On The Stabilization Of Motion Of Mechanical Systems, Constrained Geometrically Servo Constraints.

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Let the mechanical system, the position of which is determined by the generalized coordinates $q_1, \ldots, q_n$, , imposed geometrically servo constraints [1] of the form

$$\Phi_\alpha (t, q_1, \ldots, q_n)=0, \qquad (\alpha=1,\ldots,a) \qquad (1)$$

It is assumed that among the possible displacements δq_i, have such defined independent equations:

$$\sum_{i=1}^{n} a_{\theta_1 i}(t, q_1, \ldots, q_n)\delta q_i = 0 \ , \ (\theta_1=1,\ldots,a) \qquad (2)$$

at which the reactions of second-class work was carried out [1]. Possible moves, satisfying to condition (2) is called (A) -moves [2].

Bearing in mind the parametrically release of systems from servo constraints [3,4], we introduce additional independent variables η_p, corresponding to the transformation system with servo constraints (1) to the form

$$\Phi_\alpha^*(t, q_1, \ldots, q_n, \eta_1, \ldots, \eta_a)=0 \ , \quad (\alpha=1,\ldots,a) \qquad (3)$$

where $\eta_1, \ldots, \eta_a$ – parameters, characterizing the release of system from servo constraints (1). Zero values of η_p and their derivatives $\dot{\eta}_p$ corresponds relations (1) and their differentiated forms. For these values can be taken, for example, the left sides of the equations (1), calculated on the actual motion of the system [3].

Denoting N_p coercion reactions, related to the parameters η_p, we assume that the recent forced to change according to the differential equations [4-7]

$$\ddot{\eta}_p = N_p, \qquad (p=1, \ldots, a) \qquad (4)$$

Defining works of constraints on motions $\delta\eta_p$ by expression:

$$\sum_{p=1}^{a} N_p \cdot \delta\eta_p$$

for parametrically releasing systems we have liberated:

$$\delta A = \sum_{i=1}^{n} R_i^{(2)} \cdot \delta q_i + \sum_{p=1}^{a} N_p \cdot \delta\eta_p \quad (5)$$

where $R_i^{(2)}$ - the reaction of constraints of second-class (servo constraints).

Let the mode of action of the reactions of second-class, it follows that (A) -move work reactions of second-class is equal to zero for non-exempt and exempt parametrically systems. Then for arbitrary coercion reactions work (5) vanishes under conditions

$$\delta\eta_p=0, \qquad (p=1,\ldots a).$$

Assuming, that equation (1) is solvable for a of n generalized coordinates $q_1, \ldots, q_n$, taking into account the equations (3) instead of, for example, $q_1, \ldots, q_a$, introduce parameters $\eta_1, \ldots, \eta_a$. Then, equation (2) will have the form

$$\sum_{i=1}^{n} a_{\theta_1 i}(t, \eta_1, \ldots, \eta_a, q_{a+1}, \ldots, q_n)\delta\chi_i = 0, \ (\theta_1=1,\ldots,a) \qquad (6)$$

where $\chi_\alpha = \eta_\alpha$, $(\alpha=1,\ldots,a)$; $\chi_{a+s} = q_{a+s}$ $(s=1,\ldots,n-a)$.

As is well known [4-7], for such systems the equations of the principle of D'Alembert-Lagrange, can be written as

$$\sum_{i=1}^{n}\left(\frac{d}{dt}\frac{\partial T}{\partial \dot{\chi}_i} - \frac{\partial T}{\partial \chi_i} - Q_i\right)\delta\chi_i = 0 \qquad (7)$$

where T - the kinetic energy of the system; Q_i - the generalized force, corresponding coordinate χ_i.

Then it follows from (7) by (A) -moves the equations of motion:

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{\chi}_i} - \frac{\partial T}{\partial \chi_i} = Q_i + \sum_{\theta_1=1}^{a} \lambda_{\theta_1} a^{*}_{\theta_1 i} \quad , (i = 1, ..., n\ ) \quad (8)$$

where λ_{θ_1} - the factors of constraints second-class.

Equations (8) to be attached to the equation (4). Thus, we obtain ($n + a$) equations with the same number of variables. With the notation

$$\dot{\eta}_p = x_p, \qquad \eta_p = x_{a+p}$$

$$N_p = \tilde{U}_p, \qquad (p=1,...,a)$$

equation (4) will have the form

$$\dot{x} = Ax + B\tilde{U} \quad (9)$$

where

$$A = \left(\begin{array}{c|c} 0 & 0 \\ \hline E_a & 0 \end{array} \right), \qquad B = \left(\begin{array}{c} E_a \\ \hline 0 \end{array} \right),$$

$$x=(x_1,...,x_{2a})^T \quad , \qquad \tilde{U} = (\tilde{U}_1,...,\tilde{U}_a)^T \ .$$

If the system (9) is completely controllable [9], that is, matrix

$$K = \{B, AB, \ ..., \ A^{a-1}B\}$$

has the rank of a, for this system can be supplied various problems of control theory. Bearing in mind the stabilization of motion with respect to the manifold defined by servo constraints, you can search for the type of coercion

$$\tilde{U} = K_1 x$$

where K_1 - a non-zero matrix of dimension $(ax2a)$, that provide stabilization of the trivial solution of the system

$$\dot{x} = (A+BK_1)x$$

an appropriate choice of the elements of K_1, namely, that all the roots of the characteristic equation of the system (10) have negative real parts [10].

In what follows we need the explicit form of the equations (8). In order not to prolong the records we assume that all constraints, imposed on the system, are stationary. Then the kinetic energy liberated parametrically system will have the form [8]:

$$T = \frac{1}{2}\sum_{\alpha=1}^{a}\sum_{p=1}^{a} A_{\alpha p}\dot{\eta}_\alpha \dot{\eta}_p + \sum_{\alpha=1}^{a}\sum_{s=1}^{n-a} A_{\alpha,a+s}\dot{\eta}_\alpha \dot{q}_{a+s} + $$
$$+ \sum_{S=1}^{n-a}\sum_{S_1=1}^{n-a} A_{a+s,a+s_1}\dot{q}_{a+s}\dot{q}_{a+s_1}$$

where the coefficients $A_{\alpha p}, A_{\alpha,a+s}, A_{a+s,a+s_1}$ of quadratically forms is a function of $\eta_1, ..., \eta_a, q_{a+1}, ..., q_n$ and equation (8) in an explicit form will look like:

1)
$$\sum_{p=1}^{a} A_{\alpha p}\ddot{\eta}_p + \sum_{s=1}^{n-a} A_{\alpha,a+s}\ddot{q}_{a+s} + \sum_{p=1}^{a}\sum_{\alpha_1=1}^{a}[p,\alpha_1,\alpha]\dot{\eta}_p\dot{\eta}_{\alpha_1} + $$
$$+ \sum_{p=1}^{a}\sum_{s=1}^{n-a}[p,a+s,\alpha]\dot{\eta}_p\dot{q}_{a+s} + \sum_{s=1}^{n-a}\sum_{s_1=1}^{n-a}[a+s,a+s_1,\alpha]\cdot\dot{q}_{a+s}\dot{q}_{a+s_1} = Q_\alpha + R^{(2)}_\alpha,$$
$$(\alpha = 1, \ ..., \ a)$$

2)
$$\sum_{\alpha=1}^{a} A_{\alpha,a+s}\ddot{\eta}_\alpha + \sum_{s_1=1}^{n-a} A_{a+s,a+s_1}\ddot{q}_{a+s_1} + \sum_{s_1=1}^{n-a}\sum_{s_2=1}^{n-a}[a+s_1,a+s_2,a+s]\dot{q}_{a+s_1}\dot{q}_{a+s_2} + $$
$$+ \sum_{p=1}^{a}\sum_{\alpha=1}^{a}[\alpha,p,a+s]\dot{\eta}_p\dot{\eta}_\alpha + \sum_{\alpha=1}^{a}\sum_{s_1=1}^{n-a}[\alpha,a+s_1,a+s]\cdot\dot{q}_{a+s_1}\dot{\eta}_\alpha = Q_{\alpha+s} + R^{(2)}_{\alpha+s},$$
$$(s = 1, \ ..., n-a) \qquad (11)$$

where [p, a+s, α] - Christoffel's symbols of the first kind [8].

The motions, performed on a manifold, defined by servo constraints (1) is taken as the unperturbed and all other motions, performed on a manifold, defined by equations (3) - disturbances.

If the reactions $R_{\alpha}^{(2)}, R_{a+s}^{(2)}$ of servo constraints, to form the according to the laws:

$$R_{\alpha}^{(2)} = \sum_{s=1}^{n-a}\sum_{s_1=1}^{n-a}[a+s, a+s_1, \alpha]^o \dot{q}_{a+s}\dot{q}_{a+s_1} - Q_{\alpha}^o - \sum_{p=1}^{a}\left(K_{\alpha p}^{'}\dot{\eta}_p + K_{\alpha p}^{''}\dot{\eta}_p\right)$$

$$(\alpha = 1, \ldots, a)$$

$$R_{\alpha+s}^{(2)} = \sum_{s_1=1}^{n-a}\sum_{s_2=1}^{n-a}[a+s_1, a+s_2, \alpha+s]^o \dot{q}_{a+s_1}\dot{q}_{a+s_2} - Q_{\alpha+s}^o \qquad (12)$$

$$(s = 1, \ldots, (n-a)))$$

the system of equations (11) to the form:

1) $$\sum_{p=1}^{a}\left(A_{\alpha p}^o + \sum_{\alpha_1=1}^{a} A_{\alpha p}^{\alpha_1}\cdot\eta_{\alpha_1}\right)\ddot{\eta}_p + \sum_{s=1}^{n-a} A_{\alpha,a+s}^o \cdot q_{a+s}^{''} +$$

$$+ \sum_{p=1}^{a}\left\{\sum_{s=1}^{n-a}[a+s, p, \alpha]^o \cdot \dot{q}_{a+s} + \kappa_{\alpha p}^{'}\right\}\dot{\eta}_p +$$

$$+ \sum_{p=1}^{a}\left\{\sum_{s=1}^{n-a} A_{\alpha,a+s}^p \cdot \ddot{q}_{a+s} - Q_{\alpha}^p + \sum_{s_1=1}^{n-a}\sum_{s_2=1}^{n-a}[a+s_1, a+s_2, \alpha]^p \cdot \dot{q}_{a+s_1}\dot{q}_{a+s_2} + \kappa_{\alpha p}^{''}\right\}\eta_p +$$

$$+ X_{\alpha}\left(\eta_p^2, \dot{\eta}_p^2\right) = 0, \qquad (\alpha, p = 1, \ldots, a)$$

2) $$\sum_{\alpha=1}^{a}\left(A_{\alpha+a,\alpha}^o + \sum_{p=1}^{a} A_{a+s,\alpha}^p \eta_p\right)\ddot{\eta}_\alpha +$$

$$+ \sum_{p=1}^{a}\left\{\sum_{s_1=1}^{n-a} A_{a+s,a+s_1}^p \cdot \ddot{q}_{a+s_1} + \sum_{s_1=1}^{n-a}\sum_{s_2=1}^{n-a}[a+s_1, a+s_2, a+s]^p \cdot \dot{q}_{a+s_1}\dot{q}_{a+s_2} - Q_{a+s}^p\right\}\eta_p +$$

$$+ \sum_{\alpha=1}^{a}\left\{\sum_{s_1=1}^{n-a}[\alpha, a+s_1, a+s]^o \cdot \dot{q}_{a+s_1}\right\}\dot{\eta}_\alpha + \sum_{s_1=1}^{n-a} A_{a+s,a+s_1}^o \cdot \ddot{q}_{a+s_1} + X_{a+s_1}\left(\eta_p^2, \dot{\eta}_p^2\right) = 0,$$

$$(s = 1, \ldots, (n-a); \qquad p = 1, \ldots, a) \qquad (13)$$

where zero top corresponds to the unperturbed motion:

$$A_{\alpha p}^o = \left(A_{\alpha p}\right)_{\eta_p=0}, \quad Q_{\alpha}^o = \left(Q_{\alpha}\right)_{\eta_p=0}, \; [a+s, p, \alpha]^o = [a+s, p, \alpha]_{\eta_p=0},$$

and

$$[a+s, a+s_1, \alpha]^p = \left\{\frac{\partial}{\partial\eta_p}[a+s, a+s_1, \alpha]\right\}_{\eta_p=0}, \quad X_{\alpha}\left(\eta_p^2, \dot{\eta}_p^2\right), X_{a+s}\left(\eta_p^2, \dot{\eta}_p^2\right)$$ - members of the second and higher order terms η_p and $\dot{\eta}_p$.

Since the kinetic energy of the system can be expressed as a positive definite matrix [8], the sub array is positive definite. Then from (a + s_1) last equations of (13) define $\ddot{q}_{a+s_1}$:

$$\ddot{q}_{a+s_1} = \frac{1}{\left|\left(A_{a+s,a+s_1}^o\right)^T\right|}\sum_{s=1}^{n-a}\left(A^{a+s,a+s_1}\right)^o \cdot \left\{-\sum_{p=1}^{a} A_{a+s,p}^o \cdot \ddot{\eta}_p - \right.$$

$$-\sum_{\alpha=1}^{a}\left\{\sum_{s_2=1}^{a}[\alpha, a+s_2, a+s]^o \cdot \dot{q}_{a+s_2}\right\}\dot{\eta}_p -$$

$$-\sum_{p=1}^{a}\left\{\sum_{s_2=1}^{n-a}\cdot\sum_{s_3=1}^{n-a}[a+s_2, a+s_3, a+s]^p \cdot \dot{q}_{a+s_2}\dot{q}_{a+s_3} - Q_{a+s}^p\right\}\eta_p -$$

$$-\mathrm{X}_{a+s}\left(\eta_p^2, \dot{\eta}_p^2\right), \qquad (s_1=1,\dots,(n\text{-}a)) \qquad (14)$$

where - $\left(A_{a+s,a+s_1}^o\right)^T$ the transposed matrix; $A^{a+s,a+s_1}$ - cofactor of the element $A_{a+s,a+s_1}$ (a + s_1) - th row and the (a + s) -th column of the determinant of the transposed matrix $\left(A_{a+s,a+s_1}^o\right)^T$.

Substituting (14) in the first *a* group and the system of equations (13), we obtain:

$$\sum_{p=1}^{a}\tilde{A}_{\alpha p}\ddot{\eta}_p + \sum_{p=1}^{a}B_{\alpha p}\dot{\eta}_p + \sum_{p=1}^{a}\tilde{C}_{\alpha p}\eta_p + \tilde{\mathrm{X}}_\alpha\left(\eta_p^2, \dot{\eta}_p^2\right) = 0 \quad (15)$$

where

$$\tilde{A}_{\alpha p} = A_{\alpha p}^o - \frac{\sum_{s_2=1}^{n-a}A_{\alpha,a+s_2}^o \cdot \sum_{s_1=1}^{n-a}\left(A^{a+s_1,a+s_2}\right)}{\left|\left(A_{a+s,a+s_1}^o\right)^T\right|}\cdot\left\{A_{p,a+s_1}^o + \right.$$

$$\left. + \sum_{\alpha_1=1}^{a}A_{p,a+s_1}^{\alpha_1}\cdot\eta_{2_1}\right\} + \sum_{\alpha_1=1}^{a}A_{\alpha p}^{\alpha_1}\cdot\eta_{\alpha_1};$$

$$\tilde{B}_{\alpha p} = \sum_{s=1}^{n-a}[a+s, p, \alpha]^o \cdot \dot{q}_{a+s} - \frac{\sum_{s_2=1}^{n-a}A_{\alpha,a+s_2}^o}{\left|\left(A_{a+s,a+s_1}^o\right)^T\right|}\cdot\sum_{s_1=1}^{n-a}\left(A^{a+s_1,a+s_2}\right)^o \cdot$$

$$\cdot\sum_{s_3=1}^{n-a}[\alpha, a+s_3, a+s_1]^o \cdot \dot{q}_{a+s_3} + K_{\alpha p}^{'};$$

$$\tilde{C}_{\alpha p} = \sum_{s_1=1}^{n-a}\sum_{s_2=1}^{n-a}[a+s_1, a+s_2, \alpha]^p \cdot \dot{q}_{a+s_1}\dot{q}_{a+s_2} - Q_\alpha^p + K_{\alpha p}^u +$$

$$+\sum_{s=1}^{n-a}A_{\alpha,a=s}^p \cdot \ddot{q}_{a+s} - \frac{\sum_{s_2=1}^{n-a}A_{\alpha,a+s_2}^o}{\left|\left(A_{a=s,a+s_1}^o\right)^T\right|}\cdot\sum_{s_1=1}^{n-a}\left(A^{a+s_1,a+s_2}\right)\cdot\left\{\sum_{s_3=1}^{n-a}\sum_{s_4=1}^{n-a}[a+s_3, a+s_4, a+s_1]^p \cdot\right.$$

$$\left.\cdot\dot{q}_{a+s_3}\cdot\dot{q}_{a+s_4} - Q_{a+s_1}^p + \sum_{s_3=1}^{n-a}A_{\alpha+s_1,a+s_3}^p \cdot \ddot{q}_{a+s_3}\right\};$$

$$\tilde{\mathrm{X}}_\alpha = \mathrm{X}_\alpha - \frac{1}{\left|\left(A_{a+s,a+s_1}^o\right)^T\right|}\sum_{s_2=1}^{n-a}\cdot A_{\alpha,a+s_2}^o \cdot \sum_{s_1=1}^{n-a}\left(A^{a+s_1,a+s_2}\right)^o \cdot \mathrm{X}_{\alpha+s_2} \qquad (16)$$

Will explore the conditions for stability of the unperturbed motion. With the notations

$$\dot{\eta}_p = x_p, \qquad \eta_p = x_{a+p}, \qquad (p=1,\dots,a)$$

equation (14) may be written as:

$$\frac{dx_{i_1}}{dt} = p_{i_1 1}(t)x_1 + \dots + p_{i_1 n_1} x_{n_1} + \varphi_{i_1}(t, x_1, \dots, x_{n_1}), \quad (i_1=1,\dots,n_1=2a) \qquad (17)$$

Where

$$\left(\begin{array}{c:c} E_{\alpha p} & 0 \\ \hdashline -\dfrac{\sum\limits_{\alpha_1=1}^{a} \tilde{A}^{p\alpha_1} B_{\alpha_1 \alpha}}{|\tilde{A}_{\alpha p}|} & -\dfrac{\sum\limits_{\alpha_1=1}^{a} \tilde{A}^{p,a+\alpha_1} C_{\alpha_1 \alpha}}{|\tilde{A}_{\alpha p}|} \end{array}\right) \qquad \varphi = \left(\begin{array}{c} 0 \\ \hdashline -\dfrac{1}{|\tilde{A}_{\alpha p}|} \sum\limits_{p=1}^{a} A^{\alpha p} X_p \end{array}\right) \qquad (18)$$

From the expressions (16) and (18) we see that, the equation (17) represent a system of differential equations with variable coefficients. The stability of this system with respect to the manifold defined by servo constraints (1), will explore the research methods using transient stability systems [9].

We choose the auxiliary system of equations

$$\frac{dx_{i_1}}{dt} = d_{i_1 1} x_1 + d_{i_1 2} x_2 + \dots + d_{i_1 n_1} x_{n_1}, \quad (i_1=1,\dots,n_1=2a) \qquad (19)$$

where the functions $d_{i_1 1}, d_{i_1 2}, \dots, d_{i_1 n_1}, \ (i_1 = 1, .., n_1)$ selected based on the following three cases [10]:

Case 1. There are limits

$$\lim_{t\to\infty} p_{i_1 j_1}(t) = d_{i_1 j_1}, \qquad (i_1, j_1=1,\dots,n_1)$$

Case 2. $p_{i_1 j_1}(t)$ - periodic functions of time of the same period θ_3

$$d_{i_1 j_1} = \frac{1}{\theta_3} \int_o^{\theta_3} P_{i_1 j_1}(\zeta) d\zeta \quad , \qquad (i_1, j_1=1,\dots,n_1=2a)$$

Case 3. Fix a point in time $t=t_0 \geq 0$ and

$$d_{i_1 j_1} = p_{i_1 j_1}(t_o), \qquad (i_1, j_1=1,\dots,n_1=2a)$$

In cases 1, 2 and 3 that the roots λ_{i_1} of the characteristic equation

$$\begin{vmatrix} d_{11}-\lambda & d_{12} \dots & d_{1,n_1} \\ d_{21} & d_{22} \dots & d_{2,n_1} \\ \dots\dots\dots\dots & \dots \ \dots & \dots \\ d_{n_1,1} & d_{n_1 2} \dots & d_{n_1 n_1} - \lambda \end{vmatrix}_{(n_1=2a)} = 0$$

of the system (19) satisfy the inequality:

$$R_e\lambda_{i_1} < -\delta_1, \qquad (\delta_1>0;\ i_1=1,\dots,2a)$$

When the auxiliary system (19) is selected, the studies were carried out as follows. Ask specific-negative form

$$w(x)=\sum_{i_1=1}^{2a}\sum_{j_1=1}^{2a} C_{i_1j_1}x_{i_1}x_{j_1}$$

and construct a function

$$\upsilon(x)=\sum_{i_1=1}^{2a}\sum_{j_1=1}^{2a} a_{i_1j_1}x_{i_1}x_{j_1} \quad , \qquad (20)$$

satisfying the conditions:

$$\left(\frac{d\upsilon}{dt}\right)_{19} = w(x) \ ,$$

where $\left(\frac{d\upsilon}{dt}\right)_{1.16}$ -derivative, evaluated by virtue of (19).

The coefficients $a_{i_1j_1}$ of the quadratic form (20) are determined from the system of equations

$$C_{i_1j_1} = \sum_{\kappa=1}^{2a}\left(a_{i_1\kappa}d_{\kappa j_1} + a_{j_1\kappa}d_{\kappa}i_1\right), \ (i_1,j_1=1,\dots,n_1=2a)$$

It is assumed that the latter system of equations is solvable with respect $a_{i_1j_1}(i_1j_1=1,\dots,2a)$ to, that is, defect of the matrix

$$\begin{pmatrix} d_{11} & d_{12}\ \dots d_{1,n_1} \\ d_{21} & d_{22}\ \dots d_{2,n_1} \\ \dots\dots\dots\dots & \dots\ \dots\ \dots \\ d_{n_1,1} & d_{n_12}\dots d_{n_1n_1} \end{pmatrix}_{(n_1=2a)}$$

equal to zero. We compute $\left(\frac{d\upsilon}{dt}\right)_{(17)}$:

$$\left(\frac{d\upsilon}{dt}\right)_{(17)} = w(x) + \sum_{i_1=1}^{2a}\sum_{j_1=1}^{2a}\sum_{\hat{e}=1}^{2a}\Big(a_{i_1j_1}\left[P_{j_1\hat{e}}(t)-d_{j_1\hat{e}}\right]+$$

$$+a_{\kappa j_1}\left[P_{j_1i_1}(t)-d_{j_1i_1}\right]\Big)x_{i_1}\cdot x_\kappa + \sum_{i_1=1}^{2a}\sum_{j_1=1}^{2a} a_{i_1j_1}x_{j_1}\cdot\varphi_{i_1}(t,x)$$

Obviously [9] that, any function $\varphi_{i_1}(t,x)$ can be written as:

$$\varphi_{i_1}(t,x)=\sum_{\kappa=1}^{2a} h_{i_1\kappa}(t,x)\cdot x_\kappa, (i_1=1,\dots,n_1=2a)$$

therefore

$$\left(\frac{d\upsilon}{dt}\right)_{(17)} = \sum_{i_1=1}^{2a}\sum_{j_1=1}^{2a}\sum_{\hat{e}=1}^{2a}\Big(C_{i_1\kappa} + a_{i_1j_1}\left[P_{j_1\hat{e}}(t)-d_{j_1\hat{e}}\right]+$$

$$+a_{\kappa j_1}\left[P_{j_1i_1}(t)-d_{j_1i_1}\right]+a_{i_1j_1}\cdot h_{j_1\kappa}(t,x)+a_{\kappa j_1}\cdot h_{j_1i_1}(t,x)\Big)x_{i_1}x_\kappa \quad (21)$$

For the asymptotically stability of the solution $x=0$ of the system (17), is sufficient, to form variables $\{x_{i_1} x_\kappa\}$ in the right-hand side of (21) was negative definite.

It is known that, certain conditions of positive quadratic forms

$$\sum_{i_1=1}^{2a}\sum_{\kappa=1}^{2a} e_{i_1 k} x_{i_1} x_\kappa = -\frac{d\upsilon}{dt}$$

given the inequalities Sylvester [10]:

$$\Delta_{n_1} > 0, \quad \Delta_{n_1-1} > 0, \quad \ldots, \quad \Delta_1 > 0 \ , \quad (n_1=2a) \qquad (22)$$

where $\Delta_{n_1}, \ldots, \Delta_1$ - the principal diagonal minors $\left\| e_{i_1\kappa} \right\|_1^{2a}$.

So, how $e_{i_1\kappa}(i_1, \kappa = 1, \ldots, 2a)$ are variables, then for the negative definite $\left(\frac{d\upsilon}{dt}\right)$, in general, insufficient fulfillment of the conditions (22). Sylvester's inequalities should be carried out uniformly for all $x_1, \ldots, x_{2a}$, that is. should required the inequalities

$$\Delta_{n_1} > \gamma_1, \quad \Delta_{n_1-1} > \gamma_1, \quad \ldots, \quad \Delta_1 > \gamma_1 \ , \ (\gamma_1 > 0 \ ; n_1=2a) \quad (23)$$

Conditions (22) and (23) expressed the conditions for the asymptotically stability of the system (17).

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