PNEUMATIC HEAD FOR AUTOMATIC INSPECTION OF FACETING

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In precision articles faceting is generally inspected (and this includes mass production factories) by universal controlling-measuring dial instruments while the article is being revolved in a prism. Automation of the inspection of the shape of the article for selective assembly is especially difficult to achieve whenever grading into dimensional groups is performed afterwards. To ensure high quality of matching, the error of the shape should not exceed a fraction of the tolerance of one dimensional group. In units where high airtightness is required (pairs of combustion equipment, valves) limitations of allowable deviations from circularity are particularly rigid. Thus, for the components of combustion pairs this magnitude, with tolerance of 50 μ on a diameter, amounts to 0.5–0.2 μ. With measuring in the prism, the limits of measurement are larger than the tolerance of the article [1]. For instance, for prisms with angles 2α equal to 60° and 90°, instruments are necessary with measurement limits 1.5 δ and 1.2 δ, respectively, where δ is the tolerance on the diameter of an article.

For the measurement error not to exceed one half of the monitored magnitude, instruments of a very high grade are required. Thus, for the example cited above, an amplitude converter with measurement limit 100 μ and error not exceeding 0.2 or 0.1 μ is required. Moreover, for measuring amplitude, a high threshold of sensitivity is necessary. There are no amplitude converters satisfying these requirements; the class of instrument based on capacitance and inductance transducers is usually of lower sensitivity, or else their circuits are so complex that the instruments are not suitable for automatic inspection for mass production under workshop conditions. Besides, these instruments have the inherent faults of contact methods, e.g., wear of base surfaces (prism), possibility of damaging the article, and influence of contaminants. Therefore, preference should be given to the contactless method.

Most precision articles are machined by centerless grinding, and the characteristic error of the cross section is faceting which, as shown by investigation, has three- and five-apexed symmetrical and regular profiles.

A six-nozzled split pneumatic head, incorporated in the differential pattern with double-range pneumatic transducer, has considerable advantages. In designing this head it is necessary to select the following parameters: diameters of the nozzles which eliminate the influence of basing error on the error of measurements; the angle of the prism, or of rollers replacing it, which would secure minimum changes in measuring clearances in nozzles of the head; the angle between nozzles, which secures unambiguous indication of the magnitude of three- and five-apexed faceting, and faceting with a larger number of apexes.

The head consists of a six-nozzled split ring [2]. In each half, 7 and 8 (Fig. 1a), of the head are mounted three measuring nozzles. The input nozzle 9 and three measuring nozzles 2, 3, and 6 constitute one branch, and the input nozzle 10 and measuring nozzles 1, 4, and 5, the second branch of the differential pattern. The branches communicate with differential pneumatic transducer 11.

The diagram in Fig. 1a shows basing of the article within two prisms. In practice, for safe revolving of the article, excluding intense wear of supporting surfaces, the halves of the head are based, with the aid of rollers, on the article itself. In these cases the measurement limit is sharply reduced, but the error of basing occurs, caused by the wobble of rollers in consequence of which a shift of the head halves relative to the article takes place.

For elimination of this error it is necessary to maintain stability of the pressure drop in the branches of the differential system.


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It is known that with measurement by the clearance method, the area of the transfer section \( f \) is directly proportional to the magnitude of the measuring clearance \( s \)

\[
f = nds,
\]

where \( d \) is the diameter of the aperture in the measuring nozzle.

Let us consider one half of the head \( 8 \) (Fig. 1b). The middle nozzle 1 and two side nozzles 2 and 3 belong to different branches, and to eliminate the effect of the shift of the article in relation to the head on the measurement result, it is necessary to maintain equality of transfer sections of the middle and the two side nozzles; i.e.,

\[
f_1 = f_2 + f_3.
\]

In the consequence of the shift of the article relative to one half of the head, the corresponding increments in transfer sections are also equal:

\[
\Delta f_1 = \Delta f_2 + \Delta f_3, \tag{1}
\]

where \( \Delta f_1, \Delta f_2, \) and \( \Delta f_3 \) are the increments of the transfer sections in nozzles 1, 2, and 3 respectively.

When the center of the article and the head are shifted by the quantity \( \Delta a \), the changes of clearances in intermediate and side nozzles can be found from \( \Delta ABC \):

\[
\Delta s_2 = \Delta s_3 = \Delta s_1 \cos \beta, \tag{2}
\]

where \( \Delta s_1, \Delta s_2, \) and \( \Delta s_3 \) are the increments of clearances in nozzles 1, 2, and 3 respectively; \( \beta \) is an angle between the intermediate and side nozzles.

Substituting values in (1) and assuming the diameters of nozzles 2 and 3 to be equal, we obtain

\[
d_2 = \frac{d_1}{2 \cos \beta}, \tag{3}
\]

where \( d_1 \) and \( d_2 \) are diameters of the nozzles 1 and 2.

Minor discrepancies between this formula and the results of the experiment, caused by the factor of the nozzle shape, can be eliminated by lapping of their apertures.

When the article is based on prisms or rollers, the change in the diameter of the article (within tolerance limits) causes different changes of measuring clearances in middle and side nozzles. Besides, nozzles of different diameters possess various lengths of the straight-line region of characteristics. Therefore, the problem of making the best use of the operational region of nozzle characteristics amounts to calculating such an angle \( \alpha \) of the prism (Fig. 1c), or of the contact of rollers with the article, at which changes in clearances of middle and side nozzles, caused by the change in the diameter of the article, would be proportional to their diameters in accordance with (2) and (3)

\[
\Delta s_1^* = 2 \cos \beta \Delta s_2^* \tag{4},
\]

where \( \Delta s_1^* \), \( \Delta s_2^* \) are changes of clearances in nozzles 1 and 2, respectively.

Change of clearance in intermediate nozzle is found from the relation

\[
\Delta s_1' = \frac{\delta}{2} \left( \frac{1}{\sin \alpha} - 1 \right), \tag{5}
\]

where \( \alpha \) is half of the angle of contact between rollers and the article.