A relationship is established between the working life to repair for borehole shaft pumps on the deviation of the cylinder axis from rectilinearity. A new technology is considered for straightening the cylinders with restricted plastic strain. Calculations are presented on the change in shape of the cylinder axis on straightening by the new technology.

Any deviation in the axis of a long component from rectilinearity is a quality characteristic that largely determines the working life and reliability. Figure 1 shows results obtained at oil-extracting operations (initial data provided by the PIKA Company in Perm), which shows the working life (life to repair) of borehole rod pumps (BRP) in relation to the deviation of the axis of the cylinder from rectilinearity. The deviations \( d \) of the axes were measured before the pumps were lowered into the boreholes. The causes of pump failure are varied, but there is an appreciable correlation of the working life with the cylinder accuracy: for \( d > 0.5 \text{ mm} \) (throughout the length), the working life does not exceed the value defined by the approximate formula \( T = 12\cdot(1.5 - d) \).

The dashed line in Fig. 1 shows the boundary corresponding to this dependence. For small \( d \), no correlation is found between the manufacturing accuracy and the working life.

Straightening is one of the operations in making BRP cylinders, without which one does not attain the required accuracy, particularly in long cylinders. New means of measurement have been used \([1, 2]\) to provide precision monitoring of axial deviations in long cylinders from rectilinearity, which raise the quality and throughput in manufacture by algorithmizing the technological operations.

These BRP cylinders are made with straightening based on the fluctuations in the outer surface or rectilinearity of the axis of the inner surface. A check is made on the axis rectilinearity before straightening, and the parameters of the straightening are determined, and then the quality of the straightening is established from the inner surface, for which one uses either single-point monitoring instruments or special measuring equipments such as the PIKA-N4 or others.

Straightening with checks on the fluctuations in the outer surface or deviations of the axis of the outer surface is applicable in making cylinders from precision longitudinal-welded tubes if the wall thickness is almost constant along the generator, while the thickness difference around the perimeter does not exceed 0.1–0.2 mm. These requirements are not met by initial tubes made of constructional alloy steels formed by pressure working (including rolling).

One-point monitoring of rectilinearity for the axis of the inner surface involves measuring the deviations of the center of the intermediate section of the inner surface (mean on the standardized part) from the straight line (the geometrical axis) joining the centers of the extreme sections for the measuring instrument on the internal surface, whose distance apart is equal to the length of the normalized part of the cylinder and on which the measuring instrument is based. The actual deviations of the surface axis from rectilinearity are random \([3]\), and the measured parameter coincides approximately with the largest deviation of the axis from rectilinearity on the normalized length. Simulation shows that the manufacturing technology results in
a standard deviation from 20% (if the statistical characteristics of the actual axis are close to the result obtained from a model for the accumulation of random deviations in the axial curvature) to 60% (if the characteristics are close to the model for the accumulation of small angular deviations), in both cases relative to the largest standard deviation along the normalized part of the cylinder in the real axis of the internal surface from a straight line joining the centers of the extreme sections of the normalized part. The reason for such large errors is that the random position of the maximum deviation in the real axis does not coincide with the position of the measuring instrument’s sensor.

When part of a BRP cylinder is straightened by the use of single-point means of measurement, one proceeds as follows: firstly, there is only very restricted scope for reducing the deviations from rectilinearity on account of the complicated shape of the actual axis (not to zero); secondly, the shape of the actual axis after straightening may adversely affect the interaction between the cylinder and plunger and produce conditions for multipoint contact in the pump [3]. A possible solution is to perform straightening with restricted plastic strain, i.e., by an amount less than that determined by the direct measurements. For example, if the deviation from the geometrical axis is \( \delta = 0.3 \) mm before straightening in the average section of the normalized part of the cylinder, then on straightening one must strive to obtain \( \delta = 0.2 \) mm (with allowance for the sign of this quantity), not \( \delta = 0 \).

The coefficient of strain completeness in straightening \( K_s \) is taken as the ratio of the recommended deviation to that determined by direct measurement. Figure 2 shows simulation results: the statistical characteristics of cylinder straightening

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**Fig. 1.** Dependence of working life \( T \) of BRP before repair on deviation \( \delta \) of cylinder axis from rectilinearity.

**Fig. 2.** Change in average relative standard deviation \( \bar{\delta}_{av} \) for various \( K_s \) on straightening: 1) deviation from rectilinearity in axis of straightened part; 2) deviation of axis of straightened part from a parabola; — — — — — model for the accumulation of random deviations respectively angular and curvature.