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STUDY OF INFLUENCE OF INCLINE VIBRATION TO THE WORKING CONDITION OF THE VIBRATION SIEVE

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§1. INTRODUCTION

In dynamics of multibody system the principle of compatibility could be used setting equations of motion in the form of system of differential-algebraic equations. Due to the fact that the constraint conditions are added to the system in the way arbitrary, the method enables to study the motion of the system in various variants with direct computing of reaction forces.

Application of the method in design of a vibration sieve of grinding machine brings goods results in simulating process. As known, in technology of vibration grinding it's necessary to realize the kinematical conditions between rollers and sieve. But it's only possible if the reaction forces as well as other kinetical quantities are known. So as shown below the principle of compatibility and algorithms for realizing on computers are very suitable tools for solution of such technical application

§2. PRINCIPLE OF COMPATIBILITY AND COMPUTER PROGRAM

Let's study motion of mechanical system with n Lagrangian coordinates q. The s constraint conditions of the system could be written in a matrix form:

$$g\,q + g_0 = 0 \tag{2.1}$$

where resp. g_0 are matrices of dimension of $s \times n$ resp. $s \times 1$ and they are assumed to be functions of t, q and $\dot{q}$.

As shown in [3] equation of motion of system could be written in a matrix form:

$$\frac{d}{dt}\Big(\frac{\partial T}{\partial \dot{q}}\Big) - \frac{\partial T}{\partial q} = Q + R \tag{2.2}$$

where T is kinetic energy of the system, Q is matrix $n \times 1$ of generallized forces and R is matrix $n \times 1$ of reaction forces of constraints.

Additionaly we have s another equations from constraint conditions:

$$GR + G_0 = 0 \tag{2.3}$$

where G is of dimension $s \times n$ and G_0 of $s \times 1$. These matrices are calculated when the inverse matrix of inertia matrix. Christoffel coefficients and potential energy of system are known.

In order to define uniquely $2n$ unknowns we should have another $(n - s)$ equations. They could be found from the criteria of ideality of constraint (2.1). These equations have a form:

$$D^T R = 0 \tag{2.4}$$

where D is coefficient matrix of dimension $n \times (n-2)$. For an automatic generation of equations on computer we should have the matrix D uniquely defined in [2] an algorithm for deriving D is shown.

So complete system of equations (2.2), (2.3), (2.4) is prepared for defining $2n$ unknowns q and R. Generation and solution of the system on computers require application of some results of numerical mathematics. Among them we should note: solution on nonlinear algebraic system of equations, solution of differential-algebraic equations by implicit Runge-Kutta methods [1, 5], solution of underdetermined linear algebraic system of equations by Huang algorithm [2, 6] etc.

As a result of theoretical research one program code was written in Fortran-77. This was tested in many applications on 286-, 386- and 486- based personal computers and showed good results. In the next section we will use this technique of approaching to the design of vibration sieve of the grinding machine.

§3. APPLICATION IN SIMULATING MOTION OF VIBRATION SIEVE

Let's simulate the motion of rollers in the vibration sieve of the grinding machine.

The vibration sieve is modeled by one desk which could be move verticaly, horizontaly and rotate around its mass center. So three Lagrangian coordinates could present its motion: x, y, θ.

Similarly we have 3 other coordinates: s (relative motion of roller mass center on the sieve), u (distance of roller mass center from the sieve) and φ (angle of roller rotation) for defining relative motion of roller.

Forced vibration of 2-body system is realized by rotation of the excentricity with angular frequency. The system is suppoeted by system of springs and dampers as shown in Fig. 1.

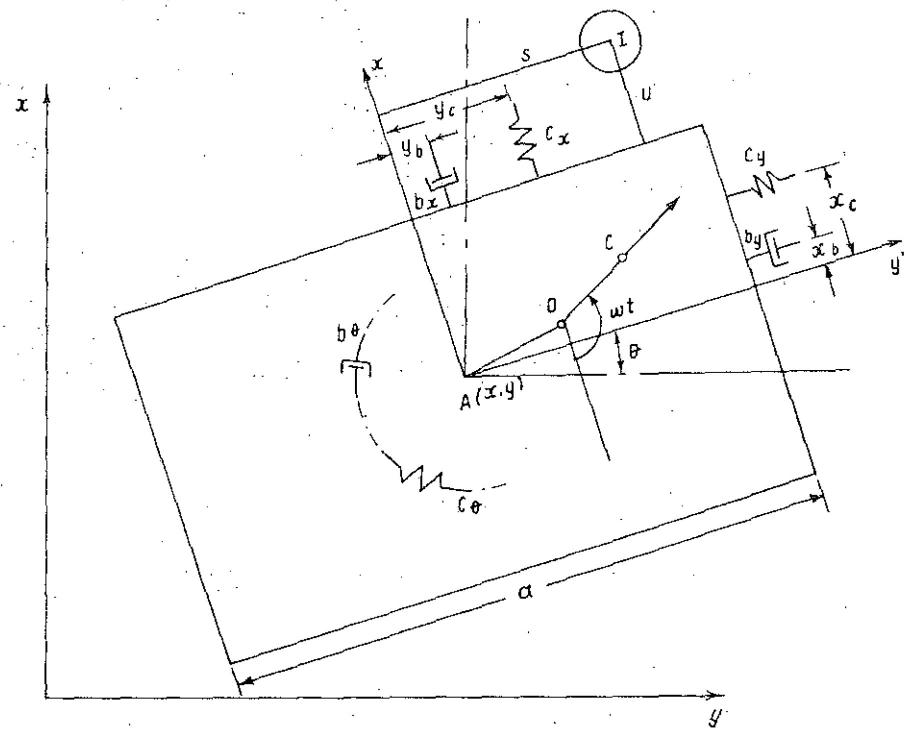

Fig. 1

For this dynamical system with 6 coordinates x, y, θ, s, u, φ we will have 2 constraint conditions [4].

$$\text{- geometrical:} \quad u = \text{const} \quad \text{or} \quad \ddot{u} = 0 \tag{3.1}$$

$$\text{- kinematical:} \quad s = r\varphi \quad \text{or} \quad \ddot{s} = r\ddot{\varphi} = 0 \tag{3.2}$$

Using principle of compatibility, described above, we could compute directly the quantities: x, y, θ, s, u, φ and R_x, R_y, R_θ, R_s, R_u, R.

It's easy to show that reaction force R_u and R_s will be normal and tangential component of contact force between the roller and the sieve. So the kinematical condition would be satisfied if it paied:

$$f^* = \frac{R_s}{R_u} < f \tag{3.3}$$

For deriving equation (2.2) we should know the kinetical energy and generalized forces. Here, we put down these expressions directly:

$$\begin{aligned}
T = {} & \frac{1}{2}(m_0 + m_1 + m_2)\dot{x}^2 + \frac{1}{2}(m_0 + m_1 + m_2)\dot{y}^2 + \\
& + \frac{1}{2}[J_0 + J_1 + J_2 + m_0\ell_0^2 + 2m_0 e(y_0 \sin\omega t - x_0 \cos\omega t) + m_2(s^2 + u^2)]\dot{\theta}^2 + \\
& + \frac{1}{2}m_2\dot{s}^2 + \frac{1}{2}m_2\dot{u}^2 + \frac{1}{2}J_2\dot{\varphi}^2 + [m_0(y_0 \cos\theta - x_0 \sin\theta + e\sin(\omega t + \theta)) + \\
& + m_2 s(\cos\theta - u\sin\theta)]\dot{x}\dot{\theta} + m_2 \sin\theta\dot{x}\dot{s} + m_2 \cos\theta\dot{x}\dot{u} - \\
& - [m_0(x_0 \cos\theta + y_0 \sin\theta - e\cos(\omega t + \theta)) + m_2(\sin\theta + u\cos\theta)]\dot{y}\dot{\theta} + \\
& + m_2 \cos\theta\dot{y}\dot{z} - m_2 \sin\theta\dot{y}\dot{u} + J_2\dot{\theta}\dot{\varphi} + m_0 e\omega \sin(\omega t + \theta)\dot{x} + m_0 e\omega \cos(\omega t + \theta)\dot{y} + \\
& + [J_0 + m_0 e(y_0 \sin\omega t - x_0 \cos\omega t)]\omega\dot{\theta} + \frac{1}{2}J_0\omega^2 + m_2 s\dot{\theta}\dot{u} - m_2 u\dot{\theta}\dot{s}
\end{aligned} \tag{3.4}$$

$$Q_x = -c_x(x + y_c \sin\theta + b\cos\theta - b) - b_x[\dot{x} + (y_b \cos\theta - b\sin\theta)\dot{\theta}] \tag{3.4a}$$

$$Q_y = -c_y(y - x_c \sin\theta + a\cos\theta - a) - b_y[\dot{y} + (x_b \cos\theta + a\sin\theta)\dot{\theta}] \tag{3.4b}$$

$$\begin{aligned}
Q_\theta = {} & -m_1 g[y_0 \cos\theta - x_0 \sin\theta + e\sin(\omega t + \theta)] - m_2 g[s\cos\theta - u\sin\theta - b\sin\theta] - \\
& - c_\theta\theta - c_x(x + y_c \sin\theta + b\cos\theta - b - \sigma_0)(y_c \cos\theta - b\sin\theta) + \\
& + c_y(y - x_c \sin\theta + a\cos\theta - a)(x_c \cos\theta + a\sin\theta) - \\
& - c_y(y - x_c \sin\theta + a\cos\theta - a)(x_c \cos\theta + a\sin\theta) - \\
& - b_\theta\dot{\theta} - b_x[\dot{x} + (y_b \cos\theta - b\sin\theta)\dot{\theta}](y_b \cos\theta - b\sin\theta) + \\
& + b_y(\dot{y} - (x_b \cos\theta + a\sin\theta)\dot{\theta}(x_b \cos\theta + a\sin\theta)
\end{aligned} \tag{3.4c}$$

$$Q_s = -m_2 g\sin\theta \tag{3.4d}$$

$$Q_u = -m_2 g\cos\theta \tag{3.4e}$$

$$Q_\varphi = 0. \tag{3.4f}$$

In these expression there are some symbols denoting parameters of vibrating model: the weights m_0, m_1, m_2, moments of inertia J_0, J_1, J_2 and some dimensions of model: x_0, y_0, x_c, y_c, x_b, y_b, a, b.

The simulating on the computers enables to choose the parameters and working conditions, e.g. radius of roller, weight of the sieve and roller, amplitude of vibration forces, working frequency, parameters of springs and dampers etc.

In order to control the conditions (3.1), (3.2) we can, for example, choose these parameters:

$$
\begin{aligned}
&m_1 = 400kg, \quad J_1 = 200kgm^2 \\
&m_2 = 0.5kg, \quad J_2 = 0.25 \cdot 10^{-4} kgm^2, \quad r = 0.1m \\
&m_0 = 1.27kg, \quad J_0 = 0.127 \cdot 10^{-3} kgm^2, \quad e = 0.01m \\
&c_x = 5 \cdot 10^4 N/m, \quad c_y = 5 \cdot 10^4 N/m, \quad c_\theta = 5 \cdot 10^4 Nm/rad \\
&b_x = 10^5 Ns/m, \quad b_y = 10^5 Ns/m, \quad b_\theta = 10^4 Nsm/rad \\
&\omega = 280 rad/s
\end{aligned}
$$

The influence of θ to the violation of both (3.1) and (3.2) depends on the set of parameters. In general we should note that values of θ is small and the constraint condition (3.1) could be violated more easily than condition (3.2). So recommended approaching is "optimization in small", that means iterative process of optimization, based on the set of parameters, choosen in advance.

CONCLUSION

The principle of compatibility in combination with good algorithms, is convenient for studying the motion of mechanical systems. The obtained results are valuable not only for theoretical research but they could be used directly for technical applications as shown in the case of grinding machine.

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REFERENCES

1. Roger K. Alexandre, James J. Coyle. Runge-Kutta methods and differential-algebraic systems. SIAM J. Numer. Anal., Vol. 27, No 3, June 1990, pp 736-752.
2. Dinh Van Phong. A Criteria of Ideality of Mechanical Constraints in Principle of Compatibility. Journal of Mechanics No 4, 1994.
3. Do Sanh. On the motion of constrained mechanical systems. The thesis of doctor of science, Technical University of Hanoi, Hanoi, 1984.
4. Do Sanh and Dinh Van Phong. Dynamical calculation for a vibration sieve of a grinding machine. Proceedings of fifth national conference on mechanics, Hanoi, 1993.
5. Dinh Van Phong. Differential-algegbaic equations and study of motion of mechanical system. Proceedings of fifth national conference on mechanics, Hanoi, 1993.
6. Bodon E. An algorithm for solving determined on under derrmined, full or definicient rank linear systems based upon the optimally conditioned ARS algorithm Optimization, 21 (1990) 2, 237-248.

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NGHIÊN CỨU ẢNH HƯỞNG CỦA DAO ĐỘNG NGHIÊNG ĐẾN SỰ LÀM VIỆC CỦA MÁY SÀNG RUNG

Trên cơ sở sử dụng nguyên lý phù hợp, việc thêm bớt các điều kiện liên kết được thực hiện dễ dàng, nhờ đó có thể mô phỏng các chế độ làm việc của các hệ cơ học. Bài báo đã sử dụng tính chất này để trình bày phương pháp và một số kết quả nghiên cứu, đã tính toán trên máy tính khi khảo sát ảnh hưởng của góc xoay nghiêng của bàn rung máy mài rung.