Study on cavitation phenomenon of twin-tube hydraulic shock absorber based on CFD

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ABSTRACT

To prevent the occurrence of the cavitation phenomenon in hydraulic shock absorber, the production process of the cavitation during the recovery process of shock absorber is studied, and the parameter model of cavitation production mechanism is built. Based on Computational Fluid Dynamics (CFD) numerical method, a high-precision mesh model of shock absorber is established and the simulation analysis is carried out by using FLUENT software. Therefore, the specific position and distribution of cavitation in the hydraulic shock absorber are obtained, and the measures to inhibit cavitation are put forward. Finally, the simulation results are verified by experimental study and the experimental results show that the cavitation is mainly distributed around the recovery valve of shock absorber, and the cavitation phenomenon becomes more obvious with increasing the piston speed; using low viscosity oil and increasing the diameter of piston rod can effectively inhibit cavitation phenomenon. This study provides a certain reference for preventing the cavitation phenomenon of hydraulic shock absorber.

1. Introduction

Due to high demanding for comfort of automobiles, the suitable design of the hydraulic shock absorber becomes very important (Faraj, Holnickiszulc, & Knap, 2016). Hydraulic shock absorber is an important part of vehicle suspension and steering system (Preda, 2016), it reduces the vibration between the wheel and the car main body through the damping force generated by the internal throttle slice (Yu, Ye, & Wang, 2011), and it can also alleviate the vibration and impact of the car main body caused by uneven road surface, which can improve comfort of the vehicle ride (Pracny, Meywerk, & Lion, 2008). However, the hydraulic shock absorber will be aged if it works for a long time in an environment with strong vibration impact and large temperature change (Dong, Yu, & Yang, 2016) and the inner part of the hydraulic shock absorber will circulate to generate high-pressure and low-pressure area. Moreover, a certain amount of air is dissolved in the oil, when the hydraulic shock absorber works for a certain time, the cavitation phenomenon will occurs. The cavitation phenomenon will seriously affect the performance of hydraulic shock absorber, apart from producing vibration and noise, and it will also reduce working efficiency of the system and shorten the working life of the shock absorber (Alsaydalani, 2017). Therefore, it is of great significance to study the cavitation phenomenon of hydraulic shock absorber.

As the cavitation phenomenon cannot be neglected in the noise control of hydraulic shock absorber, the study on the cavitation suppression has been extensively carried out by domestic and international researcher. To study the production mechanism of the cavitation phenomenon and the abnormal sound of the cavitation phenomenon in hydraulic shock absorber, Luo, Jin, and Jiang (2014) established the relationship model between the cavitation coefficient of the hydraulic shock absorber and the throttle diameter, the parameter model of the twin-tube hydraulic shock absorber was also established, Simulink simulation software was used to simulate and analyze the compression and recovery process of hydraulic shock absorber, it was found that there is no obvious relationship between the cavitation coefficient and the length of the valve hole of the hydraulic shock absorber, it is proportional to the size of the valve hole of the hydraulic shock absorber and inversely proportional to the oil of the hydraulic shock absorber, it was also shown that the abnormal cavitation noise of hydraulic shock absorber can be solved by increasing the diameter of throttle hole. By comparing and analyzing the damp force of hydraulic shock absorber oil and valve...
2. Cavitation phenomenon of hydraulic shock absorber

2.1. Mechanism of cavitation phenomenon

Usually, a certain amount of air is dissolved in the oil of the hydraulic shock absorber (Syrakos, Dimakopoulos, & Tsamopoulos, 2018), the dissolution and decomposition of air are affected by the oil temperature and the internal
pressure of the shock absorber (Hassanzadeh, Saadat, & Dadvand, 2014). The specific production process of cavitation phenomenon is shown in Figure 1. Figure 1 shows that during the recovery process of the hydraulic shock absorber, the piston rod propelling upward causes the oil pressure of the A cavity above the piston to become larger. At this time, the air will be dissolved in a large amount in the oil; when the pressure rises to a certain value, the opening pressure of the recovery valve is reached, and the oil will flow through the B cavity through recovery and compensation valves. Due to throttling loss, the pressure drops sharply at the recovery valve, when the pressure drops to the saturated vapor pressure of the oil, gas will be released from the oil around the recovery valve. Because the oil is mixed with large bubbles, resulting in the oil presents a non-contact state, this phenomenon is known as the hydraulic shock absorber cavitation phenomenon (Yuan, Song, & Liu, 2019).

2.2. Establishment of parameter model

Under constant temperature conditions, the throttle loss occurs when the recovery valve is opened, so the oil pressure at the valve orifice will be reduced below the saturated vapor pressure of the oil, at this time the oil will produce a large number of cavitation (Chao, Zhang, & Xu, 2019). The cavitation coefficient $C_a$ is usually used to characterize the degree of cavitation occurrence (Zhou, Wang, & Xu, 2007). $C_a$ can be defined by Equation (1).

$$C_a = \frac{P_0 - P_v}{\rho_0 v^2 / 2}$$  \hspace{1cm} (1)

where $P_0$ is the downstream and the lowest flow pressure of recovery valve; $P_v$ is the saturated vapor pressure of oil; $\rho_0$ is the density of the oil; $v$ is the average velocity of oil.

When the hydraulic shock absorber works, the oil flow passes through the recovery valve and produces a pressure difference $\Delta P$, which is between the upper and lower recovery valve. $\Delta P$ can be defined as

$$\Delta P = P_1 - P_0 = \rho_0 v^2 / 2$$  \hspace{1cm} (2)

where $P_1$ is the upstream pressure of recovery valve.

Equations (3) can be obtained from Equations (1) and (2).

$$C_a = \frac{P_0 - P_v}{P_1 - P_0}$$  \hspace{1cm} (3)

where $P_v$ is the saturated vapor pressure and is negligible relative to $P_0$ and $P_1$, let $P_v = 0$, Equation (3) can be simplified as

$$C_a = \frac{P_0}{P_1 - P_0}$$  \hspace{1cm} (4)

After read the literature, it is verified that it is when $C_a$ is less than 0.4, the cavitation phenomenon occurs. Therefore, $C_a = 0.4$ is the critical point of whether the hydraulic shock absorber produces cavitation phenomenon (Zhou & Li, 2008). Make $C_a = 0.4$, Equation (4) can be simplified as

$$\xi = \frac{P_1}{P_0} = 0.35$$  \hspace{1cm} (5)

Therefore, the critical pressure ratio $\xi$ of cavitation is obtained. On the other hand, the oil flowing through the throttle orifice, the physical properties of the valve orifice and the diameter of the piston hole will affect the pressure value upstream and downstream of the throttle orifice. It is necessary to consider these two properties to inhibit the cavitation phenomenon of the hydraulic shock absorber.

Li, Zhang, and Du (2018) studied the dynamic response characteristics of wide water-spaced aluminium plate under the impact of a spherical projectile, in their study, a mathematical model of cavitation coefficient was built, and the equations and ranges of the cavitation coefficient were obtained. The value of the cavitation coefficient was used to determine whether the cavitation phenomenon occurs, however, the cavitation coefficient is difficult to be measured and has only one range value, therefore, the study of the cavitation phenomenon is not
visualized in their paper. Therefore, in order to predict more intuitively whether the cavitation phenomenon of hydraulic shock absorber occurs or not, in this paper a parameter model of gas generation mechanism of hydraulic shock absorber was established, the ratio of upstream and downstream pressure $P_0$ and $P_1$ of throttle valve can replace the value of cavitation coefficient, which can concretize the mechanism of abstract cavitation phenomenon, and the ratio of $P_0$ and $P_1$ can be measured to determine whether the cavitation phenomenon occurs in the hydraulic shock absorber, at the same time, the factors affecting the cavitation phenomenon of the hydraulic shock absorber can be known through the expression of $P_0$ and $P_1$, which greatly facilitates the study of the mechanism of the cavitation phenomenon of the hydraulic shock absorber. The only disadvantage of this model is that the value of saturated vapor pressure $P_v$ is ignored, which may have some influence on the accuracy of the model.

3. Modeling of hydraulic shock absorber

3.1. Mesh model

Jiang, Zhang, and Yu (2012) have studied the non-linear characteristics of the superimposed throttle plates of the shock absorber, and the fluid mesh of the recovery valve in this paper is a dense tetrahedral grid without adding the reserved liquid clearance layer, whose setting can achieve an ideal result. However, the actual working condition of the hydraulic shock absorber is not taken into account, so the calculation error is large. To solve the problems, the model of shock absorber recovery valve mesh established in this paper and it is shown in Figure 2, the mesh model is divided in ICEM, whose full name is 'The Integrated Computer Engineering and Manufacturing code', and it is a professional CAE mesh drawing software. In Figure 2, it can be seen that the flow field in the core cavity of the hydraulic shock absorber varies sharply in normal operation, so the core cavity of the shock absorber is divided into a dense tetrahedral mesh; the flow field in the upper and lower oil cavities changes gently, in order to reduce the computation time, the upper and lower oil cavities are divided into hexahedral meshes, the total number of grids is 467825; in order to obtain more accurate simulation results, the reserved liquid gap layer is added between piston and throttle valve plate in this model, the reserved liquid gap layer can not only simulate the flow rate of through hole of hydraulic shock absorber in normal operation, but also make the calculation results more accurate. In this paper all variables of shock absorber oil are established at inflection points, which make the numerical simulation more accurate and improves second-order accuracy when calculating variable interpolation. Because there are not only tetrahedral meshes but also hexahedral meshes in the mesh model, the mesh coincidence degree after the fusion of the two meshes has a certain gap compared with the same type of mesh coincidence degree, which makes the simulation calculation of the model have certain errors.

3.2. Materials and boundary conditions

The cavitation phenomenon is studied in FLUENT, the reference pressure is set to 0 Pa (Yang, Hu, & Liu, 2017), the kinematic viscosity of the shock absorber oil is 13.05 mm$^2$/s, the density is 870 kg/m$^3$, and the viscosity index is 198; the solution method adopts standard $k - w$ model (Peng, Davidson, & Holmberg, 1997), and the Euler-Lagrange model for multiphase flow is used (Vreman, 2011); the surrounding wall is set to a non-slip wall; the oil is the first phase, the air is the second phase (Yang, Teng, & Zhang, 2019), and the two-phase cavitation is applied, the selected cavitation model is Schnerr and Sauer (Mao, 2010), and other options remain default; the velocity fluid inlet and pressure type fluid outlet are adopted, and the oil volume fraction at inlet is 100%; using the dynamic mesh macro in UDF(User-Defined
3.3. CFD solution settings

In order to save computational time and get more accurate fluid simulation results, it is necessary to select the suitable solution settings in FLUENT as following:

1. In order to improve the convergence of simulation and take account of the accuracy of simulation, the relaxation factor is 0.65.
2. The PISO algorithm suitable for transient fluid analysis is adopted to solve the simulation, which can improve the accuracy of the simulation results (Liang, Tian, & Zhang, 2012).
3. Only the moving mesh at the throttle plate is considered, and the moving mesh is not considered in the rest of the flow field.
4. Flow field grids are composed of tetrahedron and hexahedron grids, which lead to errors in calculation. Different types of flow field grids which recomposed of tetrahedron and hexahedron types should be merged to avoid the computational errors and ensure the accuracy of solution information transmission, the overlap of different types of grid spatial positions should be maintained as far as possible.
5. The adaptive step size is adopted to reduce the time step under the convergence condition to improve the computational efficiency.

3.4. Analysis of simulation results

In order to reduce the computational complexity, only a quarter period of the harmonic enforcement is selected in this study, in this period, the velocity of the shock absorber increases with the increase of time. The simulation speed $v = 0.37$ m/s, $v = 0.62$ m/s and $v = 1.04$ m/s are all sinusoidal motion amplitudes, the motion frequencies are 1.45, 2.05 and 3.28 Hz respectively, and the displacement amplitudes are all 60 mm, so the corresponding theoretical maximum speed should be 0.55, 0.77 and 1.23 m/s, respectively. Because the cavitation phenomenon of hydraulic shock absorber usually occurs in the low-speed working condition of the hydraulic shock absorber, and there are friction and various uncertain factors in the internal of the hydraulic shock absorber, such as the manufacturing and assembly errors of the internal parts of the hydraulic shock absorber, in order to better study and analyze the cavitation phenomenon of the hydraulic shock absorber, the simulation speed selected in this paper is less than the theoretical maximum speed, so the simulation speed selected in this paper is 0.37, 0.62 and 1.04 m/s, respectively. When $t = 0.21$ s, $v = 0.37$ m/s, the simulation results are shown in Figure 3. It can be seen that the recovery valve begins to open slightly as the oil impinge on the recovery valve. Due to the existence of throttle loss, the pressure near the recovery valve and the piston hole decreases (Nochnichenko & Uzunov, 2017), resulting in the cavitation phenomenon of hydraulic shock absorber is first produced near the recovery valve and piston hole, however, the cavitation phenomenon is not obvious; the indicator diagram shows that the damping

Figure 3. The gas-phase distribution cloud chart and indicator diagram of hydraulic shock absorber ($t = 0.21$ s, $v = 0.37$ m/s). (a) the gas phase distribution cloud map; (b) the hydraulic shock indicator diagram.
Figure 4. The gas-phase distribution cloud chart and indicator diagram of hydraulic shock absorber ($t = 0.48\, \text{s}, \nu = 0.62\, \text{m/s}$). (a) the gas phase distribution cloud map; (b) the hydraulic shock indicator diagram.

Figure 5. The gas-phase distribution cloud chart and indicator diagram of hydraulic shock absorber ($t = 1\, \text{s}, \nu = 1.04\, \text{m/s}$). (a) the gas phase distribution cloud map; (b) the hydraulic shock indicator diagram.

force is about 60 N, and hydraulic shock absorber works normally. Figure 4 shows that the recovery valve has been partially opened when $t = 0.48\, \text{s}, \nu = 0.62\, \text{m/s}$, because of the increase of oil speed and throttle loss, resulting in a falling faster in hydraulic pressure, so the cavitation phenomenon is more obvious, and cavitation are distributed along the upper edge of the recovery valve; the indicator diagram shows that the damping force is about 400 N, and hydraulic shock absorber works slightly abnormal. Figure 5 shows that the recovery valve has been fully opened when $t = 1\, \text{s}, \nu = 1.04\, \text{m/s}$, the oil throttle loss reaches the maximum, the pressure at the recovery valve drops to the minimum, and the oil speed also reaches the maximum, at this time, cavitation phenomenon is most obvious, the cavitation is all around the recovery valve mouth, and has the tendency to spread to the downward cavity; the indicator diagram shows that the damping force is about 800 N, and shock absorber works abnormally. Figure 6 shows the distribution of cavitation tested in the experiment, it can be seen that the cavitation phenomenon distributes around the recovery valve, and the cavitation phenomenon becomes more serious with the increase of piston rod speed, which verifies the simulation results.

At the same time, Hu, Bai, and Ruan (2012) of Zhejiang University of Technology used CFD commercial
software FLUENT to numerically calculate the flow field inside the digital valve. The conclusion is that the cavitation phenomenon mainly occurs in the low-pressure zone of the valve orifice, and the velocity, the area of diffusion and the duration of the cavitation phenomenon are different within the valve orifice. Because the pressure at the throttle valve orifice is the smallest in this paper, it is easy to produce cavitation phenomenon here. Therefore, the conclusion that the cavitation phenomenon proposed by Hu et al. (2012) mainly occur in the low-pressure zone of the valve orifice is consistent with the conclusion that the cavitation phenomenon mainly distribute around the throttle valve in this paper, which proves the correctness of the simulation conclusion.

4. Measures to inhibit cavitation phenomenon

4.1. Using low viscosity oil

When low viscosity oil is used in the hydraulic shock absorber, the damping force generated by the recovery valve of the shock absorber will be correspondingly reduced. The oil damping force is affected by the oil throttling effect, the weaker the throttling effect, the smaller the throttling loss, and the smaller the oil damping force. Therefore, when the low viscosity oil is used, the throttle loss at the throttle orifice will be reduced correspondingly, and the pressure at the throttle orifice will be increased, resulting in the oil hydraulic pressure not less than the saturated vapor pressure of the oil. At this situation, the cavitation phenomenon is difficult to occur, the low viscosity oil dampers can inhibit cavitation.

In order to validate the appeal theory, the multiphase flow simulation was carried out in FLUENT, oil with kinematic viscosity \( \nu \) of 13.05, 14.05 and 15.05 mm\(^2\)/s is used respectively, piston diameter is 1.5 mm and the simulation experiments are carried out under the same other conditions. The simulation results are shown in Figure 7, Figure 7 shows that when kinematic viscosity is 15.05 mm\(^2\)/s, cavitation phenomenon is the most obvious compared with the other two kinematic viscosities in the three time periods of \( t = 0.21 \) s, \( t = 0.48 \) s and \( t = 1 \) s, which indicates that the oil with high kinematic viscosity is more likely to cause cavitation phenomenon in all working conditions of the shock absorber; when the kinematic viscosity is 13.05 mm\(^2\)/s, cavitation phenomenon is the least obvious compared with the other two kinematic viscosities in the three time periods of \( t = 0.21 \) s, \( t = 0.48 \) s and \( t = 1 \) s, which indicate that the oil with low kinematic viscosity can inhibit the cavitation phenomenon in all working conditions of shock absorber. It can be proved that oil with low kinematic viscosity can better inhibit the cavitation phenomenon of hydraulic shock absorber, which verifies the above theory.

At the same time, An et al. (2018) of Shanghai Jiaotong University measured and analyzed the damping force of the hydraulic shock absorber by changing the hydraulic oil, piston assembly and compensating valve sheet of the shock absorber, and obtained the conclusion that replacing the hydraulic oil, piston assembly and compensating valve sheet of the shock absorber can inhibit the cavitation phenomenon of the hydraulic shock absorber. The low motion viscosity oil proposed in this paper can inhibit the cavitation phenomenon of the hydraulic shock absorber, the conclusion of cavitation phenomenon of hydraulic shock absorber is consistent, which proves that the use of oil with low kinematic viscosity can suppress the cavitation phenomenon of hydraulic shock absorber.

4.2. Using large-aperture piston

When the hydraulic shock absorber uses large-aperture piston, the larger the aperture, the weaker the throttling...
Figure 7. The gas phase distribution cloud map under different kinematic viscosities. (a) Kinematic viscosity of oil $\nu = 13.05 \text{ mm}^2/\text{s}$; (b) Kinematic viscosity of oil $\nu = 14.05 \text{ mm}^2/\text{s}$; (c) Kinematic viscosity of oil $\nu = 15.05 \text{ mm}^2/\text{s}$. 
effect, the smaller the damping force produced at the recovery valve, the smaller the throttling loss correspondingly, resulting in a greater pressure at the recovery valve. At this time, the hydraulic shock absorber is not easy to produce cavitation phenomenon.

In order to validate the appeal theory, the multiphase flow simulation was carried out in FLUENT, the piston diameter $D$ of 1.0, 1.5 and 2 mm is used respectively, kinematic viscosity is 14.05 mm$^2$/s and the simulation experiments are carried out under the same other conditions. The simulation results are shown in Figure 8. Figure 8 shows that when piston diameter is 1.0 mm, cavitation phenomenon is the most obvious when compared with the other two piston diameter in the three time periods of $t = 0.21$ s, $t = 0.48$ s and $t = 1$ s; when the piston diameter is 2.0 mm, cavitation phenomenon is the least obvious when compared with the other two piston diameter in the three time periods of $t = 0.21$ s, $t = 0.48$ s and $t = 1$ s. Therefore, the use of large-aperture piston can also effectively inhibit the cavitation phenomenon, which verifies the above theory.

At the same time, Luo, Jin, and Jiang (2014) of Chongqing Jiaotong University have established the relationship model between the cavitation coefficient of the hydraulic shock absorber and the diameter of the throttle hole, the parameter model of the twin-tube hydraulic shock absorber was also established. Through Simulink simulation software, the process of compression and recovery of the hydraulic shock absorber was simulated and analyzed, the conclusion was that the abnormal cavitation noise of the hydraulic shock absorber can be solved by increasing the diameter of the throttle hole is obtained, it is consistent with the conclusion that using large diameter piston can inhibit the cavitation phenomenon of hydraulic shock absorber in this paper. It proves that using large diameter piston can suppress the cavitation phenomenon of hydraulic shock absorber.

5. Analysis of experiment

5.1. Experiment preparation

In order to verify that low kinematic viscosity shock absorber oil and the large-aperture piston can inhibit cavitation phenomenon, and to verify the accuracy of FLUENT multi-phase flow simulation, the shock absorber dynamometer experiment was carried out.

The experiment equipment in this paper is QJ-4A-10 shock absorber servo indicator manufactured by the Department of Instrument Engineering of Shanghai
Figure 8. The gas phase distribution cloud map under different piston diameters. (a) Piston diameter $D = 2$ mm; (b) Piston diameter $D = 1.5$ mm; (c) Piston diameter $D = 1.0$ mm.
Jiaotong University, the amplitude of the shock absorber servo indicator is 60 mm, using 8-channel signal conditioning instrument system, and the test power supply is 380 V three-phase power supply; in order to better meet the normal working condition of the shock absorber, the temperature chosen in the test is 25°C, which is room temperature; at the same time, in order to make the shock absorber servo indicator measure test data more accurately, the shock absorber servo indicator adopts non-contact infrared sensor and 16 bits A/D-PC compatible data collector. In order to average the test data and reduce the test error, 20 double cylinder hydraulic shock absorber of S50-230GH2 type with the same structural parameters were used in the test samples. The experiment is calculated on DELL Precision T3620 workstation, the specific experiment equipment is shown in Figure 9.

5.2. Analysis of experiment results

Figure 10 is the indicator diagram of shock absorber at $t = 0.48$ s, $f = 2.05$ Hz, and the kinematic viscosity is 13.05, 14.05 and 15.05 mm$^2$/s respectively (when $t = 0.48$ s, the cavitation phenomenon is obvious, which is beneficial to the verification of the test). Figure 10 also shows that when the kinematic viscosity of the oil is 13.05 mm$^2$/s, the indicator diagram is full, which indicates that at this time shock absorber works normally and cavitation distribution is not serious; when the kinematic viscosity of the oil is 15.05 mm$^2$/s, the indicator diagram is distorted and the graph is unsatisfactory, which indicates that the shock absorber works abnormally and the cavitation phenomenon is obvious. Therefore, low kinematic viscosity oil can inhibit the cavitation phenomenon.
Figure 10. Indicator diagram under different kinematic viscosities.

Figure 11. Indicator diagram under different piston diameters.

Figure 11 is the indicator diagram of the shock absorber at $t = 0.48\,\text{s}$, $f = 2.05\,\text{Hz}$, and the diameters of the piston holes are 1.0, 1.5, 2 and 3 mm respectively. Figure 10 shows that the indicator diagram of the shock absorber is seriously distorted when the diameter of the piston holes of the shock absorber is 1.0 mm, which indicates that at this time working environment of the shock absorber is bad and the cavitation phenomenon is serious; when the diameter of the piston hole of the shock absorber is 3.0 mm, the indicator diagram of the shock
absorber is full, which indicates that the shock absorber works normally, and the distribution of cavitation phenomenon is not obvious. Therefore, the large-aperture piston can effectively inhibit the cavitation phenomenon.

It can be concluded that low viscosity oil and large-aperture piston can effectively inhibit the cavitation phenomenon of the hydraulic shock absorber, which verifies the accuracy of FLUENT multi-phase flow simulation results.

6. Conclusions

(1) This paper simulated the cavitation phenomenon in the recovery valve of the hydraulic shock absorber based on CFD numerical method, which is found that the specific location of the cavitation is mainly near the throttle valve of the recovery valve, and the methods of using oil with low kinematic viscosity and piston with large aperture to inhibit cavitation were put forward and verified by experiment, the experiment results are in agreement with the simulation results, also it was shown that the cavitation suppression method proposed in this paper can effectively inhibit the cavitation phenomenon in the recovery valve of hydraulic shock absorber. Because the cavitation phenomenon is the main reason for the fluid noise of hydraulic shock absorber, this paper has the advantages of inhibiting the cavitation phenomenon of hydraulic shock absorber and solving the noise problem of hydraulic shock absorber, which has certain theoretical value and practical engineering significance.

(2) In this paper, a parameter model of the mechanism of cavitation in hydraulic shock absorber was established, and the abstract cavitation coefficient was replaced by the ratio of the upper and lower pressure of throttle valve which can be measured in practice, which greatly facilitates the study of the mechanism of cavitation in hydraulic shock absorber. The composite grid of recovery valve was also established, and the core cavity was divided into hexahedral grid, and the upper and lower oil cavities were divided into hexahedral grid. The model is as close as possible to the actual physical model, and the Euler-Lagrange model was used to solve the multiphase flow. By adding a reserved liquid clearance layer between the piston and throttle valve sheet, the flow rate of oil through the common through hole in the hydraulic shock absorber can be simulated. Also the turbulent motion of oil and the phenomenon of pressure on oil-gas cavitation were fully considered in the numerical calculation, which makes the calculation result more accurate.

(3) The purpose of this paper is to study the cavitation phenomenon of hydraulic shock absorber in depth, so it is necessary to quantify the cavitation phenomenon in the experimental results and carry out simulation analysis. However, due to the short age and backwardness of test equipment, this part of the test can not be carried out, which makes the article has certain limitations. Therefore, for the sake of the rigor of the article, the future work of this paper mainly focuses on the quantification of hydraulic shock absorber cavitation phenomenon. It is hoped that Fluent and Matlab can be used to carry out joint simulation so as to realize the quantitative simulation analysis of hydraulic shock absorber cavitation phenomenon. At the same time, more professional testing equipment should be actively introduced to measure and verify the hydraulic shock absorber cavitation phenomenon quantitatively, and ultimately achieve the goal of quantifying the hydraulic shock absorber cavitation phenomenon.

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