MEASUREMENTS OF DEVIATIONS FROM ROUNDNESS IN COMPONENTS PRODUCED ON CENTERLESS GRINDING MACHINES

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The most widespread methods for measuring, under production conditions, the deviations from roundness of external surfaces consist of the two-contact method for measuring the ovality and even faceting, and the three-contact method for measuring odd faceting. In the three-contact method the tested article is rotated in a V-block or on two rollers, and the deviations from roundness are evaluated by means of a measuring head located in such a manner that the axis of the measuring stem coincides with the bisector of the block angle, or else is inclined at a given angle to it. The three-contact method is simple and suitable, as distinct from the rigid-centers measuring method, for eliminating the error due to the eccentricity of the tested surface with respect to the axis of the centers.

The special feature of this method consists of the fact that the displacement of the measuring stem which contacts the tested surface and, hence, the readings of the measuring head do not coincide with deviations from roundness, but depend on the angle of the V-block and the shape of the tested surface.

V-blocks with a vertex angle of 60° are most frequently used for measuring faceting.

By comparing the faceting measurements made on V-blocks with an angle of 60° and on a roundness meter it was found that even in testing articles with a pronounced trihedral shape the two measurements are not identical and have no definite relationship to each other. It thus became necessary to find an optimum V-block angle for measuring faceting of components produced on centerless grinding machines. These investigations were based on previous research [1-2]. It was assumed therein that the faceting of the tested components has the shape of a regular geometrical figure which has rounded vertices and a constant diameter, and is characterized by a constant distance between any two parallel tangents to it.

For this condition the measuring head readings \( \delta_s \) are proportional to the deviations \( \delta_R \) from roundness, i.e., \( \delta_s / \delta_R = k \), where \( k \) is a coefficient of proportionality. Curves of the relationship of \( k \) to the V-block angle \( 2\alpha \) have been plotted analytically in [2] for the four most frequently encountered deviations from roundness in centerless grinding consisting of ovality, and three, five, and seven-sided faceting. In this work an optimum angle of 108° is recommended, since the value of \( k \) is then the same for all the three types of deviations from roundness (see figure).

A careful analysis of the relationships thus obtained has forced us to cast doubt on the recommendations made in [2]. On the basis of his work the author of [2] arrived at the conclusion that in centerless grinding of cylindrical 20 x 20 mm rollers the most common type of deviation from roundness is trihedral, with pentahedral faceting occurring less often and heptahedral very seldom. It will be seen from the figure that for an ellipse, trihedron, and heptahedron coefficient \( k \) is the same and equal to 1.38 when measured on a V-block with an angle of 108°. However, components with a heptahedral faceting occur in practice extremely seldom, and ovality can be measured on two-contact instruments; moreover, this measurement cannot be excluded because it is made simultaneously with that of the diameter.

Thus, the coincidence of \( k \) values for three types of deviations from roundness in measuring on a V-block with an

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angle of 108° provides hardly any advantages. However, the values of $k$ for a pentahedron and a trihedron measured on the above V-block differ considerably and amount to 2.24 and 1.38. It will be seen from the figure that in addition to an angle of 108°, it is also worth noting angles of 90° and 120°. The curves corresponding to the most frequently encountered trihedral and pentahedral faceting intersect at the point of (2, 90°) and those corresponding to pentahedral and heptahedral faceting intersect at (2, 120°).

It was necessary to solve two principal problems by finding which deviations from roundness actually occur in grinding external rings and by determining, on the basis of previously obtained patterns, the optimum angle for the V-block. For this purpose we tested 3500 rings in 69 batches of various precision classes in the range from 47 to 150 mm.

All the rings were tested on three V-blocks with angles of 60°, 90°, and 108°, and 10-12% of the specimens in each batch were tested on a V-block with an angle of 120° and with a roundness meter.

The actual coefficients of proportionality for each ring were obtained separately in the form of ratios of the measuring head readings taken on a three-contact instrument with different V-blocks to the maximum faceting amplitudes obtained on a roundness meter.

In analyzing the results thus obtained it was found that in centerless grinding the faceting often approaches the trihedral shape, and less often a pentahedral and heptahedral shape. Rings were also found whose external surfaces have various, usually odd, numbers of faces (9, 11, 13, 15, 17, or more). However, the shape of the majority of rings cannot be assigned to any of the above categories. This is due to the fact that the shape in centerless grinding depends on a large number of factors, such as the position of the article’s center with respect to the center line of the grinding wheels, the angle of the supporting ruler, the grinding rates, the dynamic characteristic of the system, the initial error of the ground components, and other factors.

All the rings of an indefinite shape as well as rings with a number of faces exceeding seven were nominally denoted by us as polyhedrons. The table carries mathematically processed measurement results (for maximum values of coefficient $k$). In finding the optimum V-block angles we used as criteria the mean coefficient $k$, the rms deviation $\sigma$ which characterizes the dispersion in the values of $k$, and the indexes $k_o = \sigma / k$ of the relative dispersion of coefficients $k$.

In view of the fact that 5-6 rings out of a batch of 50 were measured on the roundness meter, it became necessary to find an appropriate criterion for establishing the type of faceting in the remaining rings. Such a criterion was found to be the ratios of coefficients $k$ for three V-blocks with angles of 60°, 90°, and 108°. From the knowledge of these ratios of the rings measured on the roundness meter it is easy to evaluate the type of faceting for the remaining rings in the batch.

These investigations enabled us to arrive at the following conclusions.