METHOD FOR AUTOMATIC CHECKING OF COMPONENTS WITH ANY CURVILINEAR PROFILE

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There is at present further extension in the application of the widely-used diverse machines and devices which have programmed machining and testing of components with complicated curvilinear profiles. All such devices can be divided into two groups. The first group comprises closed-loop systems, i.e., devices with feedback, and the second group open-loop systems, i.e., devices without a feedback.

Both groups have certain advantages and disadvantages for controlling components with curvilinear profiles. Closed-loop systems are complicated and expensive, they must contain in their feedback circuits complex and expensive displacement or position transducers which have a large operating range and whose errors determine directly the precision of the device as a whole (in addition to the effect of other sources of errors). All existing open-loop systems contain kinematic chains which comprise sliding pairs, mechanisms for converting rotating into reciprocating movements etc. The presence of a large number of links, even with high precision of their manufacture, leads to a low total accuracy of such devices.

At the same time open-loop systems have a number of substantial advantages as compared with closed-loop systems. The main advantages consist of their relative simplicity and low cost, and their high reliability. The advantages of systems of this type are fully implemented by reproducing given curves (according to a program) by means of mechanisms with few links whose kinematic errors are sufficiently small.

A three-bar motion is the simplest mechanism suitable for the above purpose. It is also the simplest of any possible mechanism with lower pairs and, with the remaining conditions being equal, it has the smallest kinematic error compared with any other mechanism. The above circumstances indicate the advisability of developing a control method for curvilinear profile components based on the utilization of a three-bar motion controlled by a discrete programming device.

The principle of operation of this device which can reproduce any curve is shown in Fig. 1. If disc $A$ is rotated with an angular velocity $\omega_1$ and link $a_2$ with angular velocity $\omega_2$, the pen fixed at point $M$ of link $a_2$ will draw on disc $A$ a certain curve $L$. For constant values of $a_1$, $a_2$ and $\omega_2/\omega_1 = k$ a curve will be drawn which belongs to a family of epi- or hypocycloid curves [1, 2].

Any curve can be drawn for given values of $a_1$ and $a_2$ determined from the relationship

$$a_1 + a_2 = \rho_{\text{max}}; \quad a_1 - a_2 = \rho_{\text{min}},$$

where $\rho_{\text{max}}$ and $\rho_{\text{min}}$ are the maximum and minimum values of a radius vector for a given curve with a variable $k$ determined in the following manner.

By projecting links $a_1$ and $a_2$ onto a perpendicular to the radius vector of the given curve we obtain equation

$$a_1 \sin(\theta - \omega_1 t) + a_2 \sin(\theta - (k-1)\omega_1 t) = 0,$$

from which we find $\Theta$, the angle of rotation of radius vector $\rho$

$$\Theta = f_1(\omega_1, k, a_1, a_2).$$

By substituting the value thus found for $\Theta$ in the equation of a given curve

$$\varrho = f_2(\Theta)$$

and in the equation of the curve which is produced by the mechanism (in the system of coordinates related to disc $A$),

$$\varrho = a_1 \cos(\theta - \omega_1 t) + a_2 \cos(\theta - (k-1)\omega_1 t).$$
we find from the last two equations the sought-for relationship of $k$ to $\omega_1 t$, $a_1$ and $a_2$

$$k = f_3(\omega_1 t, \ a_1, \ a_2).$$

We have examined above the computation of parameters $a_1$, $a_2$, and $k$ of a measuring device mechanism for the case when the curve is given by an equation. The curve which describes the controlled profile is in practice often given in the form of a table which relates the value of the radius vector to the component's angle of rotation (or the lift to the angle of rotation). It is advisable to use a computer for obtaining the values of $k$, which are very difficult to calculate and, therefore, it is obviously unimportant whether the curve is presented in the form of an equation or a table. A certain drawback of the table presentation of the curve consists of a somewhat greater expenditure of labor and the time required for feeding the data into a computer.

A model of the device was made (Fig. 2) for plotting a wide variety of curves with a radius vector range from 0 to 120 mm. The types of curves plotted by means of this mechanism were limited by the use of nonreversing modified step-by-step mechanisms of electromechanical counters SB-1M/100.

The curve reproduced by the relative movement of the mechanism links (Fig. 1) can be used as a reference curve for comparison with the controlled profile.

The kinematic part of the device for controlling components with curvilinear profiles described by any curve is shown in Fig. 3. Motor $M_1$ rotates the controlled component $A$ with an angular velocity $\omega_1$, motor $M_2$ rotates link $a_2$ with an angular velocity $\omega_2$. The link mechanism whose jewel bearing is concentric with axis O directs the measuring tip axis of instrument I (a clock-type indicator or a displacement transducer with an operating range slightly larger than the expected value of the profile absolute error) along the radius vector of the nominal (reference) profile. The measuring tip of instrument I rests against the tested profile at point N, and is displaced by the rotation of the component in the direction of the nominal profile's radius vector to a distance equal to the controlled profile's error $\Delta p = \rho_{\text{nom}} - \rho_{\text{act}}$. This error is read on a clock-type indicator or plotted by a recording instrument as a function of the component's angle of rotation. Production testing can be carried out by means of a two-position electrical-contact transducer, which transmits a signal when error $\Delta p$ exceeds its tolerance $\delta$, or by means of a multiposition electrical-contact transducer which provides appropriate signals for sorting out the testing components into groups.

The drives may consist of induction motors $M_1$ and $M_2$ coupled to rotation angle transducers in the feedback circuit in such a way that the drive of each rotating link will consist of a closed-loop system. However, in view of the fact that the measuring effort in testing is relatively small, it is advisable to use for propulsion purposes mass-produced step-by-step servomotors which are normally used in programmed systems (for instance, motor ShD-4). A program which provides the required ratio $k$ between the angular velocity of tested component $A$ and link $a_2$ can be recorded on any program-carrying device used at the present time, for instance, on a magnetic type. Two ShD-4 motors can be controlled by a mass-produced programming desk PRS-3-61 [3], designed for three motors (the use of the third motor will be discussed below), or by a mass-produced control unit BU-1-60 combined with any device for controlling each motor by means of a unitary code. The programming device for controlling the two motors in this instance may consist of a two-channel stereo tape recorder (for instance, of the "Yauza-10" type).

In practice it is more convenient to use programming desk PRS-3-61; firstly, because it has all the required devices, including a tape-propelling mechanism and a device for reading out the program and,