Suppressing Actuator Simulation Analysis Based on Matlab

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Abstract. In order to analyze the dynamic response of the suppressing actuator, the dynamic simulation model of the suppressing actuator based on MATLAB is established in this paper. According to the principle of the suppressing actuator, the suppressing actuator model is presented based on mass-spring-damper system. To simulate the collision between brake lining and brake disc, a Herbert-Mcwhannel collision contact model is introduced to perfect the dynamic model of the suppressing actuator. And the dynamic model simulated in Matlab/Simulink. Then the influence of the fluid pressure $P$ and the restitution coefficient $C_r$ is analyzed. The results show that the optimized hydraulic pressure control can reduce the actuating overshoot, and the brake lining of low restitution coefficient can shorten the response time of the actuator.

Introduction

Suppression Actuator is a brake actuator. Different actuators are suppressed from being actuated directly by an electric cylinder or a hydraulic cylinder, and the actuation pressure is controlled by the spring potential energy output actuation pressure, the hydraulic cylinder or the electric cylinder providing the opposing force. FIGURE 1 shows a simplified schematic diagram of a suppression actuation device.

![Figure 1. Suppression actuator principle.](image)


Compared with electric cylinders or hydraulic cylinders, this type of operation has the characteristics of small structure, easy to implement automatic control, and loss of voltage and self-locking. It is widely used in heavy-duty transportation devices, such as mine hoists and engineering. Transport vehicles[1]. Therefore, it is necessary to study the operating characteristics of its actuation system. Here we analyze the dynamic response of the inhibitory process.

![Figure 2. Suppression of actuator mass spring damping system.](image)
Establish a Mathematical Model to Suppress the Actuator

According to the simplified schematic diagram of the suppression actuation device, it can be seen that when the brake pressure needs to be loaded, the hydraulic cylinder 1 lowers the hydraulic pressure, inhibits the spring 5 against the hydraulic pressure to push the brake lining 3 to the left, so that the brake lining 3 presses against the brake disc 2 occurs. Here is simplified as a mass spring damping system as shown in Figure 2. Where \( F \) is the hydraulic pressure, \( P \) is the hydraulic pressure, \( A \) is the hydraulic cylinder cross section, \( C_1 \) is the hydraulic viscous drag coefficient, \( C_2, k_2 \) simulates the energy exchange between the simplified inertia 4 and the brake disc 2, \( k_1 \) is the spring stiffness coefficient, \( \mu \) is Inertia frictional resistance coefficient, \( m \) is the system to simplify the inertial mass, \( x \) is the established coordinate system, the spring compression position (travel position) is the origin of the coordinate system, the simplified inertia is close to the direction of the brake disk is the positive direction of the coordinate system. Then establish the kinetic equation for suppressing the actuator:

\[
\begin{cases}
F_k - F - F_{v_1} - F_N - F_{\mu} = m\ddot{x} \\
F_{v_1} = k_1(x_0 - x) \\
F = PA \\
F_{v_1} = \text{sgn}(\dot{x})c_1\dot{x} \\
F_{\mu} = \text{sgn}(\dot{x})\mu mg
\end{cases}
\]

where \( x_0 \) is the initial compression amount of the suppression spring 5 and \( F_N \) is the contact force of the simplified inertia 4 with the brake disc 2.

In suppressing the actuation of the actuator, the simplified inertia 4 comes into close contact with the brake disc 2 from disengagement, which is a contact collision process. Therefore, the \( F_N \) term in this dynamic equation has discontinuous and non-linear properties. Here we use the Herbert-Mcwhannell collision contact force model[2].

\[
F_N = k_2\delta^{1.5} + c_2\dot{\delta} = k_2\delta^{1.5} + \frac{6k_2(1-C_r)^{1.5}\delta^{1.5}}{(2C_r - 1)^2 + 3}\delta
\]

In the formula, \( C_r \) is taken as the material recovery coefficient (0.5~0.9), \( \delta \) is the contact compression of the material, and \( k_2 \) is the stiffness coefficient of the material. Here, the exponential function is used to simulate the phenomenon that the infiltration depth increases with the stiffness coefficient which is \( k_2 = e^{A-Bx} \). A, B has the compressibility of the material to choose from, here take \( A=0.262, B=10 \), which is \( k_2 = e^{0.262-10x} \).

Combining equation (2) with equation set (1) suppresses the mathematical model of the actuator:

\[
\begin{cases}
F_k - F - F_{v_1} - F_N - F_{\mu} = m\ddot{x} \\
F_{v_1} = k_1(x_0 - x) \\
F = PA \\
F_{v_1} = \text{sgn}(\dot{x})c_1\dot{x} \\
F_{\mu} = \text{sgn}(\dot{x})\mu mg \\
k_2 = e^{0.262-10x}
\end{cases}
\]
Create a Simulink Model

Here we use the Simulink environment in Matlab to model the suppression actuator mathematical model. The established Simulink simulation model is mainly divided into two areas, namely the dynamic equation part and the collision contact model part (as shown in Figure 3). The collision contact model part is connected to the simulation system with a sub-module. The collision contact model (Figure 4) is divided into two parts: the momentary memory part and the contact force calculation part with the moment of inertia just in contact with the brake disk.

Simulink Model Simulation and Analysis

According to actual conditions, parameters are assigned to the model. The list of parameters is shown in Table 1. All units adopt international units.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/Pa</td>
<td>7e6</td>
</tr>
<tr>
<td>A/m²</td>
<td>0.000804</td>
</tr>
<tr>
<td>C₁/(N/(m/s))</td>
<td>200</td>
</tr>
<tr>
<td>Cr</td>
<td>0.7</td>
</tr>
<tr>
<td>μ</td>
<td>0.2</td>
</tr>
<tr>
<td>m/kg</td>
<td>2.34</td>
</tr>
<tr>
<td>k₁/(N/m)</td>
<td>2.6e5</td>
</tr>
<tr>
<td>x₀/m</td>
<td>0.06</td>
</tr>
<tr>
<td>x₁/m</td>
<td>0.02</td>
</tr>
</tbody>
</table>

In the table, x₁ is the gap between the initial (pre-action) brake lining and the brake disc.

By taking in the parameters, the dynamic response of the model can be calculated. Since the actuator system is concerned with the performance of the active impulse, the actuation response, and the actuation stability, this paper analyzes these three parameters. It is assumed here that the
The system structural parameters have been selected by the operating conditions of the brake, that is, the basic dimensions $A$ of the hydraulic cylinder of the system, the viscosity parameter $C_1$, the inertia $m$, the system friction $\mu$, the spring structure parameter $k_1$, and the system structural parameters $x0, x1$ are determined. Therefore, the effects of the controllable parameters $P$ and $Cr$ on the system's actuation preload, actuation response and actuation stability are analyzed.

Change the different hydraulic pressure control methods, observe the contact force response of the system, and analyze the action impulse. The designed hydraulic pressure control method is shown in Table 2. The table shows the hydraulic pressure when the vehicle's hydraulic pressure drops from the hydraulic pressure to 0s, and then it drops to 0 MPa after 0.002s, which is the theoretical hydraulic pressure value. This process reflects different ways of controlling. The above situation is simulated. Figure 5 shows the simulation results of system contact force change. It can be seen from the above that the control method of hydraulic pressure is more important in suppressing the dynamic response of the actuator. The different control methods will affect the size of the impact contact force, that is, the action of forward impulse; and the action of impulse and control. The hydraulic pressure in the mode does not change linearly. With regard to the selected control mode, the hydraulic pressure first drops to 7 MPa, then to 0 MPa, and the actuator kicks first.

<table>
<thead>
<tr>
<th>0s Hydraulic value/MPa</th>
<th>0</th>
<th>5</th>
<th>7</th>
<th>10</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002s Change in hydraulic pressure/MPa</td>
<td>0→0</td>
<td>5→0</td>
<td>7→0</td>
<td>10→0</td>
<td>14→0</td>
</tr>
</tbody>
</table>

Figure 5. Change of contact force under control of different hydraulic pressures.

Select different material recovery coefficient $Cr$, observe the displacement response of the system and analyze the behavioral response. Figure 6 shows the model simulation results. It can be seen from this that the greater the coefficient of restitution of the material, the more severe the dynamic vibration of the system. This is consistent with the actual situation. Because the greater the material's coefficient of restitution, the smaller the energy loss in the collision process, which represents the system, will cause the collision between the brake linings and the brake discs to increase dramatically. Therefore, under the purpose of improving the actuation response, a brake lining with a small coefficient of material restitution can be selected, which reduces the system vibration and improves the action response capability.
Contrary to suppress the stability of the actuator, the phase diagram of the system dynamics equation (as shown Figure 7) is analyzed. It can be seen that the system has a balance point, and the balance point belongs to the stable focus and has strong resistance to external disturbances, that is, the actuator. The stability of the operation is good; it can also be seen that the selection of different hydraulic pressure control modes and material recovery coefficients has little effect on the stability of the system. This is because the change of model parameters does not change the structure of the system.

**Conclusion**

In this paper, a simulation model for suppressing actuators based on Matlab is established. The effects of hydraulic pressure control parameters and material recovery coefficients on the actuator preload, actuator response, and actuator stability are analyzed. The meaningful conclusions are as follows:

1. The choice of hydraulic pressure will affect the actuator's actuated frontal impulse, and the selected hydraulic pressure and the actuator's actuated forward impulse are linearly related;
2. Selecting a brake lining with a small coefficient of material recovery can shorten the actuation response time of the actuator and improve the operating efficiency;
3. Suppressing the actuator system is a stable system, strong resistance to external disturbances.
References
