for $\theta = \pi$ we find that

$$\Delta F_1 = 2e_1 \sin \beta$$

(19)

and the largest difference in readings is

$$\Delta F_1, \text{max} = 4e_1.$$ 

(20)

In the latter case, if the maximum accumulation of errors in the step of the wheel lies precisely at the middle of the number of teeth, the kinematic error will be equal to half the measured value:

$$\Delta F_2 = \frac{\Delta F_1, \text{max}}{2}.$$ 

(21)

Moreover, if equality $\sin \frac{\pi z}{2} = 1$ is met for the cyclic error of the $z$-th frequency, the kinematic error will be completely detected. Otherwise the measurements will provide a value of $\Delta F_2$ smaller than the actual value by the cyclic error which depends on the ratio $\pi Z/\lambda$.

In the case when the maximum accumulation of errors in the step of the wheel does not lie in the middle of the number of teeth, the measured value will be smaller than half the kinematic error.

Thus, the difference method used in measuring the total kinematic error like the comparison method for measuring the accumulated error in the majority of cases provides an evaluation which is lower than the actual error [1].

Conclusions. Analysis of the difference method of testing the kinematic error in gears shows that, irrespective of the form of the kinematic error curve, this method provides accurate determination of the component amplitudes in the total error of the gear. The method also provides a direct evaluation of the total kinematic error of a gear with an accuracy adequate for practical purposes.

The method can be applied by means of a moving-coil kinemometer made by the Chelyabinsk measuring instrument plant and a harmonic analyzer.

LITERATURE CITED


GAUGE BLOCKS FOR LARGE SIZES

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Block gauges are made in the USSR up to a length of 1000 mm, and units constructed with them up to 4000 mm and more (up to 15000 mm). Blocks of large sizes are used for testing and adjusting certain universal measuring devices and for other special purposes when high precision of linear measurements is required.

Investigation of the accuracy of large-size blocks is now acquiring immediate interest in connection with the rising precision in the manufacture of large-size details and units of machines, and the absence of sufficiently accurate universal measuring instruments for their testing. Moreover, it is also necessary to solve the question as to the possibility of using gauge blocks as references for setting large-size wooden caliper gauges to the required dimensions for measuring [1, 2] articles made to accuracy classes 2 and 2a according to GOST 2689-54. It is known that micrometer hole gauges cannot provide such precision.
Our investigations were carried out with block gauges of 1000, 1500, 2000, 2500, 3000, 3500 and 4000 mm. These blocks were made up with block gauges of grades 2, 3, and 4. We determined the error due to building up blocks from gauges, to the lack of rigidity in large blocks, and to the limiting error in measuring blocks. In every case strict temperature conditions were maintained.

The error due to building up gauges into blocks by means of coupling cramps (GOST 4119-49) was evaluated on small blocks up to 1000 mm. The clamping effort was provided in two ways, by means of a special screwdriver with a ratchet which limited the effort to 50 kg-wt (490 N), and by means of an ordinary screwdriver. In either method the bearing points of the block placed on the measuring machine were at a distance of \( \frac{L}{6} \) of the block length from the measuring surfaces.

It was established experimentally that a reduction in the length of a large-size block due to the clamping of gauges with a standardized effort of 50 kg-wt (490 N) amounts to 1 \( \mu \) per coupling irrespective of the size of the block. A change in the clamping effort varies the length of the block, which changes for each clamping, oscillating between 1 and 5 \( \mu \) per coupling.

When blocks up to 1500 mm in length are used it is necessary to account for the reduction in their length due to clamping as a systematic error. In blocks over 1500 mm in length this systematic error need not be taken into account owing to its relatively small size as compared with other errors.

The error due to the lack of rigidity in large blocks can be characterized by the reduction in the size of a block (owing to bending) and by the deviation of its ends from parallelism.

The reduction in the length of the block (due to bending) was determined by us along the narrow face of the block as a difference between the lengths of blocks supported at the Airy points and at the ends.

Experiments have shown that in transferring the block supports from the Airy points to their ends the length of blocks changed by an amount which was found empirically to equal

\[
\Delta L = 0.05 \cdot e^{2L} \mu
\]

where \( L \) is expressed in meters and is virtually independent of the number of cramps used.

By comparing the results thus obtained with GOST 10-58 on "Micrometer hole gauges" it was found that in transferring the supports from the Airy points to points removed by 100 mm from the measuring surfaces, block lengths up to 3000 mm changed within tolerances specified by the standard.

Deviations from parallelism of the ends of block gauges over 1000 mm in length were evaluated at three points along the middle line parallel to the long edge of the measuring face, with two points approximately 1-2 mm from the short edges of the measuring face and one point at the middle.

We took as a criterion of the deviation from parallelism the maximum difference between the length of the block at one extreme point as compared with its length \( L \) at the middle.

Tests have shown that the deviations from parallelism of gauge blocks with bearing points at \( \frac{L}{5} \) from the ends of the block are considerable (for blocks 4000 mm long it was 0.02 mm) and for bearing points at the ends these values could be very large (0.22 mm for lengths of 3500 mm and 0.28 mm for 4000 mm). In using large-size blocks it is, therefore, necessary to ensure that they are supported at the Airy points or placed on wooden liners, and that the testing tips of measuring machines or indicators (in setting caliper gauges) should contact the middle of the measuring faces of blocks.

The maximum error (±35) in determining the actual length of large-size blocks on an end measuring machine under normal clamping conditions is equal to

\[
35 = \pm (-0.6 + 6 \cdot 10^{-3} L) \mu.
\]

**Conclusions.** As the result of the experiments thus carried out it was found that:

1. The errors due to lack of rigidity in blocks 1000 and 1500 mm long are small compared with the error in measuring the blocks, whereas the same error in blocks from 2000 to 4000 mm long increases considerably the total error of the block.

2. Blocks 2000 and 2500 mm in length can be made up of 3rd, 4th, and 5th grade gauges and used as gauges of the 5th grade, since the error in such blocks does not exceed the error in certifying gauge blocks of grade 5.