APPLICATION OF SERVOSYSTEMS WITH A STEP DRIVE TO THE AUTOMATION OF LINEAR AND ANGULAR MEASUREMENTS

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Recently instrument systems using automatic control by means of a step drive have found application in measurement technology. The possibilities of using such systems, particularly for the measurement of pulse duration, and the basic circuits and design methods are shown in [1]. A description of an instrument for checking the rectilinearity of surfaces and using a "flexible reducer" scheme based on a step drive for changing recorder scales is given in [2].

This article considers the possibilities of using instrument servosystems having a step drive for automating a number of opticomechanical schemes that have found use in measurement technology for monitoring linear and angular quantities (displacements). We are referring to those opticomechanical schemes which convert measured displacements of an object into proportional displacements of a light mark at its output, with subsequent measurement of these displacements using, as a rule, the method of visual comparative evaluation.

Combining these opticomechanical schemes with a photoelectric servosystem the executive organ of which is a step motor permits not only automation of the displacement measurement process, but also, in some cases, a qualitatively new positive effect, which will be shown below using as an example a practical scheme for an opticomechanical profilograph-profimeter.

The basis for automating the measurements of such combined devices is the tracing of the displacements of the light mark images at the output of the opticomechanical part; by virtue of the discrete (step) character of the unbalance signal processing, the total swing of the light mark displacement is divided into a number of approximately equal parts, each of which corresponds to one step of the drive motor. Counting the parts between two points of the swing gives the distance between these points, measured in linear units equal to one motor step. Thus, the discrete character of the unbalance signal processing affords direct numerical information about the measured displacements.

Figure 1 shows in very general form the block diagram of such devices. The opticomechanical part 1 converts the measured displacements applied to its input into light mark displacements proportional to them; at the beginning of the displacement of the latter, the photoelectric transducer 3 puts out an unbalance signal, which is suitably amplified and shaped by the electronic section 4. The step drive 5 is kinematically coupled with a compensator 2 (in this particular case compensation is produced by shifting the phototransducer itself), with a highly accurate metric coupling 6 (for example, a micrometric screw) being in the kinematic coupling loop, converting the rotor rotation into a linear displacement of the servosystem control element, which is simultaneously a measure of the displacement readout. Each pulse passing into the step motor control circuit rotates the rotor one step. Simultaneously a pulse pair is applied to the electronic counter 7, which, at the termination of the measured displacement, records the number of steps processed by the step motor. In some cases it is convenient to make a continuous graphical recording of the measured displacements, for example in the analysis of the rectilinearity of surfaces. This can be accomplished directly by means of a kinematic coupling of the step motor rotor to the marker of a recording device.

We shall make an approximate evaluation of the measurement error of such a system. Let the opticomechanical part convert the measured displacements into light mark displacements having a proportionality coefficient \( k \), which is determined in percent with an error of \( \varepsilon_1 \). Then the measurement error is determined by the expression:

\[
\text{Error} = k \frac{\varepsilon_1}{100}
\]
where \( L \) is the length of the measured line; \( e_2 \) is the error of the metric coupling; \( e_3 \) is the error introduced by the light mark; \( e_4 \) is the error due to the nonlinearity in displacement conversion.

So far as the error \( e_2 \) is concerned, it is due to the technological factors in manufacturing the coupling. For example, technologically it is possible to make micrometric pairs having a runout error within the limits of 3-5 \( \mu \) over a moving part length up to 50 mm.

The value of the error \( e_3 \) introduced by the light mark can be kept within the limits of 1 \( \mu \) in the case of a sufficiently well focused image. The error \( e_4 \) enters into (1) only in certain cases. Its actual value is hundredths of a percent of the measured swing.

As an example we shall consider several practical schemes using servosystems having a step drive.

Figure 2 shows the schematic of an instrument for monitoring the rectilinearity of guide surfaces [3].

The mark generator 1, consisting of a light source 2, a condenser 3, and a point diaphragm 4, forms a point light source displaced along the monitored surface. The objective of viewing tube 5 is an axicone 6, which, through microobject 7, forms an image of the point source in the plane of scanning slit 8; the slit scanning plane is perpendicular to the viewing tube's optical axis. With a shift of the point light source from the system's optical axis, the light mark in the scanning plane is also shifted from the optical axis. Phototransducer 9 set behind the scanning slit puts out a signal to selective amplifier 10 tuned to the scanning frequency. The unbalance signal is obtained in the form of the first harmonic of the signal taken from the phototransducer. Shaping circuit 11 is used to convert it into pulses having a fixed frequency and shape, and, dependent on the direction of shift of the light mark, they are applied to the channel for right or the channel for left rotation in control circuit 12 for the step motor 13 kinematically coupled with the micrometric pair 14. The latter acts on compensator 15, which is a plane-parallel plate. When the compensator turns around the axis perpendicular to the plane of the drawing, the image of the light mark in the scanning plane is deflected such that the unbalance signal at the selective amplifier output goes to zero. The reversible counter 16 shows the algebraic sum of the pulses worked off by the step motor; i.e., for each point of the monitored swing there is a value of the deflection of the surface from the optical axis, in units of length equal to the value of one motor step.

Interesting possibilities are the combinations of servosystem using a step drive and a mirror multiplier [4], used in particular for measuring linear displacements. The schematic of such a device is shown in Fig. 3.

The light source 1 shines through condenser 2 and slit 3 positioned in the focal plane of objective 5. After objective 5 parallel light beam falls on rotating mirror 7 and prism reflector 6. Mirror 7, suspended on a crossed-spring hinge and connected to rod 8, is in contact with the shifting object and is a measuring mirror. The prism reflector 6 serves to set up \( n \) – the number of reflections of the mirror multiplier, which is at an angle of light beam incidence \( \omega \) and with an angle \( \beta \) between mirrors 6 and 7, with the relationship

\[
n = \frac{\omega}{\beta} + 1.
\]