

# Review and prospect of research on hydraulic pulsation attenuator

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**Abstract.** The pressure pulsation attenuator is able to decrease the fluid fluctuation of the hydraulic pump effectively, so it is widely used in construction machinery.

This paper reviews the history and progresses of the research on the pressure pulsation attenuator in China and overseas, summarizes its two types: H-type rigid structure and built-in flexible material, meanwhile, discusses its future research area.

## 1. Introduction

Hydraulic accumulator and vibration damping device have been widely used in hydraulic system. Types of common accumulator are the components for storing the energy, easing the concussion and absorbing the pressure fluctuation. The research of all kinds of accumulators and vibration damping devices has been improved abroad. The pulsation attenuator, which is used to reduce the flow pulsation and pressure pulsation in the hydraulic system, has a vigorous development trend both at home and abroad.

The pressure fluctuation is caused by the flow pulsation against the system impedance, and the flow pulsation of the pump is related to the pump's kinematics and working conditions. Practice has proved that the installation of a variety of hydraulic attenuator has a significant role to reduce the input impedance of the system and increase the attenuation and absorption of pressure pulsation.

## 2. Issues Raised

Due to the structure form of the power source, load characteristics, system parameters, working conditions and other reasons, the fluid transmission device usually inevitably has the pressure concussion and fluctuation of different frequency and amplitude, and it adversely affects the system. In the hydraulic system, the pressure impact and pulsation are transmitted through the hydraulic pipeline as the sound wave, and radiate noise to the surroundings.

In addition, when the pulse frequency is same with the natural frequency, it causes the resonance of the system, and not only the system components are worn out, and the noise radiation is increased dramatically, resulting in system components or lines damaged, broken [1]. In short, the impact of pressure and pulsation decreases the performance of the system, affecting the accuracy of the actuator,



reducing the service life of the hydraulic mechanism. Therefore, it is necessary to pay enough attention to the research of its limitation and elimination technology.

### 3. Foreign Research Overview

Since 1871, after the United States Balduin applying for the first patent on the accumulator, in 1965, based on lumped parameter frequency analysis method John G. Russell analysed the system. The analysis results show that the ratio of the flow and pressure pulsation in the system is determined by the two order differential, two order oscillation and the proportion of links. The attenuation of pressure pulsation caused by flow pulsation, is achieved by the use of the accumulator in the resonant state to realize huff and puff of the pulsating flow.

In 1967, in order to solve the hydraulic lift in the process of starting, stopping and walking in shock and vibration in the vibration, Hitachi Limited's Ken Ichiryu [2] et al., made dynamic analysis of hydraulic valve and attenuator, and the direct and indirect analysis of the hydraulic system, proposed a method to eliminate the oil column hydraulic elevator vibration by attenuator.

From the analysis of the retrieved data, we can see that in the middle of 60s, the comprehensive study on the attenuation of [3-5] has been started. In the United Kingdom and the United States, in order to minimize the pressure pulsation, the study is limited to the simple model system and the analysis of the matching problem between the attenuator and the system. In Japan, Entered in 70s, Chikawa Johyung, Takenaka Rio et al, who were still committed to the study of the mechanism of hydraulic components for pipeline and the pulsating, and a number of academic papers has been published.

In mid 70s, in countries such as Britain and the US a lot of research work has done for improving the selection and calculation of the widely used attenuator and the application of computer aided design. In West Germany, from the beginning of the 1974 Dr. Hoffmann[6] of Braunschweig Technology University published successive papers on "O+P" (hydraulic and pneumatic) about pressure pulsation of attenuation system of accumulator and other special attenuation elements. Research assistant, Institute of science, Stuttgart University, West Germany, W. Herzog, after analyzing all kinds of the previous attenuators, focused on the study of the performance of the single-expansion-attenuator, and compared it with the mechanical vibration system [7] while in the state that the load is in the closed end.

Since entering in 80s, the study of attenuator has been more and more in-depth, involving more and more widely. In countries such as Britain and the US, in addition to doing research and application of general body structure and the simplified and optimized accumulator, the research work on the pressure pulsation attenuator also was continued, and research on the energy-saving effect of the system and the pulsation attenuator has become an important aspect of the study.

### 4. Domestic Research Review

In our country, the research on the transmission, reflection and superposition of the pressure pulsation and the shock of accumulator and pipeline system is also carried out. In 1979, using the wave method, two types of the oscillation and resonance pressure pulsation filter are analyzed. From 1980, the research of the development of hydraulic pulsation reducing device is started. Some achievements have been obtained in the research of the single expansion impedance matched filter and the new type of broad band pulse attenuator. Beijing Aviation Institute has done some work on the calculation of hydraulic pipe pulsation, experiment and attenuation method. In addition, some domestic research institutes, for specific hydraulic machinery used in the pulsation attenuator system, also made some analysis and research work [8-9].

In general, the main research direction of the present study is the H attenuator with rigid structure and the pulsation attenuator with a flexible material.

#### 4.1. Study on H Type Pulsation Attenuator

Hydraulic pulsation attenuator is a structural element, mainly composed of the quality of room and

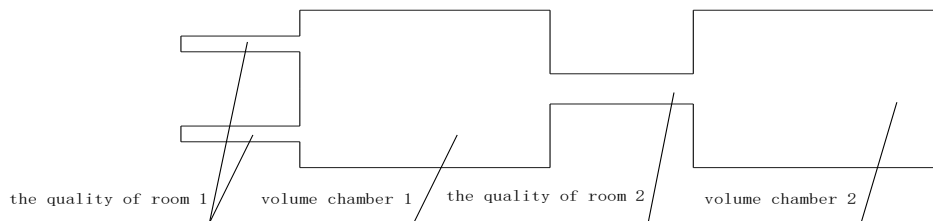
volume chamber, connected in sequence[10].When the quality of room is the multi channel output, that is, it is the porous hydraulic pulsation attenuator, take the stress and withstand pressure into account, its layout is the porous uniform distribution.

The working principle of the hydraulic pulsation attenuator is to make use of the reasonable collocation of the quality of room and volume chamber, and to distribute each part reasonably according to the geometric size, so as to effectively absorb the frequency pulsation of a certain noise source.

The design of pulsation attenuator' absorption frequency is very important for the hydraulic system, so Du Yun [11] employs lumped parameter method, ignores the influence of hydraulic resistance, and analyzes the relationship between the resonance frequency and the structure of the two-chamber pulsation attenuator; the resonant frequency formula of two-chamber pulsation attenuator is reduced:

$$\omega_1 = \frac{\sqrt{2\pi a}}{2\sqrt{\frac{L_1(V_2+V_4)}{D_1^2} + \frac{L_3V_4}{D_3^2} + \left[\frac{L_1(V_2+V_4)}{D_1^2} - \frac{L_3V_4}{D_3^2}\right]^2 + \frac{4L_1L_3V_4^2}{D_1^2D_3^2}}}, \quad \omega_2 = \frac{\sqrt{2\pi a}}{2\sqrt{\frac{L_1(V_2+V_4)}{D_1^2} + \frac{L_3V_4}{D_3^2} - \left[\frac{L_1(V_2+V_4)}{D_1^2} - \frac{L_3V_4}{D_3^2}\right]^2 + \frac{4L_1L_3V_4^2}{D_1^2D_3^2}}}$$

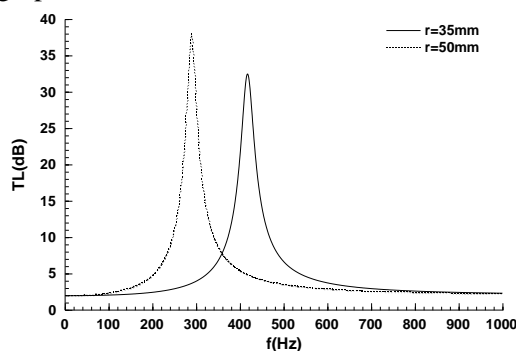
As can be seen from the above formula, we can design the structural parameters of the pulsation attenuator according to the resonance frequency, so as to maximize the attenuation function.



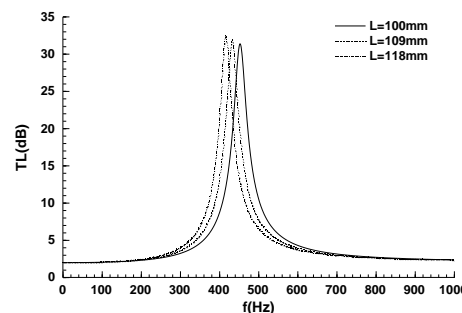
**Figure 1** diagram of two-chamber(2-1)hydraulic muffler

On the basis of the one-orifice pulsation attenuator, the research and discussion of the porous H type [12-13] attenuator is conducted. The so-called porous refers to the increase in the number of the quality of room and parallel tube, also known as the porous quality of room. In order to discuss conveniently, the volume of the chamber is called the chamber; the number of the quality of room and the number of parallel tubes, taking figure 1 as an example, is known as the two-chamber (2-1) type hydraulic muffler.

Using theory modeling and programming, draw Figure 2 to figure 5. And analyze the above graphic.



**Figure 2**



**Figure 3**

Figure 2 length variation of volume chamber of one-chamber double-orifice hydraulic muffler

Figure 3 diameter variation of volume chamber of one-chamber double-orifice hydraulic muffler

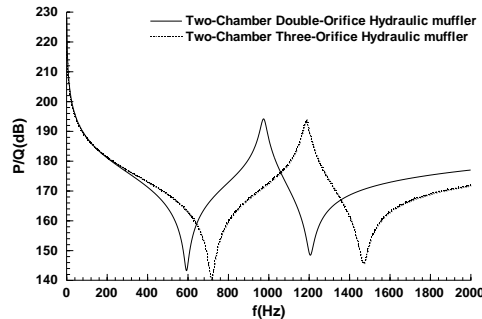
**Figure 4**

Figure 4  $P/Q$  diagram of two-chamber double-orifice/ three-orifice hydraulic muffler

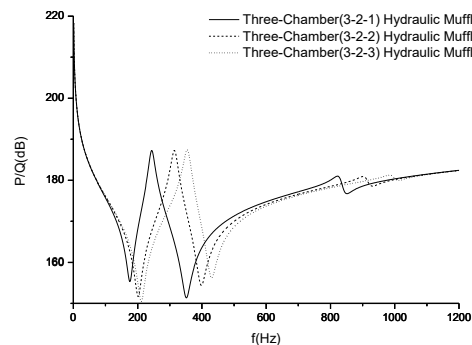
**Figure 5**

Figure 5  $P/Q$  diagram of three-chamber (3-2-1)/(3-2-2)/(3-2-3) hydraulic muffler

(1) As can be seen from the Figure 2, in the case of the same structural parameters, if the diameter of the chamber is changed  $d = 70\text{mm} \rightarrow d = 100\text{mm}$ , the peak value of the absorption noise source moves rapidly to the low frequency, and the amplitude of the pulsation attenuation increases rapidly with the increase of the diameter of the chamber.

(2) As can be seen from the Figure 3, in the case of the same structural parameters, if the length of the volume chamber is changed  $l = 100\text{mm} \rightarrow l = 118\text{mm}$ , the peak value of the absorption noise source and the amplitude of the pulsation attenuation are not changed widely with the increase of the length of the chamber. It can be concluded that the change of the chamber length has little effect on the attenuation amplitude.

(3) As can be seen from Figure 4, the pulse attenuation amplitude for the noise sources of two-chamber double-orifice hydraulic muffler is higher than that of the three-orifice hydraulic muffler, and the peak moves to the high frequency.

(4) As can be seen from Figure 5, the amplitude of attenuation at high frequency is very small and can be ignored even though the volume chamber and the quality of room are increased. Only the three-chamber's absorption peak shift right comparing with one-chamber and two-chamber hydraulic muffler. This indicates that the attenuation of the three-chamber hydraulic muffler at high frequency is not very obvious.

(5) Compared with figure 4 and Figure 5, it can be seen that the attenuation performance of the two-chamber hydraulic muffler can be substituted for the three-chamber hydraulic muffler. The attenuation range and amplitude of the two-chamber hydraulic muffler can fully meet the needs of Engineering practice.

#### 4.2. Pulsation Attenuator with Built-in Flexible Material

Based on the H model, the flexible material of attenuator pulsation attenuator with built-in flexible material is used to reduce the propagation velocity of the pressure wave, so that the structural parameters of the pulsation attenuator are reduced. It is mainly divided into two categories: built-in elastic mass spring vibration system and built-in thin plate vibration system.

Gaofeng [14] designed a pulsation attenuator based on mass spring vibration system, adopting a plurality of Bayesian-washers-reverse-stacking-form, experiments show that the pressure fluctuation of pump in 28MPa at the highest speed significantly reduced.

He Shanghong et al. [15-16] proposed a new type of hydraulic pulsation attenuator based on flexible film or thin plate vibration, which can be used in a wide frequency range to play the role of double filtering. After opening the orifices on the thin plate, it is also called a porous balance cavity. According to theoretical analysis, the perforation rate should be controlled at about 5%.

## 5. Conclusion

To sum up, a lot of research work has been done at home and abroad on the study of the performance of accumulator and pulsation attenuator and its system. To establish a theoretical model is for the application service practice. Because the structural parameters of hydraulic muffler components are miniaturized, it will reduce its impact on the flow capacity of hydraulic system, the stiffness and strength to increase in the number of orifices excessively. From the processing technology, the increase of orifices makes the processing more difficult. Therefore, the quality of H type rigid pulsation attenuator should not exceed 2 orifices, the built-in flexible material perforation rate should be less than 5%. At present, there is no mature system analysis method and test method for hydraulic muffler, so it is necessary to study the characteristics of hydraulic system. As the pump speed will change, so the study on the follow-up pulsation attenuator will become a research hotspot. The analysis on internal flow field will be conducted with the software FLUENT and CFD, and changes in pressure can be visually observed, meanwhile provide a reference for the theory of mathematical modeling design; With the improvement of test methods and the test accuracy, the pressure pulsation attenuator miniaturization will increase to a new level and provide better service for engineering technology.

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