WAYS FOR SPEEDING UP PNEUMATIC TESTING OF DIMENSIONS

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The widespread idea that pneumatic dimension-testing instruments are very sluggish is only partly true. It is a fact, however, that pneumatic instruments are inferior with respect to their operating time and their amplitude-frequency characteristic to the majority of mechanical and electrical instruments [1]. The inertia of manometer-type pneumatic instruments increases with a rise in their transfer ratio. However, it is often possible to make pneumatic measurements, including high-precision measurements, in less than 0.3-0.6 sec, which normally fully meets the output requirements of both visual and automatic testing. It is possible to classify the methods for speeding up pneumatic measurements into parametric, design, and operational methods, bearing in mind, however, that each method in fact combines all the three with the name being provided by the predominant one.

Parametric methods consist of a correct selection of the pneumatic measuring system’s parameters (Fig. 1). In this case it is necessary to determine a reasonable relationship between the instrument’s pneumatic transfer ratio \( K = \frac{dh}{ds} \) and the efficiency of testing, since variations in the input-nozzle orifice diameter \( d_1 \), effective pressure \( H \), measuring gap \( s \), and internal diameter \( d_h \) of the measuring chamber hose which lead to a reduction in the operating time also reduce the value of \( K \). If \( h \) and \( d \) are increased simultaneously, so that \( K \) remains constant, the operation time is also reduced. This is due to the fact that the rise in \( K \) with an increasing \( H \) is faster than a simultaneous rise in the operation time, whereas the relationships of \( K \) and the operation time to \( d_1 \) are approximately similar and in the first approximation are inversely proportional to \( d_1^2 \). The minimum operating time for a given \( K \) is attained with a maximum \( H \).

In the USSR, the lower pressure boundary of factory compressed-air lines usually amounts to 0.3 MN/m², whereas pressure stabilizers operate successfully with a pressure drop of at least 0.1 MN/m². Therefore, the maximum obtainable operating pressure \( H \) amounts to 0.2 MN/m². A pressure of \( H = (0.15-0.20) \) MN/m² is often used in testing automatic machines when high efficiency is required. It should be stressed that we are aiming at attaining an optimum output and measurement sensitivity for a given instrument, i.e., for a constant transfer ratio of the instrument’s metering part. However, if it is possible to raise this ratio, thus providing the required total transfer ratio for a small \( H \), the instrument’s inertia can be reduced. A low-pressure instrument with a highly sensitive membrane box can serve as an example of the above arrangement.

The value of \( d_1 \) is selected specifically for each case, bearing in mind that a rise in \( d_1 \) reduces the operating time, but it also decreases the value of \( K \) and increases the error of measurement. For instance, in measuring a tolerance field of \( 20 \) μ with a bellows transducer and a 1-m long hose which connects the transducer to the measuring unit, the operating time amounts to 1 sec if we assume a pneumatic-instrument measurement error of \( 0.6 \) μ (\( d_1 = 1.0 \) mm). However, if a rise in this error up to \( 2 \) μ (\( d_1 = 1.5 \) mm) is assumed, the operating time is reduced to 0.4 sec.

In a general case in fixing the value of \( d_1 \) for differential instruments, it is possible to use the following equation [2]:

\[
\frac{\beta h}{\Delta h} = \frac{\beta}{\Delta H} \frac{\kappa_5 \Delta H}{2H} \frac{1}{\frac{2H}{\beta h}}
\]  

(1)
Depend on the measuring nozzle diameter $d_2$. For a given transfer ratio of the instrument, the operating time is then reduced. In certain instances the value of $d_2$ is limited to $(0.5-1.5)$ mm, owing to the small dimensions of the tested surfaces. Even when such limitations do not exist, it is necessary to consider the inconvenience and impossibility of working with small measuring gaps. Especially in double-nozzle pneumatic instruments, the value of $d_2$ is often fixed at $1.5$ mm. Dimensions of $d_2 > 2$ mm are seldom encountered.

Design methods for improving the dynamic properties of instruments include the use of delta valves and pneumatic amplifiers, a reduction in the size of the measuring chamber, a maintenance of its pressure close to the measuring pressure, and, finally, operation at a low pressure with a membrane box used as a sensing element.

The delta valve (Fig. 2) consists of a differential-instrument contact head in which a variation in the size of the detail changes simultaneously two input and two output cross sections of the instrument. This provides a relatively high $K$ for an adequately large input cross section (an equivalently large $d_1$).

On the basis of the equations for the two branches (subscripts 1 and 2) of an instrument with a delta valve which are written as

$$h_1 = \frac{H}{1 + \left(\frac{a - s}{s}\right)^2},$$

$$h_2 = \frac{H}{1 + \left(\frac{s}{a - s}\right)^2},$$

where $a$ is the full stroke of a delta-valve piston, we obtain

$$K = \frac{d (h_1 - h_2)}{ds} = \frac{\Delta H}{a}. \quad (2)$$