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Simulation research on the performance parameters of snake -shaped oil pressure shock absorber dynamic performance parameters

Linman Yang[1,a], Yongqiang Liu[1,b], Zan Zhang[2,c,*]

[1]*Department of Mechanical Engineering, Shijiazhuang Tiedao University, Shijiazhuang, China*
[2]*Department of Mechanical Engineering, Shijiazhuang Tiedao University, Shijiazhuang, China*
**Corresponding author*

Abstract: *This paper presents the structural design and analysis of an oil pressure shock absorber designed to mitigate hunting motion in locomotives. A physical model of the absorber is developed based on the working principles of hydraulic dampers, incorporating force-displacement (F-S) and force-velocity (F-V) characteristics. A parameterized model for the hunting-resistant oil pressure shock absorber is then created. The model is designed to simulate the performance of the absorber under various locomotive operating conditions, including high-speed linear motion and low-speed curve navigation.Key structural and oil-related parameters are considered in the modeling process. The mathematical model of the hydraulic shock absorber is further translated into a Simulink simulation, where the effects of oil temperature, oil pressure, and air bubbles within the hydraulic fluid are evaluated. The results of a bench test validate the accuracy of the simulation model.Finally, the paper applies the orthogonal test method, utilizing the orthogonal optimization approach from applied statistics, to optimize the design parameters of the rail-hunting hydraulic shock absorber.*

Keywords: *Preventing hunting motion, Hydraulic shock absorber, Vehicle dynamics*

1. Introduction

1.1. Research Background

Under the premise of ensuring stability and safety of operation, the achievement of high -speed railway vehicles and the volume of major transportation are the goals of the continuous pursuit of countries. The technical problems of existing locomotives should be improved and the disadvantages of traditional technology should be overcome[1].

The problems to be solved mainly include: locomotive operation stability locomotive, smooth operation, and the ability of the locomotive curve. It can be seen from the movement characteristics of the rotation pair that to make the vehicle have good ability to pass the curve, the stability of the vehicle's straight line operation has deteriorated; on the contrary, to increase the stability of the vehicle operation, it must be at the cost of sacrificing the locomotive. Considering the relationship between the two aspects, we can make a reasonable design. It is not easy to develop a new high -speed steering gear. The first thing to think of railway workers is to improve the parameters of the existing parts of the existing steering frames. It mainly uses vehicle dynamic theory and uses computers as auxiliary tools to perform dynamic optimization analysis and parameters[2].

1.2. Main research Content

This article uses anti -snake oil pressure shock absorber as the research object. The damping characteristics are theoretically required to be ideal and linear, but the locomotive will be affected by various factors during the journey and cannot achieve rational characteristics. Therefore, according to this theoretical model, studying the operation of locomotives is inaccurate. Only by establishing a non -linear model based on its influencing parameters can the actual situation of the locomotive be closer to the locomotive, and then the parameters are improved and optimized to approach the ideal characteristics.

Mainly achieve the following two goals:

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(1) The damping characteristics of the hydraulic shock absorber cannot be simulated by relying on a single parameter and simple linear model. Because the locomotive will be affected by various factors during the journey: It is not possible to achieve the rational characteristics. Therefore, the operation of the locomotive based on a single theoretical model is inaccurate[3]. Only by establishing a non -linear model based on its influence parameters can the actual situation of the locomotive can better reflect the actual characteristics of its operation. The damping characteristics are similar to the working conditions of the train at high speed.

(2) With the continuous improvement of the running speed of the train, the design of the hydraulic shock absorber itself cannot only adopt a conventional static computing model. It should start with the damping system of the snake -resistant hydraulic subtraction, which will be preferred by the parameters that affect the damping characteristics. Only in this way can we better convert the vibration of the mechanical system into other forms of energy, thereby reducing the snake movement of the locomotive.

2. The principle of the oil pressure shock absorber damping system of the snake line

2.1. The working principle

Anti -snake -resistant oil pressure shock absorber is widely used in various high -speed passenger cars, and is vertically installed between the car body and the steering architecture frame. Modern high -speed passenger cars require the anti -snake oil pressure shock absorber to achieve two stretching and compression. The vibration reduction of the direction is linear to achieve the damping characteristic curve[4].

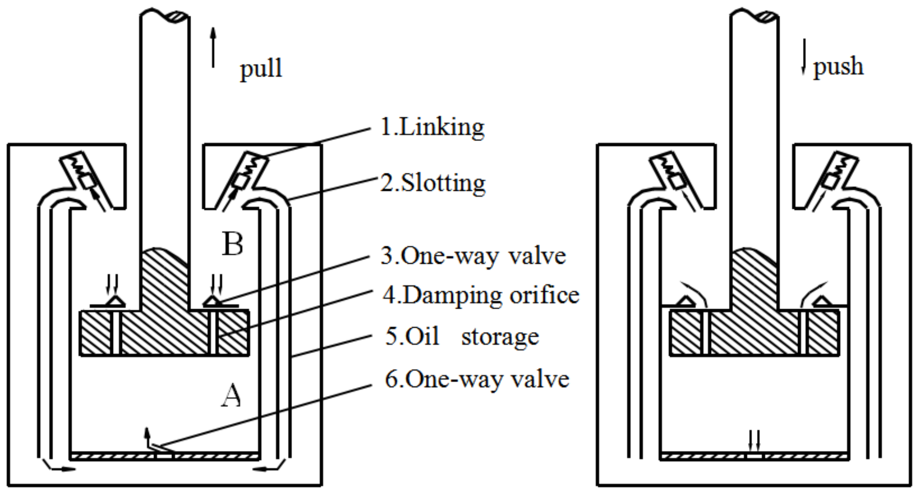

Figure 1: Principles of liquid resistance characteristics of hydraulic shock absorber

The process of the hydraulic shock absorber vibration reduction is shown in Figure 1.The shock absorber is under the upward force, which drives the piston to do the upward stretching movement. The oil of the B cavity is squeezed. Under the action of pressure, one -way valve 3 is closed, valve 6 is opened, and the low pressure oil is supplemented from the oil storage cylinder 5 oil to the pressure cylinder A cavity. During a downward force, the shock absorber is under the power of the piston. When the piston does the downward compression movement, the B -cavity oil pressure decreases, the A cavity oil pressure rises, the one -way valve 6 is closed, and the valve 3 is opened. The oil of the A cavity passes through the slender chip hole 4 and the valve 3 to the B cavity. A large amount of oil in the A cavity flows into the B cavity in large quantities. At this time, the A cavity and B cavity are high -pressure oil. Since the area of the A cavity is greater than the B cavity, the shock absorber provides an upward pressure to prevent the compression of the oil pressure shock absorber. Therefore, the holder can achieve vibration reduction in two directions.

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2.2. Characteristic model

Although the damping characteristics of the existing damper's structure are not linear, the linear damping effect should be achieved when designing a shock absorber. (Linear damping refers to the damping force of the vibrator and the vibration speed in the working area of the train approximately presenting a qualified relationship, that is, the anti -snake oil chores to reduce the anti -vibrator to achieve linear damping). On the one hand, when the locomotive is running at a high speed, the anti -snake shock absorbers can provide a large rotation damping force to prevent the locomotive from occurring. On the other hand, when the locomotive is running at a low speed, the anti-snake shock absorber can provide a lower damping force, enhancing the locomotive's ability to navigate curves.

As shown in Figure 2, the damping regulating system consists of three regulatory valves 1, 2, and 3. The essence of each regulating valve is the structure of the overflow valve, consisting of the valve seat and the valve core. The first two regulatory valve structures are exactly the same. The valve seats are attached to a fixed slender throttle A1 and A2. The high -precision fit surface between the valve seat and the surface of the valve core. It can provide appropriate pressure, so that the valve core and valve seat are tightened. The pressure of the two damping regulating valves can be represented by P1 and P2. The difference between the third regulating valve and the previous two is that there is a fixed throwing hole A3 on the valve core, and the valve seat has a larger fixed fixed -festival circulation hole A4. You can provide appropriate pressure, and the opening pressure of the regulating valve 3 is P3.

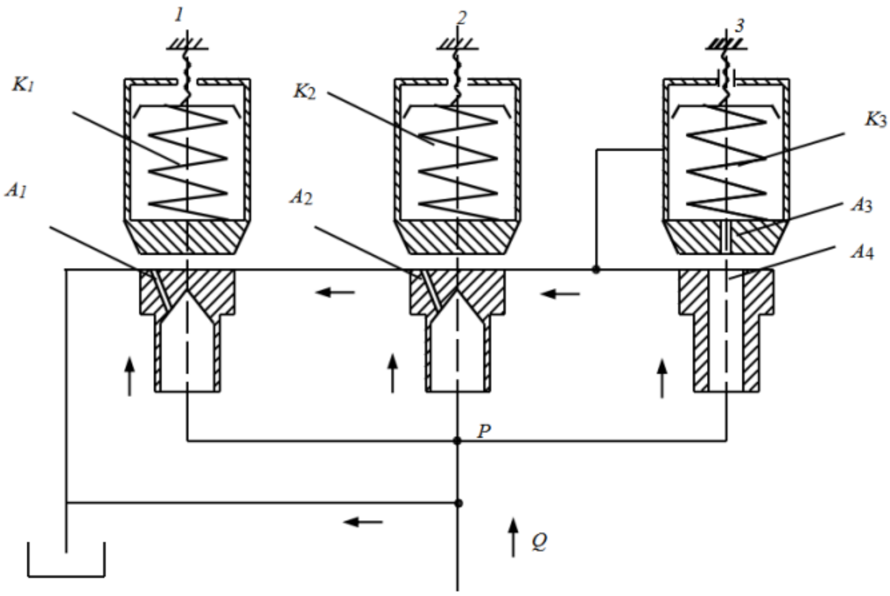

Figure 2: Model of Anti -Snake Hydraulic Vibration Division Definter damping regulating system

When the motorcycles are incentives to go down in different roads, there will be different impact vibration speeds. The total flow Q flowing through the damping adjustment system will increase, and the total pressure P of the corresponding system will rise rapidly with the increase of flow. When the corresponding adjustment pressure of the three regulatory valves is reached, the three regulating valves reaches the corresponding adjustment pressure, and will be turned on in order, and a certain squeezing oil film will be generated between the valve core and the valve seat. The valve core has a certain opening height H1, H2, and H3. The squeezing oil membrane will change with the change of flow, so it provides a variable damping.

In the damping characteristic diagram of the snake -resistant hydraulic shock absorber, the slope of 1 and 2 is large, and the 3 and 4 segments are similar to a straight line. Therefore, from the overall point of view (As shown in Figure 3). At paragraph 1 and 2, the vibration speed of the oil -resistant oil pressure shock absorber V1 and V2 of the snake -resistant oil pressure shock device is relatively small, but the corresponding damping force is very large. Therefore, the slope of section 1 and 2 is very large, and the macro is close to the linearness. Essentially, when the vibration speed exceeds V2, the shock absorber operates and theoretically maintains a constant value. However, this is based solely on theoretical analysis. In fact, due to the deviation of pressure -regulating deviations, saturation power will be slightly improved. In order to resist saturation, the corresponding damping force should be provided. The F3 and F4 are very close, so the 3 and 4 sections are similar[5].

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Therefore, the damping force and vibration speed of the shock absorber can be approximately presented in the working area before the maximum operation speed of the train, that is, the anti -snake -resistant hydraulic shock absorber theoretically realizes linear damping.

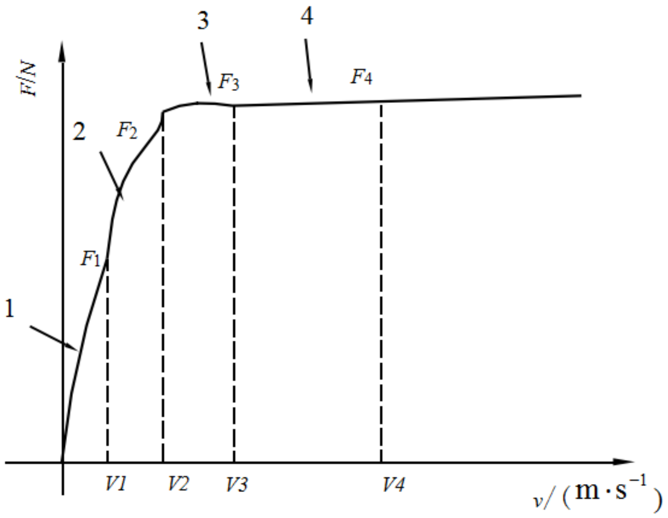

Figure 3:The damping characteristics of the snake -resistant hydraulic shock absorber

2.3. Optimization goal of the damping system

After a period of running for a period of running, the damping valve will occur to a certain amount of wear. It will deviate from the rated damping characteristic curve when working at work.

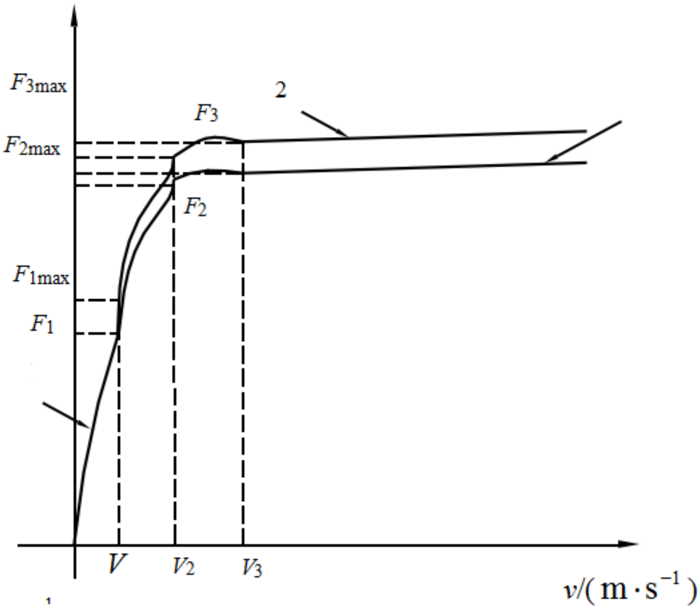

Figure 4:The damping characteristics of the snake -resistant hydraulic shock absorber

In Figure 4, V1, V2, and V3 are the three key speed points of the oil pressure shock absorber. F1, F2, and F3 are the rated damping for three speed points, respectively. The maximum damping force of the point respectively, each damping hole must be calculated according to the maximum damping force when designing.

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3. Simulation modeling of snake -resistant oil pressure shock absorber damping system

3.1. Vibration reduction oil characteristic simulation and building mold

The hydraulic oil in the shock absorber pressure cylinder is constantly moving compared to the inner wall of the pressure cylinder, and a force on the pressure cylinder can be known by Newton's second law[6].

At the same time, the force of the molecules is also relative. At the same time, the resistance between molecules will also produce a molecule. The force provided between the inner wall of the pressure cylinder and the molecule is called internal friction, that is, the viscosity of the liquid.

The viscosity of the oil can be represented by the following formula:

$$\mu = \frac{\mu_0}{2}[1+1.5\varepsilon + e^{a_p(p-p_0)-\lambda(t-t_0)}] \tag{1}$$

In the formula, μ_0 - the initial viscosity of hydraulic oil; ε -The volume percentage mixed in the air.Simulation modeling of hydraulic oil flow of hydraulic oil absorbers.

3.2. Oil Volume Shock Spring-Mathematical Model of Linking System

The cavity of the hydraulic cavity of the hydraulic subtiller of the snake line can be represented by the following formulas

$$K_{oil} = \frac{\beta_e(\frac{\pi}{4}d^2)^2}{V_{oil}} = \frac{\beta_e \pi^2 d^4}{16V_{oil}} \tag{2}$$

Pistons diameter in the formula:

K_{oil}——The piston rod diameter;

β_e——The pressure cavity inner tube height;

d——Pistons diameter;

V_{oil}——The vibration speed of the shock absorber.

3.3. Simulation modeling of hydraulic oil flow of hydraulic oil absorber hydraulic oil

The oil volume of the oil in the piston cavity of the snake -resistant oil pressure shock absorber is:

$$V_{oil} = m_{oil} / \rho \quad K_{oil} = \frac{\beta_e(\frac{\pi}{4}d^2)^2}{V_{oil}} = \frac{\beta_e \pi^2 d^4}{16V_{oil}} \tag{3}$$

The volume change of hydraulic oil is as follows:

$$\Delta V_{oil} = \frac{dV_{oil}}{d\rho}\Delta\rho = -\frac{m_{oil}}{\rho^2}\Delta\rho = -\frac{V_{oil}}{\rho}\Delta\rho \tag{4}$$

The density of hydraulic oil is as follows:

$$\Delta\rho = \frac{\partial\rho}{\partial p}\Delta p + \frac{\partial\rho}{\partial T}\Delta T + \frac{\partial\rho}{\partial\varepsilon}\Delta\varepsilon \tag{5}$$

$$= \frac{\rho_0}{2}\left[e^{\beta(p-p_0)-\alpha_T(T-T_0)}(\beta\Delta p - \alpha_T\Delta T) - \frac{p_0/p}{(1+\varepsilon p_0/p)^2}\Delta\varepsilon \right]$$

Based on the above three, it can be concluded:

$$\Delta V_{oil} = -\frac{V_{oil}\rho_0}{2\rho}\left[e^{\beta(p-p_0)-\alpha_T(T-T_0)}(\beta\Delta p - \alpha_T\Delta T) - \frac{p_0/p}{(1+\varepsilon p_0/p)^2}\Delta\varepsilon \right] \tag{6}$$

The quality of the hydraulic oil in the formula;

p——The density of hydraulic oil;

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β——The compression coefficient of oil;

ε——The percentage of air volume;

α_T——Oil coefficient.

4. Anti -snake hydraulic vibrator simulation analysis

4.1. Oil parameter simulation

From the previous chapter of the dynamic characteristics of the vibrator's oil, it can be known in Figure 5, that the air content of hydraulic oil temperature and oil on the dynamic characteristics of hydraulic oil cannot be ignored. Different oil temperatures are different from that of the air content in oil on the oil characteristics. It can be simulated by Matlab/Simulink. From the simulation curve, the degree of changes in various parameters on the degree of oil and the characteristics of the oil[7].

The equivalent density of the oil in the anti-snake hydraulic shock absorber changes with variations in oil temperature. In figure 6,when the oil temperature changes between 0 ° C and 90 ° C, the equivalent density of the oil decreases by 4%, and the equivalent viscosity of the oil is equivalent. Fall 75%. The loss of the oil of the oil pressure shock absorber oil in the anti -snake -resistant oily oil pressure reduction is different under different oil temperature. When the oil temperature changes between 0 ° C and 90 ° C, the equivalent flow loss of the oil increases To 37.5%of the original flow .

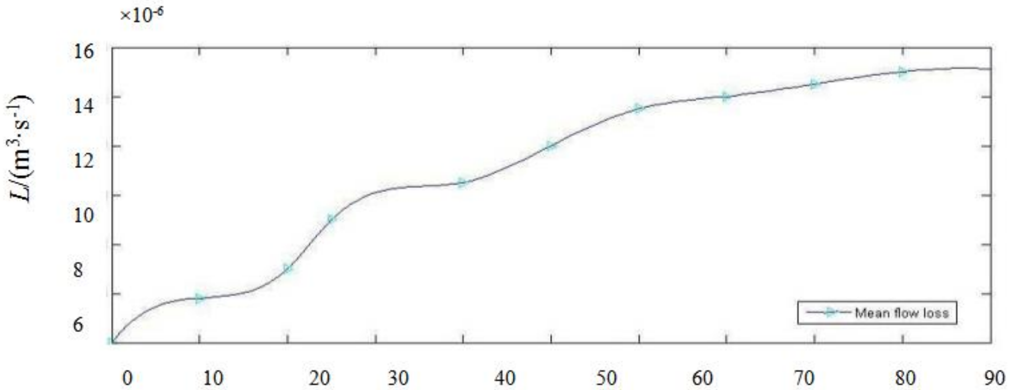


Figure 5: Different oil temperature under the temperature of oil equivalent flow of oil changes

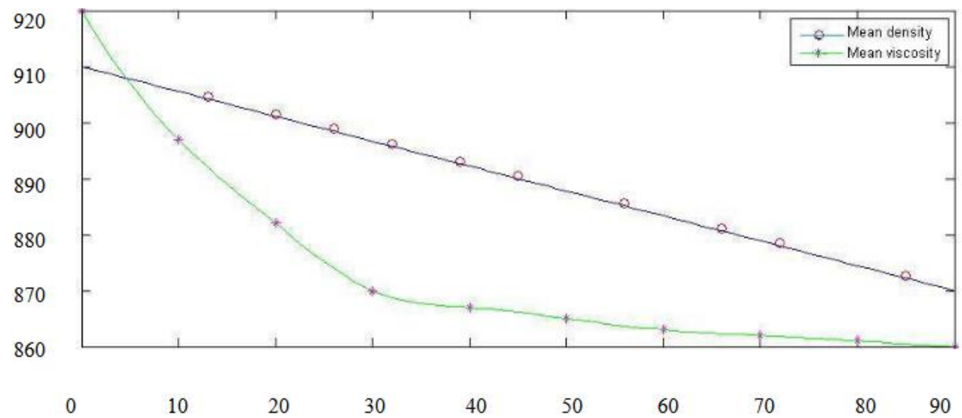
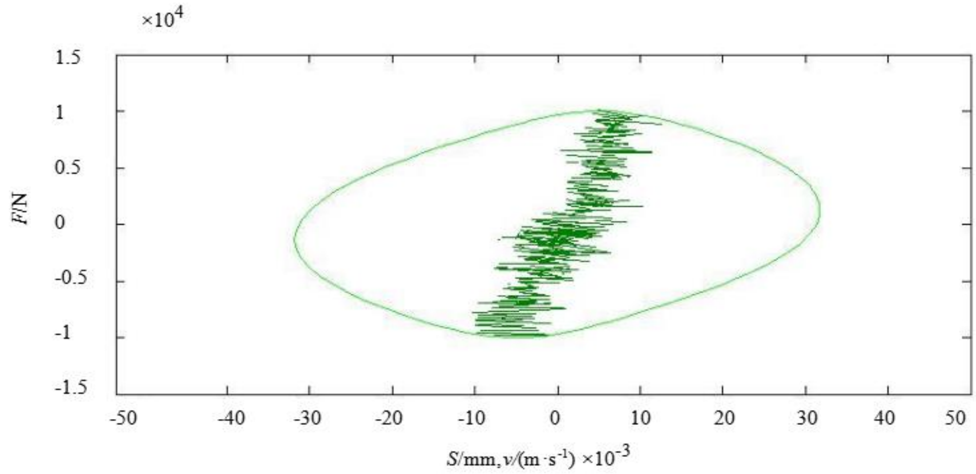


Figure 6:Different oil temperature under the equivalent density and viscosity of oil under temperature

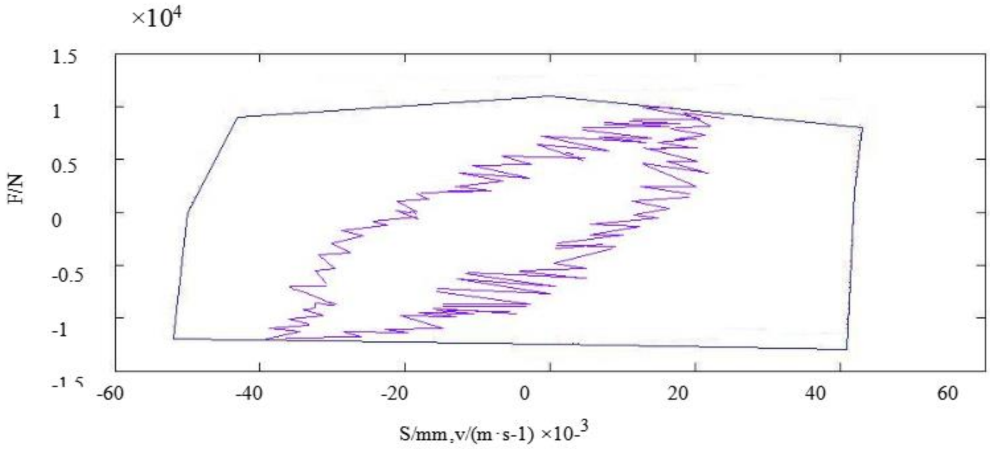
4.2. Simulation of the shock absorber F-V and F-S characteristics

Convert the mathematical model of the hydraulic shock absorber into a Simulink model, and then obtain the damping characteristic curve using simulation software.

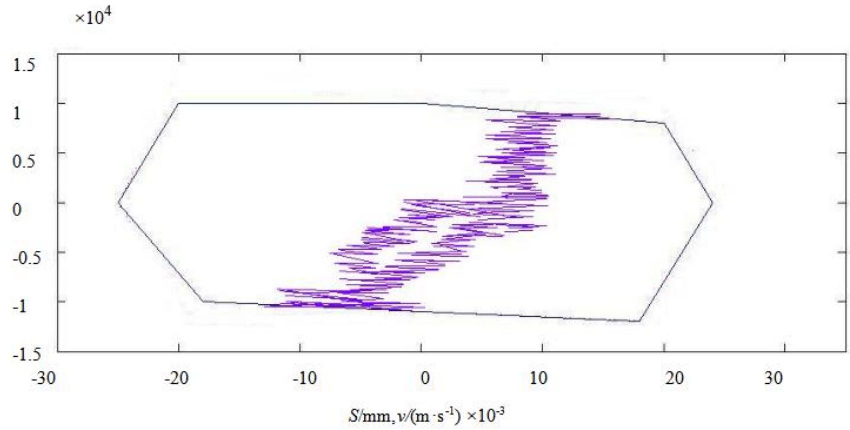
The shock absorber did not implement the curve through the simulation (as shown in Figure 7 (a)) when it moved under the maximum speed of the damping characteristic curve. Anti-snake-resistant oil pressure shock absorber is at the speed of rated conditions, and obtained curves (as shown in Figure 7 (b)) through simulation. The damping characteristic curve of the shock absorber under the limit is obtained by simulation (as shown in Figure 7 (c) and (d)).



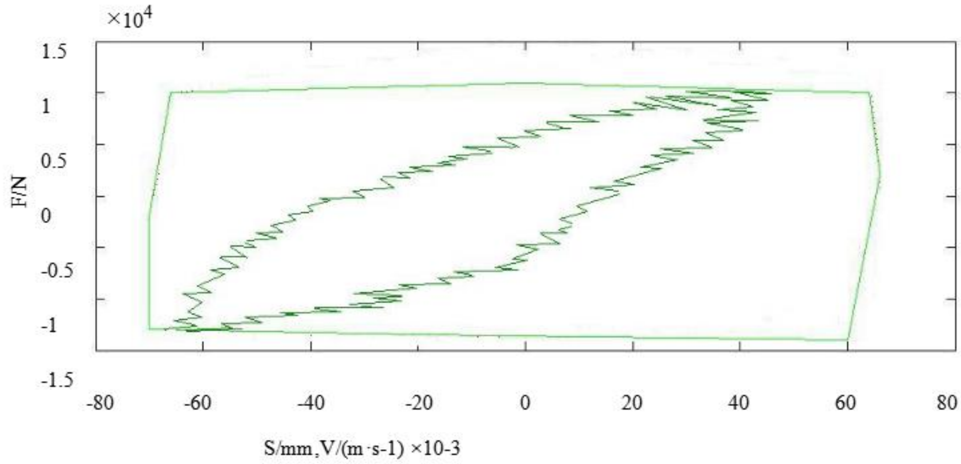
(a)Simulation curve1



(b)Simulation curve2



(c)Simulation curve3

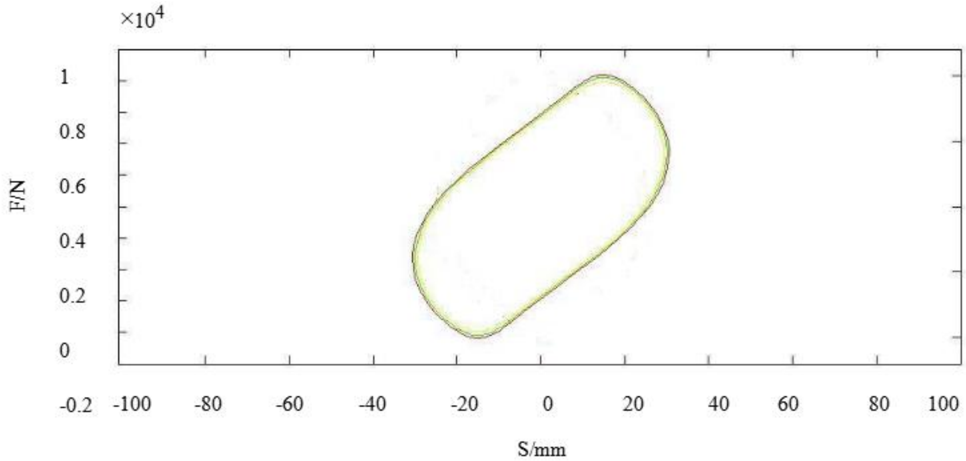


(d)Simulation curve4

Figure 7:Linking feature simulation diagram

4.3. Analysis of the impact on the impact of the shock absorber parameter

There are three simulation curves from the inside to the outside. The corresponding temperature is 85 ° C, 70 ° C and 40 ° C. It can be seen from the impact of different temperature on the damping force. With the gradually increased temperature, the corresponding maximum damping force is getting lower and lower, and the total listening energy absorbed by the oil pressure shock absorber is also declining) Show). The influence curve of oil temperature on energy absorption (as shown in Figure 8(b)) and the impact on maximum damping (as shown in Figure 8(c)) illustrate the relationship between hydraulic oil temperature and the performance of the anti-snake hydraulic shock absorber. From the figure, it can be observed that, with the continuous increase in the temperature of the hydraulic oil, the temperature of the hydraulic oil keeps rising steadily. As the temperature of the hydraulic oil continues to rise, both the maximum damping force and the energy absorption capacity of the anti-snake hydraulic shock absorber show a consistent downward trend. This indicates that the performance of the shock absorber is highly influenced by changes in oil temperature, leading to a gradual decline in its effectiveness as the temperature increases.



(a)The effect of different oil temperature on the damping characteristics of the shock absorber

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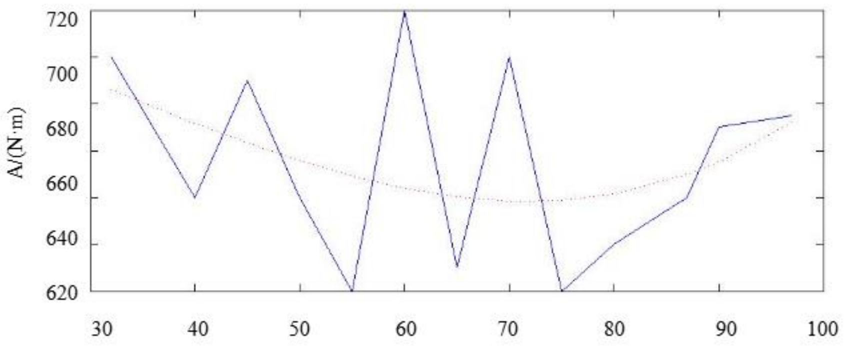
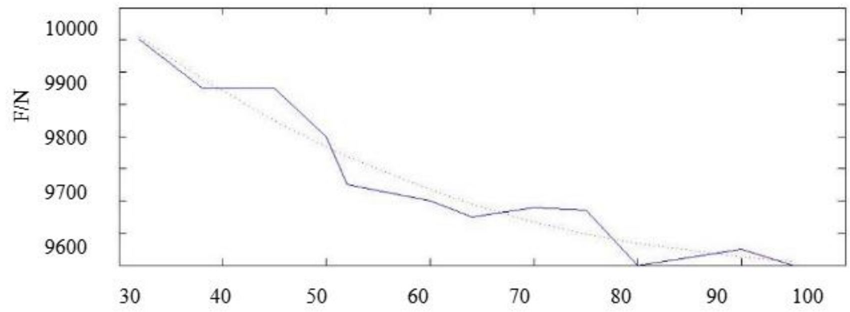


(b)The effect of oil temperature on absorb energy



(c) The maximum damping force with the changing curve of the oil temperature

Figure 8: Simulation of temperature on F-S characteristics

4.4. Test verification of simulation results

In order to ensure that the shock absorber is safe and reliable during the actual progress, the tablet test to the shock absorber is necessary for the shock absorber before loading. When conducting the tablet experiment, first of all, the external inspirational effects applied to the simulation in the simulation are on the shock absorbor, and then read from the microcomputer console that receives the response, so that the response curve can be easily compared with the simulation curve.

5. Conclusions

This article conducts an in-depth study on the anti-hunting hydraulic damper. Initially, structural and oil-related parameters for the shock absorber are established, followed by the development of oil flow and loss equations specific to the anti-hunting hydraulic damper. A parameterized dynamic model of the shock absorber is then created based on these equations.The model is used to simulate various oil parameters, allowing for observation of the effects of oil temperature, oil pressure, equivalent stiffness, oil-air content, and installation gaps on the shock absorber’s damping performance. The simulation results are compared with experimental data obtained from bench tests on the anti-hunting hydraulic damper. The close alignment between the simulation and experimental results validates the accuracy of the parameterized dynamic model.

Additionally, the study explores optimization strategies for the damper's parameters to enhance vehicle comfort.

The main work content of this thesis and the conclusions obtained in the research process are:

(1) The impact of the oil parameters of the oil pressure shock absorber of snake anti -snake lines was fully studied; the dynamic characteristics model of the shock absorber oil oil was established. Observe the simulation diagram and obtain the degree of impact of the above factors on the dynamic characteristics of the shock absorber oil. The established hydraulic oil dynamic characteristics model laid the foundation for subsequent simulation analysis.

(2) In the dynamic modeling of the hydraulic shock absorber, the influencing factors caused by leakage and shock absorber oil caused by the gap between the internal structure of the shock absorber and the leaks caused by the compressor of the oil reductioner oil are considered, and then the shock

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absorber is established.

(3) In the establishment of a dynamic model of the shock absorber parameterization, the impact of the equivalent rigidity and installation gaps of the shock absorber was fully considered, and the vibrator parameterization model was obtained.

(4) Compare the simulation curve obtained by software and the curve of the tablet experimental data. The comparison shows that the results of the two are consistent, so the parameterized model of the anti -snake -resistant oil pressure shock absorber is accurate.

(5) Based on the model established above, the effects of the impact of the oil temperature, component rigidity, oil and air content, and installation gaps on the shock absorber are analyzed by software.

(6) The optimization scheme of the shock absorbers parameter of vehicle comfort is studied. Mainly optimize the screening through the orthogonal test. The parameters of the hydraulic vibrator of the locomotive and vehicle anti -snake -resistant hydraulic shock absorber are optimized through application statistics.

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