Realization of Servo-Constraints by Electromechanical Servosystems

M. Kh. Teshaev1*

1 Bukhara Technological Institute of Food and Light Industry, ul. K. Murtazaeva 15, Bukhara, 705017 Republic of Uzbekistan

Received April 30, 2009

Abstract—In this paper we consider a problem of realization of geometric servo-constraints. To this end we construct a digital servosystem whose executive element is a direct current motor of independent excitation. We present the full system of equations for a digital servo-system and discuss the questions of stable realization of servo-constraints.

DOI: 10.3103/S1066369X10120042

Key words and phrases: servo-constraints, realization, digital servo-system, controlled object, digital computer, code-voltage transformer, transducer amplifier.

In the analytical mechanics the concept of servo-constraints has been introduced by H. Beghin [1]. The methods used in [1] have been further developed in the works of P. Appel [2], A. Przeborski [3], V. S. Novosyolov [4], M. F. Shul’gin [5], V. V. Rumyantsev [6, 7], V. I. Kirgetov [8], A. G. Azizov [9, 10], and others. In these papers considerable attention has been paid to generalizing the basic principles of dynamics for systems with servo-constraints, to writing equations of motion, and to defining reactions of servo-constraints. The development of methods of analytical mechanics for systems with servo-constraints was mainly based on using the peculiarities connected with the non-ideality of servo-constraints. These peculiarities manifest in the fact that for such systems the elementary work of servo-constraint reaction forces on virtual displacements allowed by constraints differs from zero [1, 2, 9, 10].

The mentioned works are of importance, but in order to apply methods of analytical dynamics to solving a wide range of actual problems, one has to take into account other peculiarities connected with stable realization of servo-constraints. Sh. S. Nugmanova [11] was the first to call attention to this fact. Based on the theory of parametric release [12] and the theory of forced motions [13], A. G. Azizov constructed a theory that allows one to apply methods of analytical mechanics to systems with servo-constraints including the issues of their stable realization [9, 10].

In this paper we study the realization of servo-constraint and develop one of possible approaches. Consider the following problem of realizing servo-constraints [1]:

\[ \Phi_\alpha(t, q_1, \ldots, q_n) = 0 \quad (\alpha = 1, \ldots, a), \]

(1)

where \( q_1, \ldots, q_n \) are generalized coordinates and \( t \) is the time variable.

For the parametric release of the system from servo-constraints [9, 10] we introduce additional independent variables \( \eta_\alpha \) which reduce system (1) to the form

\[ \Phi^*_\alpha(t, q_1, \ldots, q_n, \eta_1, \ldots, \eta_a) = 0 \quad (\alpha = 1, \ldots, a), \]

where parameters \( \eta_1, \ldots, \eta_a \) characterize the release of the system from servo-constraints (1). Zero values of parameters \( \eta_\alpha \) and their derivatives \( \dot{\eta}_\alpha \) correspond to constraints (1) and their differentiated forms. We can take for these values, for instance, the left-hand sides of Eqs. (1) computed for the real motion of the system [9, 10].

According to papers [6, 7] and [9, 10], servo-systems represent a typical example of systems with servo-constraints. Because of this the stated problem can be solved with the help of an electromechanical digital servo-system (DSS) [14].

*E-mail: muhsin_50@mail.ru.
Analyzing the requirements to the dynamic accuracy of DSS and taking into account the workload of a digital computer (DC), one can construct autonomous or nonautonomous DSS. An autonomous system is a servo-system in which the DC is only a driver unit. If the driven and workable signals are compared in the DC itself, then such a system is called nonautonomous. In other respects both systems are identical. Namely, the signal from the DC or an additional computing device (ACD) goes to the number-to-voltage converter (NVC), passes through the transducer amplifier (TA), and feeds the electric machine (EM) that acts on the controlled object (CO) and changes its kinematic characteristics. By means of a converter scheme (CS) the signal is taken from the measuring sensors and transferred to the DC or ACD.

Nowadays in electric drives of industrial robots the direct current EM are most commonly used due to the simplicity of the speed and torque regulation. There exist general-purpose EM as well as special ones, namely, high-torque EM with increased overload capacities and low-inertia ones with the minimal moment of inertia [15].

For the power supply in direct current EM which are used in industrial robots and other industrial machines, the thyristor and transistor transducers with pulse-duration modulation (PDM) are most widely used. The transistor transducers are used in low-power drives (up to 0.5 kW) and for low-voltage EM. The thyristor transducers are appropriate for high-power drives with high-torque EM [15].

Undoubtedly, nowadays microprocessor systems [16] are brought into forefront because they allow us to increase significantly the flexibility of control, and in so doing realize in real time-scales complex algorithms for digital control as well as complex algorithms for rearranging electric-drive control structures.

Let us now write equations for an electromechanical digital servo-system. The load-bearing element of DSS is an electric motor, and as was indicated by H. Beghin [1]: "... The reactions of servo-constraints are electromagnetic forces acting on the rotor from the stator". As an electric motor we use the direct current one of independent excitation. Then, taking into account the kinematic relation \( \hat{q} = i^{-1}_a \varphi \), we write the equations of motion of a CO with holonomic stationary constraints [17] in the form

\[
\sum_{p=1}^{a} A_{\alpha p} \dot{q}_p + \sum_{s=1}^{n-a} A_{\alpha,a+s} \dot{q}_{a+s} + \sum_{p=1}^{a} \sum_{s=1}^{n-a} [a + s, p, \alpha] \cdot \dot{q}_p \dot{q}_{a+s} + \sum_{s=1}^{n-a} \sum_{s_1=1}^{s} [a + s, a + s_1, \alpha] \cdot \dot{q}_{a+s} \dot{q}_{a+s_1} + \sum_{s=1}^{n-a} \sum_{s_2=1}^{s} [a + s, a + s_2, a + s] \cdot \dot{q}_{a+s} \dot{q}_{a+s_2} + \sum_{s=1}^{n-a} \sum_{a=1}^{a-s} [\alpha, p, a + s] \cdot \dot{q}_p \dot{q}_{a+s} = Q_\alpha - J_{\hat{y}_a} \cdot \ddot{r}_a^2 \cdot \dot{\eta}_\alpha + i_\alpha \cdot e_{e_m \alpha} \cdot I_\alpha \quad (\alpha = 1, \ldots, a),
\]

\[
\sum_{\alpha=1}^{a} A_{\alpha s, a} \dot{\eta}_\alpha + \sum_{s=1}^{n-a} A_{\alpha s, a+s_1, a} \dot{q}_{a+s_1} + \sum_{s=1}^{n-a} \sum_{s_1=1}^{s} [a + s_1, a + s_2, a + s] \cdot \dot{q}_{a+s_1} \dot{q}_{a+s_2} + \sum_{s=1}^{n-a} \sum_{s_2=1}^{s} [\alpha, a + s, a + s] \cdot \dot{q}_p \dot{q}_{a+s_2} + \sum_{s=1}^{n-a} \sum_{a=1}^{a-s} [\alpha, a, a + s] \cdot \dot{\eta}_\alpha \dot{q}_{a+s_1} = Q_{\alpha+s} + i_{a+s} \cdot e_{e_m \alpha+s} \cdot I_{\alpha+s} - J_{\hat{y}_{a+s}} \cdot \ddot{r}_{a+s}^2 \cdot \dot{\eta}_{a+s}, \quad (s = 1, \ldots, n - a), \quad (2)
\]

where \( A_{\alpha p} \) is the coefficient of kinetic energy, \([a + s, p, \alpha]\) are the Christoffel symbols, \( Q_\alpha \) are generalized forces, \( J_{\hat{y}_a} \) is the inertia moment of the armature, \( i_\alpha \) is the reduction ratio, and \( I_\alpha \) is the current intensity of the armature circuit.

Since the processes that take place in the servo-system are interconnected, we should add to the equations of motion of the CO the equations for other elements of the digital servo-system. Let us write the wanting equations.

Usually the measuring sensors transform kinematic parameters into voltages. The measuring sensors, such as potentiometers, tacho-generators, rotative transformers, selsyns, and others, can be described by the following equation [18]:

\[
T_{j_2}^D \cdot \dot{U}_{j_2}^D + U_{j_2}^D = K_{j_2}^{DF} \cdot j_2 \quad (j_2 = 1, \ldots, n)
\]

RUSSIAN MATHEMATICS (IZ. VUZ) Vol. 54 No. 12 2010