on one of its ends, coaxially aligned with its main axis. After examining and comparing both methods and considering their costs, we have chosen to use the first one, in which the workpiece is positioned horizontally between two centers and revolves around its axis. An indicator is used to sweep the outer profile of the part (Fig. 1). The jig holding the indicator slides horizontally and can be brought into contact with the profile of the workpiece at any point on its surface.

The device allows us to measure parts of various lengths and diameters with limitations on their length and diameter due to the construction of the device. The measurements of the largest part that fits the device are as follows: length 195 mm, diameter 80 mm. One of its drawbacks is that it is unsuited for measuring bores.

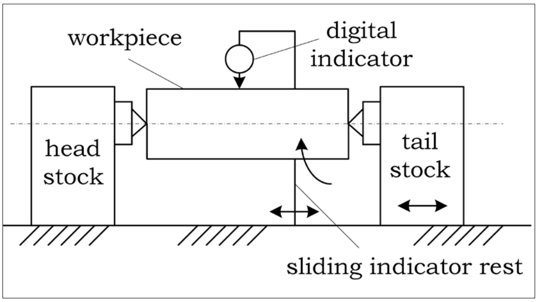

Fig. 1. *The theoretical model of the device.*

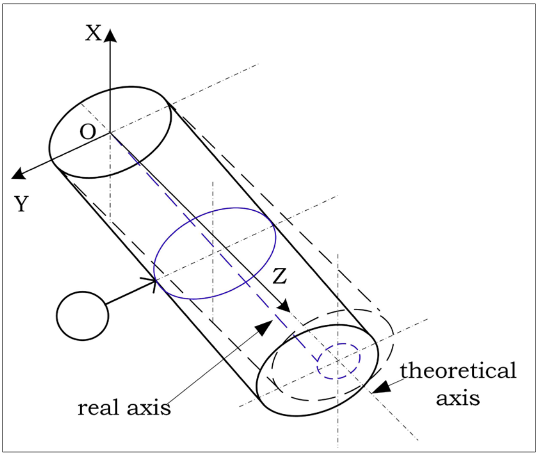

Fig. 2. *Examining the coaxiality of the live centers, three-dimensional model.*

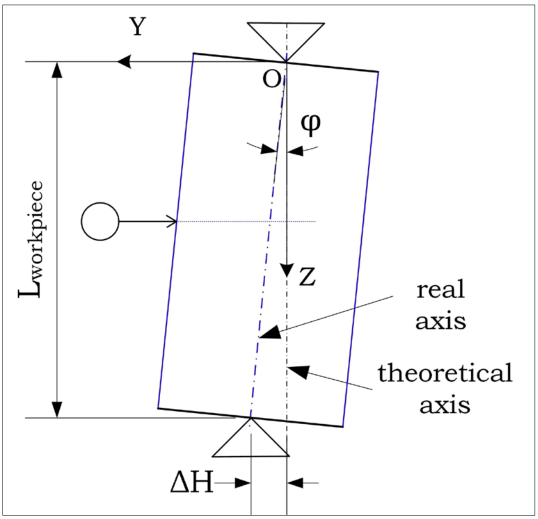

Fig. 3. *Examining the coaxiality of the live centers in the horizontal plane.*

3. Examination of systematic errors

Scientific research considers errors to be a deviation between real and theoretic (nominal) values. There are two major categories of errors: random and periodic errors. This paper examines the latter; therefore, it does not address random errors.

There are numerous methods for determining periodic errors **[6–11]**. Study **[6]** formulates and elaborates on the concept of periodic errors and uses a V-block for moving the measuring device. Studies **[7, 8]** measure the circularity as a function of the points of measurement, the radius of the indicator ball and eccentricity. Studies **[9, 10]** measure the circularity as a function of the points of measurement, the radius of the indicator ball and eccentricity. Studies **[11]** examines the coaxiality of a turbine shaft, however, this study proposes a model with seven measurement errors.

Regarding the structure, this paper proposes a model made of two systematic error measurements which considers the eccentricity of the live centers and the tilt of the dial indicator axis.

3.1. Examining the coaxiality of the live centers

During assembly or manufacturing, it is possible for the live centers to shift radially in relation to each other. **Figure 2** eshows a three-dimensional sketch which includes the conical surface. This surface is the result of the difference between the ideal and real axes of the centers. The measured profile is an ellipse in every measuring plane.

The coaxiality problem of the centers is broken down into two directions.

3.1.1. Examining the coaxiality of the live centers in the horizontal plane

The centers are offset from one another along the OY axis by a distance of ΔH (**Figure 3**). Since this distance has a constant value, which results from the construction of the device, it has a φ inclination angle:

$$\varphi = \operatorname{arctg}\frac{\Delta H}{L_{darab}}. \qquad (1)$$

According to (1), if ΔH is constant and the length of the workpiece increases, the value of φ angle decreases continuously.

3.1.2. Examining the coaxiality of the live centers in the vertical plane

The centers are offset from one another along the OX axis by a distance of x_p (**Figure 4**).

Since this distance has a constant value, which results from the construction of the device, it has a θ inclination angle:

$$\theta = \arcsin \frac{x_P}{R}, \tag{2}$$

where R is the radius of the workpiece.

This vertical shift is shown as ΔV on the indicator:

$$\Delta V = R(1 - \cos\theta). \tag{3}$$

According to (3), if x_P is constant and the value of R continuously increases, the value of ΔV decreases

3.2. Tilt in the axis of the digital indicator

Figure 5 shows the tilt in the axis of the digital indicator. In this case, there is an angle of δ between the axis of the indicator and the horizontal plane.

Due to the tilt, the indicator does not show the rea Δy difference but:

$$m = \frac{\Delta y}{\cos\delta}. \tag{4}$$

If the value of δ continuously increases for a given Δy difference, the height m shown on the indicator also increases, however, this increase is inconsequential.

3.3. Compensation for systematic errors

Currently the measuring device is in the planning and construction phase. The construction allows the indicator to move along the OX and OY axes. The actuators for these movements are electric motors. Both the operation of the motors and the processing of the data from the indicator will be performed via software.

For measuring coaxiality, the centers have a two-step cylindrical surface with known dimensions and tight tolerances. Indicating either cylindrical surface in any given cross section results in a circle. The center points of these circles can then be determined. These two center points on the same live center form an axis and if the coaxial deviation has a value different than zero, then the two centers have two separate axes. This distance can then be determined via software.

The tilt in the axis of the indicator is created using a part with a known Δy radial deviation. During production or assembly, a δ≠0° angle may appear, however, if this is kept below 5° its effect is insignificant since the Filetta 611-343 indicator has a resolution of 0.01 mm and an accuracy of ±0.02 mm.

4. Conclusions

Measuring circular deviation is a measuring method used in practice, one for which the industry uses various devices. This paper focuses on the periodic errors in a circularity measuring device intended for laboratory use. Familiarity with the device is crucial for its successful operation. The paper proposes an error measuring model comprised of five parts.

The paper proposes a model comprised of two parts measuring periodic errors and also deals with compensating methods for said error. Since the measuring device is currently under planning and construction, the paper contains no measured results.

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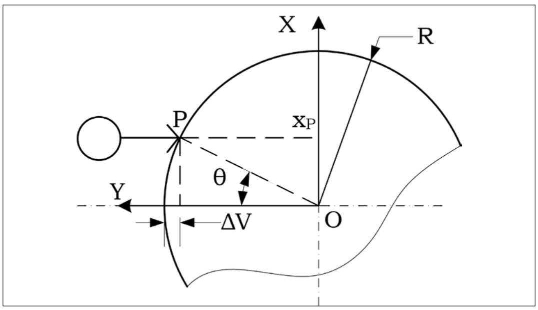

Fig. 4. *Examining the coaxiality of the live centers in the vertical plane.*

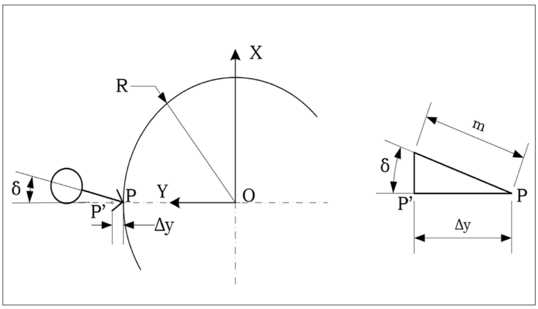

Fig. 5. *Tilt in the axis of the digital indicator.*

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