In accordance with GOST 24642-81 [1], the basis for reckoning deviations from rectilinearity in a plane is provided by an adjacent straight line, and the deviations may be reckoned from the average straight line. The baseline used in production is often the so-called leveling straight line [2, 3], which passes through the extreme points on the curve derived from measurements. This baseline simplifies the processing. To derive deviations from rectilinearity in space, one considers the projections of the deviations from rectilinearity in two mutually perpendicular planes.

In accordance with whether one uses the mean straight line or the leveling one, one gets differing systematic errors [2, 3]. In [3], the difference in the estimates of rectilinearity in a plane resulting from these baselines was estimated as 10%, although in fact it may be much larger.

To estimate this error, we consider measurements and theoretical studies on deviations from rectilinearity of axes in a plane and in space. When one considers deviations in a plane, the parameter \( \Delta \) determined from the average straight line is compared with the measurement from the leveling straight line \( \Delta' \), i.e., one derives the systematic error in the measurements by using the leveling straight line instead of the average one as the baseline. Also, one can compare the results obtained on determining deviations from these baselines with readings taken on adjacent straight lines.

We made measurements on a tube having an outside working surface of diameter 70 mm, wall thickness 4.5 mm, and length 5000 mm. The item 1 (Fig. 1) was set up on two V blocks 2 such that the support was at 1/5 of the length from the ends. Five stands 3 with dial gauges 4 were set up along the item; two at the ends of the tube and three between the supports. The readings on the dial gauges were taken for each 90° of rotation around the longitudinal axis, with the positions of the points in two mutually perpendicular longitudinal sections derived as the half-differences of the readings on each gauge before and after rotation of the tube through 180° (measurement method proposed by B. E. Kostich).

An advantage of this method is that the resulting position found for the axis is independent of any variation in outside diameter.

When one derives the projections of the axis on the two planes, one uses not only the positions of the five points in the sections but also the two points above the supports.

Measurements made in this way may have an error due to the item bending under gravity, and the error is the larger the greater the deflection or the deviation from rectilinearity in relation to the radius of the cylindrical surface. In these measurements, the maximum deviation from rectilinearity of the axis in a plane was 3.5 mm, while the maximum deflection (with the item set up on V blocks at distances of 1/5 of the length from the ends) did not exceed 0.2 mm. With the two factors acting together, the maximum error in determining the coordinates of points on the axis may be 0.02 mm. This error is small by comparison with the measured deviation, and it has identical effects on the determination of deviations from the different baselines, so that error was not incorporated in this experiment.


We measured 77 such tubes. After constructing 154 projections of the axes on two mutually perpendicular planes, we determined the deviations from rectilinearity relative to the baselines. The various forms of deviation were classified in terms of the numbers of intersections of the axis with the leveling straight line.

Most of the curves (115 or 75% of the total) characterized deviations from rectilinearity without intersection with the leveling straight lines (curve I of Fig. 2), and these may be called convex (concave) curves in accordance with GOST 24642-81. The systematic error of measurement, i.e., the differences in the values from the leveling and mean straight lines, was negative and ranged from 0 to $-23.6\%$ of the measured deviation (on average $-7.7\%$), i.e., the deviation from rectilinearity determined from the mean line was greater than that identified on measurement from the leveling line. For 34 curves (22% of the total), there was in each case one intersection with the leveling straight line (curve II in Fig. 2). The systematic error in 22 cases was positive (from 0 to 47.6% of the measured deviation, on average 19%), while in 12 cases it was negative (from $-1.2$ to $-19.7\%$, average $-9.4\%$). Finally, five curves had two intersections each with the leveling line. The systematic error in four cases was positive (from 0.4 to 6% of the measured deviation), and in one case was negative ($-2.4\%$).

We now consider the reason for the systematic error. The baselines constructed in accordance with GOST 24642-81 and the leveling straight line in general pass through different points on the curve from which one determines the deviations from rectilinearity. They are displaced one relative to the other and rotated. Parallel displacement of the baseline is significant only in determining the disposition of surfaces and the gap between them and does not influence the determination of deviations from rectilinearity. However, the systematic error in measuring deviations from rectilinearity in a plane is independent on the angle between the different baselines.

Let the deviation from rectilinearity be determined by the coordinates of two points (A and B or $A_1$ and $B_1$ in Fig. 2) in a system in which one of the axes coincides with the mean straight line constructed for the measured profile (axis). When the baseline is changed, the deviations will be reckoned from a straight line rotated relative to the average straight line through a certain angle ($\gamma_1$ or $\gamma_2$ in Fig. 2). As different scales are used in constructing the projections of the axes on the X and Y coordinates, $\gamma_1$ and $\gamma_2$ are shown with distortions, although the values do not exceed $1'$.

Two cases are possible. In the first, the points defining the deviations remain unchanged. Then the systematic error in measuring the deviations from rectilinearity when one uses the leveling straight line is defined by

$$\delta = A'(\cos \gamma - 1) \pm l \sin \gamma,$$

where $A'$ is the deviation from rectilinearity reckoned from the mean straight line, $l$ is the distance between the projections on the abscissa for the points defining the deviation, and $\gamma$ is the angle formed by the average and leveling straight lines.

The error of measurement for most of the tubes was determined by the second term, since the first term is close to 0 if $\gamma$ is small and $A'$ is reckoned essentially in a direction parallel to the Y axis. Figure 2 shows that the error is always negative if there are no intersections of the leveling straight line with the curve characterizing the deviation, whereas it is positive if there is a single intersection. As the end points on a curve of the second type lie in different coordinate quadrants, one expects a systematic error larger in magnitude here by comparison with a curve of the first type, which is due to the possibility of a large rotation of the leveling straight line relative to the average one. For