STUDY ON MOVEABLE ROLLER CONTROL OF THE ROLLER PRESS

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The roller press is widely used in grinding material due to its high efficiency and power saving. It becomes the fast-developing grinding-equipment. In grinding process, the stochastic variance of granularity, flux, density of materials leads the forces on the moveable roller and hydraulic system are stochastically varied. The clearance between rollers is also varied. While the fluctuation of the clearance is too large, it induces that the bad adaptive to materials and low grinding efficiency. Therefore, it is significant that keeping the clearance stabilization by controlling the vibration of moveable roller and hydraulic system. In this paper, a model of the vibration control is established, based on the principle of the roller press. The control strategy is put forward by variable structure control. A simulation is given.

Keywords: moveable roller, roller press, variable structure control, hydraulic system

1 INTRODUCTION

In 1980s, the roller press with high press crush characteristic began to be employed in industry. Because the benefit of power saving and production increasing, the roller press is widely applied in many fields such as cement industry, mine industry, metallurgy and chemical industry now. Germany, America, Denmark, and Russia etc. have done much research on theory and have improved on its construction and manufacture technology in the past 20 years. The roller press characteristic is obviously improved. But there still are many problems need to be solved. In material grinding process, the granularity, flux, density of materials are stochastic. So the forces on the moveable roller and hydraulic system are stochastically varied. The clearance between rollers is also varied. While the fluctuation of the clearance is too large, it induces that the bad adaptive to materials and low grinding efficiency. Therefore, it is significant that keeping the clearance stabilization by controlling the vibration of moveable roller and hydraulic system.

Hydraulic systems are widely used in the control system studies because it has a nonlinear dynamic behavior when the operating point of state changes. The nonlinear dynamic property makes the control design difficult. Some important dynamic information may be lost if the hydraulic system is linearized during the design. So it is important to select a nonlinear control approach particularly suitable for hydraulic systems.

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Variable structure control (SVC) theory was first proposed and elaborated on in the early 1950s in the Soviet Union by Emelynov and several co-researchers. It is a powerful nonlinear control method capable of providing robust performance for nonlinear dynamic system. The sliding model of SVC has useful invariance properties in the face of uncertainties of plant such as external disturbance and structural parameters and therefore becomes a candidate for moveable roller control of roller press. Based on variable structure control, this paper discusses the theory of controlling the movable roller and hydraulic system. The research work provided the theory foundation to solve the vibration problem.

2 THE MOVABLE ROLLER CONTROL MODEL

2.1 The vibration model of movable roller and hydraulic system

During the roller press being stable state operation, the hydraulic system keeps the press by power accumulator. The pump station only operates at starting the device or when the hydraulic system press decreases at the defined value. The moveable roller and hydraulic system principle in the process show in figure 1.

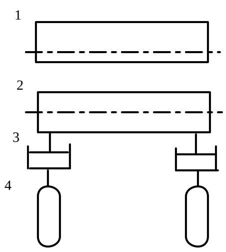

Fig.1 The principle of roller

1-fixed roller 2-moveable roller 3-cylinder 4-power accumulator

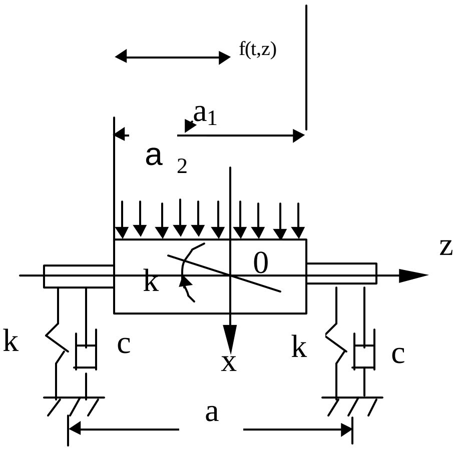

Fig.2 The vibration model of moveable roller

For the sake of simplifying the model, we ignore the oil stiffness of cylinder pipe system. We just consider the gas elasticity stiffness of power accumulator. The vibration model movable roller and hydraulic system are showed on figure 2. In fig.2

O—mass center

x—horizontal displacement of mass center

?—decline angle of movable roller

$f(t, y)$—distribution of outside force

The vibration equation is

$$\begin{cases} m\ddot{x} + 2c\dot{x} + 2k = F(t) \\ J\ddot{q} + 2lc\dot{q} + 2lkq = T(t) \end{cases} \quad (1)$$

Where

$$l = a^2 + (a_1 - a_2)^2 \quad (2)$$

$$F(t) = \int_0^{2a_1} f(t, y)dy \quad (3)$$

$$T(t) = \int_0^{2a_1 - a_2} yf(t, y)dy - \int_{-a_2}^{0} yf(t, y)dy \quad (4)$$

Where, J, m, k, and c respectively express the inertia moment, mass, elasticity coefficient, and damp coefficient. Among them, c and k are separately calculated by the below equations.

$$c = \frac{1}{2} \times \frac{4Q_f}{pwx_m} \quad (5)$$

$$k = \frac{1.4S^2 P_0 V_0^{1.4}}{(V_0 - Sx)^{2.4}} \quad (6)$$

In the equations

Q_f—the friction force of two roller sides

? —the system vibration frequency

x_m—the amplitude of forced vibration

P_0,V_0—the initial press and volume of power accumulator

S—the cylinder piston area

Where, k can be written as

$$k = [1.4S^2 P_0 / V_0][1 + (2.4S / V_0)x + \cdots] \quad (6)$$

let

$$k_0 = 1.4S^2 P_0 / V_0 \quad (7)$$

$$k_x = k_0(2.4S / V_0)x = 3.36S^3 P_0 / V_0^2 x \quad (8)$$

hence

$$k \approx k_0 + k_x \quad (9)$$

can be written as

$$\begin{cases} m\ddot{x} + 2c\dot{x} + 2k_0 x + 2k_x x = F(t) - u(t) \\ J\ddot{q} + 2lc\dot{q} + 2lk_0 q + 2lk_x q = T(t) - T_u \end{cases} \tag{10}$$

1.2 Design for movable roller control

From (10), we can find that there are nonlinear terms ($2k_x x$, $2lk_x$?) and external disturbance terms ($F(t)$, $T(t)$). The model belongs to nonlinear stochastic one. Variable structure control (VSC) is one of the major approaches to dealing with a nonlinear system with parameter uncertainties and external disturbance.

We can respectively discuss (10a) and (10b) by variable structure control (VSC) approaches, due to they are independent. We simplify the equation as linear contracted form.

To (10a), let

$$X = (x, \dot{x})^T \qquad A_1 = \begin{bmatrix} 0 & 1 \\ -w_0^2 & -2Vw_0 \end{bmatrix}$$

$$U = (0, -u(t))^T \qquad B = \begin{bmatrix} 0 & 0 \\ 0 & -m^{-1} \end{bmatrix}$$

2?? $_0$=2c/m $\qquad W = \begin{bmatrix} 0 & 0 \\ 0 & m^{-1} \end{bmatrix} \begin{Bmatrix} 0 \\ F(t) \end{Bmatrix}$

? $_0$=2k$_0$/m

Hence, state function is

$$\dot{\mathbf{X}} = \begin{bmatrix} A_1\mathbf{X} \\ a(\mathbf{X}) \end{bmatrix} + \mathbf{BU} + \mathbf{W} \tag{11}$$

$$s(x) = c^T x \tag{12}$$

Linearize

$$\begin{bmatrix} \mathbf{x} \\ s \end{bmatrix} = \begin{bmatrix} x_1 \\ \vdots \\ x_{n-1} \\ s \end{bmatrix} = \mathbf{Tx}\,,\ \mathbf{T} = \begin{bmatrix} \mathbf{I}_{n-1} \vdots 0 \\ \cdots\cdots\cdots \\ \mathbf{c}^T \end{bmatrix} \tag{13}$$

In which, I_{n-1} is (n-1)×(n-1) dimensions unit matrix. Differentiating (13) and get

$$\frac{d}{dt}\begin{bmatrix} \bar{\mathbf{x}} \\ s \end{bmatrix} = \mathrm{T}\left\{\begin{bmatrix} \mathbf{A_1x} \\ a(\mathbf{x}) \end{bmatrix} + \mathbf{Bu}\right\} \tag{14}$$

notes

$$T=[T_1\ T_2] \qquad \mathbf{T_1}=\begin{bmatrix}\mathbf{I}_{n-1}\\ \tilde{\mathbf{c}}^T\end{bmatrix} \qquad \mathbf{T}_2=\begin{bmatrix}0\\1\end{bmatrix}$$

Where, let c_n=1, and symbol $\tilde{\mathbf{c}}^T$ is given

$$\tilde{\mathbf{c}}^T=[\mathbf{c}_1,\mathbf{c}_2,\cdots,\mathbf{c}_{\mathbf{n-1}}]$$

Then, (14) can be written as

$$\frac{d}{dt}\begin{bmatrix}\bar{x}\\ s\end{bmatrix}=\mathbf{T_1A_1x}+\mathbf{T_2}a+\mathbf{T_2}m^{-1}u$$

notes

$$A_1=[A_{11}\ A_{12}]$$

Where A_{11} is (n-1)×(n-1) matrix, A_{12} is (n-1) ×1 matrix, we can get

$$\dot{\bar{\mathbf{x}}}=\mathbf{A_{11}}\bar{\mathbf{x}}+\mathbf{A_{12}}x_n$$

$$\dot{s}=\tilde{\mathbf{c}}^T\mathbf{A_{11}}\bar{\mathbf{x}}^T+\tilde{\mathbf{c}}^T\mathbf{A_{12}}x_n+a(\mathbf{x})+m^{-1}\mathbf{u}$$

Substitute x_n solved by (12) into two above equations, and obtain

$$\dot{\bar{\mathbf{x}}}=(\mathbf{A_{11}}-\mathbf{A_{12}}\tilde{\mathbf{c}}^T)\bar{\mathbf{x}}+\mathbf{A_{12}}s \tag{15a}$$

$$\dot{s}=\tilde{\mathbf{c}}^T(\mathbf{A_{11}}-\mathbf{A_{12}}\tilde{\mathbf{c}}^T)\bar{\mathbf{x}}+a(\mathbf{x})+m^{-1}\mathbf{u}+\tilde{\mathbf{c}}^T\mathbf{A_{12}}s \tag{15b}$$

When s=0, the sliding model function is induced by (15a)

$$\dot{\bar{x}}=(\mathbf{A_{11}}-\mathbf{A_{12}}\tilde{\mathbf{c}}^T)\bar{\mathbf{x}} \tag{16}$$

and $\tilde{\mathbf{c}}^T$ is obtained. So the pole points of sliding model (16) can be matched at will, and equation (16) asymptotically stabilizes. Now we lead to switch function

$$s(x)=\mathbf{c}^T\mathbf{x}=[\tilde{\mathbf{c}}^T 1]\mathbf{x} \tag{17}$$

let $\dot{s}$ in (16) be equal to attractive law
We obtain VSC

$$u=-m[e\,\mathrm{sgn}\,s+ks+\tilde{\mathbf{c}}^T\mathbf{A_1x}+a(\mathbf{x})] \tag{18}$$

In same way, deduce

$$T_u=-J[e\,\mathrm{sgn}+ks+\tilde{\mathbf{c}}^T\mathbf{A_2x}+a_1(\mathbf{x})] \tag{19}$$

3 SIMULATION

3.1 The parameters of roller press

Table 1 lists the parameters of moveable roller and hydraulic system of HFC800×200 roller press.

m	k_0	c	J	$2a$	$2a_1$	a_2	p_{min}	p_{max}	n
[kg]	N/mm	[Ns/mm]	[kg mm^2]	[mm]	[mm]	[mm]	[MPa]	[MPa]	
2100	9.2×10^3	21.3	9.1×10^7	400	200	150	9	10.6	4

Table 1: The parameters of HFC800×200 roller press[1]

3.2 Simulation

The vibration of the moveable roller and moveable roller which is controlled by VSC are shown in Fig. 3, Fig. 4. Compared between two figures, we found that the amplitude of Fig.3 is 18~19 mm. It is larger than the value of Fig.4. The simulation results show that VSC is effective the vibration control of moveable roller.

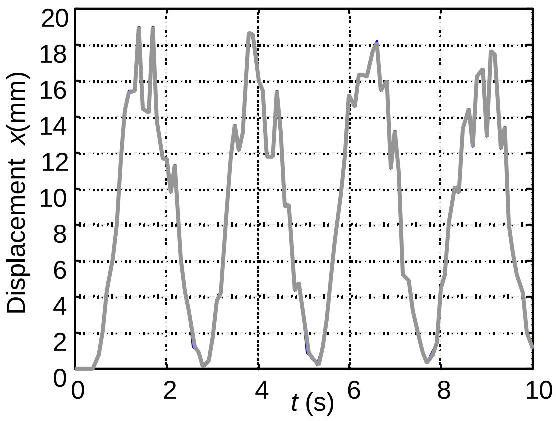

Fig.3 Displacement of moveable roller

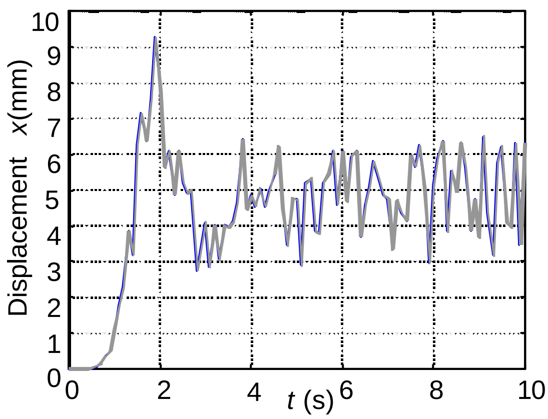

Fig.4 Displacement of controlled moveable roller

4 CONCLUSION

In this paper, the vibration control model of moveable roller of roller press with nonlinear characteristic and uncertain external disturbance is established. VSC is employed to deal with the vibration control. Simulation results reflect the control strategy is a very strong technique to deal with this kind problem.

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