MEASURING THE DIAMETER OF CYLINDRICAL ARTICLES BY THE METHOD OF RUNNING A ROLLER OVER THEIR SURFACES

B. N. Ivanov and V. A. Mel'nichuk

Translated from Izmeritel'naya Tekhnika, No. 9, pp. 14-16, September, 1964

An analysis of the error in the method of automatically testing shaft diameters by running a roller over their surface [1] shows that the measurement precision is affected by several factors, many of which are difficult to predict. The main factors consist of: 1) inaccuracy in determining the diameter of the running roller when the instrument is first adjusted; 2) wear of the roller in the course of its use; 3) kinematic error in the transmission coupling the roller to the pulse transducer; 4) inaccuracy in determining the rotation angle of the roller; 5) inaccuracy in manufacturing the roller rotation angle transducer; 6) slipping of the roller on the measured surface when their axes are not parallel; 7) error in counting the measuring pulses; 8) deviation of the measured article's surface from an ideal shape (ovality, faceting etc.).

An analysis of the factors listed under 1-7 shows [1] that the above method in its present form cannot be used for testing shafts, for instance, with diameters of 1000 to 3000 mm and a 3rd Class accuracy.

The deviation of the tested article's surfaces from an ideal shape constitutes one of the main factors affecting the precision of measurement.

Nonuniform allowances in machining, errors in locating the component, etc. make the surface of the article approach the shape of an oval or ellipse. The normally obtained noncircularity falls within tolerances for the diameter and is not tested separately. Only in exceptional cases, when special requirements are set for the component, is the tolerance for noncircularity (ovality, faceting) smaller than that for the diameter. In such a case the noncircularity is tested separately.

The measurement of the diameter by running a roller over the article's surface is an indirect method, since it is not the diameter which is measured, but the length of the article's cross-sectional perimeter. Thus, the instrument will not measure the maximum diameter but a certain conditional mean diameter (always smaller than its maximum), which in practice can be considered equal to

$$D_{ar} = 0.5(D_{max} + D_{min}),$$

where $D_{max}$ and $D_{min}$ are the diameters of the ellipse.

For instance, for ellipses inscribed in circumferences with diameters of 500, 1000, 2000 and 4000 mm with a difference between their semiaxes (a and b) equal to half the tolerance for a corresponding diameter of the shaft made to the third class of accuracy, i.e., with $a - b = 0.07$, 0.1, 0.14 and 0.2 mm, the corresponding values of mean diameters obtained by the running roller method are: 499.93, 999.90, 1999.86 and 3999.80 mm.

The computations were based on the formula for evaluating the length of an ellipse

$$L = \pi (a + b) \left(1 - \frac{1}{4} \frac{a^2}{b^2} + \frac{1}{64} \frac{a^4}{b^4} + \frac{1}{256} \frac{a^6}{b^6} + \ldots \right) = \pi (a + b) K$$
where

$$\lambda = \frac{a-b}{a+b}.$$

It is possible to consider for the above values that $K$ is virtually equal to 1, and then we find that

$$L \approx \pi (a + b).$$

For a shaft cross-section maximum actual diameter of 500–400 mm with an ellipticity not exceeding the 3rd Class of precision, the instrument will read within 0.07–0.2 mm of the actual dimensions, which amounts to 50% of the guaranteed tolerance. This error will be considerably larger if the shafts are made to a lower class of accuracy. In order to obtain a correct evaluation of a diameter in the presence of ellipticity, it is necessary to measure the ellipticity and apply the required correction to the instrument readings.

The authors of this article have developed an instrument which can read the maximum diameter and the difference of the elliptical semiaxes [2]. The instrument is based on the running roller method with a normal discrete roller rotation-angle transducer. The required result is attained by incorporating in the transducer reading, which corresponds to the measured component’s mean diameter, a correction equal to the deviation of the actual dimensions of the component from the mean diameter thus obtained.

The photoelectric transducer used for measuring shafts by the running roller method (Fig. 1) consists of roller 1 and disc 2 with a circular grid. Roller 1 and disc 2 are mounted on the same axle located in instrument casing 3. The casing is mounted on guide rails of setting device 4, by means of which the roller is pressed against measured component 5.

The disc is covered by jacket 6, which carries illuminator 7, photocell 8 and grid 9. In order to apply a correction for the inaccurate shape of the measured shaft’s cross-section, the photocell, illuminator and stationary grid are mounted on jacket 6, which can rotate about the axis of disc 2 and provide in the course of measurement additional pulses corresponding to the applied correction. Casing 3 is coupled by means of lever transmission 10–11 to stationary base 4 which is mounted on the lathe carriage. The rotation axis of lever 11 is made to coincide with that of disc 2. The ratio of lever 11 arms provides the required transfer ratio for correcting the pulse count. The transfer ratio is adjusted by screw 13.

The upper arm of lever 11 is clamped between rigid support 14 mounted on bracket 15 of transducer casing 3 and support 16 rigidly fixed to jacket 6 of disc 2. Support 16 serves at the same time as the core of electromagnet 17 fixed to bracket 15.

Lever 11 is hinged to drawbar 10, whose left-hand end is connected to stationary base 4 by means of rotating pivot 18 with floating bush 19, which slips for efforts exceeding a preset value (the well-known principle [3] of a floating contact).

In measuring the diameter of a shaft with an elliptical cross-section, the reciprocating movement of the spring-loaded part of the device is produced by the rotation of the shaft. This movement is equal to the difference between the elliptical semiaxes and corresponds to the difference between the maximum and mean diameters of the measured component.

This displacement is used for applying the correction to the instrument readings by means of the lever transmission, which in the course of measurements displaces the photocell, the grid and the illuminator in the opposite direction to the rotation of the disc.

Electromagnet 17 is switched in before measurements so as to press lever 11 against rigid support 14 by means of support 16. At the beginning of counting the electromagnet is switched off. The beginning of measurement can correspond to two cases.

If at the beginning of measurement the running roller is located over a section in which the component’s diameter is increasing, the moving part of the setting device together with the transducer which is mounted on it is displaced to the left. In such a case the upper end of lever 11 rests against rigid support 14, and lever 11 is displaced to the left in a direction parallel to its original position, thus moving drawbar 10 in the "floating" bush 19 fixed to