DEVICE FOR CONTACTLESS MEASUREMENTS OF THE THICKNESS OF DIELECTRIC PLATES

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We present the results of testing a device for grading glass plates for liquid-crystal displays and monitoring the thickness of a ribbon of window glass during its manufacture. The capacitive method used provides highly accurate and contactless real-time measurements.

This device is based on the design of capacitive transducers of analogous devices intended for measurement of geometrical parameters of electrical wires [1], glass pipes [2] and fibers [3].

An advantage of these measuring devices is the fact that they have relatively large measurement zones and the electrodes of the transducers do not touch the surface of the objects to be inspected. This makes it possible to carry out contactless measurement even under very unfavorable conditions for production processes. In particular, the device for measuring the diameter of dielectric fibers in [3] has a measurement zone of ± 1 mm, with a gap between the working electrodes of 4-5 mm, and the device for measuring the diameter of glass pipes has a measurement zone of ± 2 mm and an interelectrode gap of 10-15 mm. Thus, the familiar device for measuring the diameter of an optical fiber in [4] allows for fluctuation of the position of the fiber by no more than ± 0.2 mm, with a gap between electrodes of the capacitor equal to several millimeters. As a result, the relative size of the measurement zone decreases by about an order of magnitude.

The measuring capacitor of the device described by the authors is a three-point capacitive transducer, with an operating principle identical to that for the capacitive sensor presented in the description of the device for grading glass pipes. However, a distinguishing design feature in our device is the measuring electrode 6 (Fig. 1), which does not have a rectangular shape but rather is cylindrical with a 1.5 mm × 45° bevel 5 on its edge.

The use of bevels on the electrodes of capacitive gages is a fundamentally new design, since in this case formation of a uniform electrostatic field in the measurement zone is assured. Shifting of the test object within its range does not result in exceeding the permissible measurement error. And the required size of the zone is achieved as a result of choosing the optimal design dimensions of the capacitive gages by mathematical modeling [5].

The capacity of such a capacitor when a dielectric plate is introduced into its measurement zone is determined by the expression

\[ C = \frac{0.089\varepsilon eSK}{d - \delta(1 - 1/e^2_d)} \]  

where \( \varepsilon \) is the dielectric constant of the materials of the plate to be measured; \( S \) is the area of the measuring electrode, cm²; \( K = F(d, S, \xi, L, n \times \varphi) \) is a coefficient taking into account the nonuniformity of the field strength within the measurement zone; \( L \) is the length of the protective zone, cm; \( \xi \) is the gap between the measuring and protective electrodes, cm; \( n \times \varphi \) is the size of the bevel on the edge of the measuring electrode, mm/deg; \( d \) is the gap between the capacitor plates, cm; \( \delta \) is the thickness of the plate to be measured, cm; \( \varepsilon_0(T, W, p) \) is the dielectric constant of the air between the capacitor plates, where \( T, W, p \) are the temperature, humidity, and pressure of the environmental air; \( T_M \) is the temperature of the material from which the inspected piece is made, °C.

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Fig. 1. Design of capacitive transducer: 1) insulating disks; 2) shield; 3) high-voltage electrode; 4) protective electrode; 5) bevel; 6) measuring low-voltage electrode; 7) test piece.

Fig. 2. Error in the thickness measurement $\Delta h/h$, %, vs. the displacement of the test plate in the measurement zone $l$, mm, for transducers with different design dimensions. For the measuring electrode, where the curves 1 and 2 are for $S = 0.13 \text{ cm}^2$, $n \times \phi = 0$ and 0.5 mm $\times$ 45°; curves 3-6 are for $S = 1.13 \text{ cm}^2$, $n \times \phi = 0, 0.5, 1.0$, and 1.5 mm $\times$ 45°, respectively.