UDC 532.5 (083)
DOI: http://dx.doi.org/10.20535/2521-1943.2017.80.109169

# Characteristics of throttles in hydraulic shock absorber considering temperature changes of fluid

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Received: 24 March 2017 / Accepted: 03 September 2017

***Abstract***. *The work is devoted to experimental research of throttles characteristics in hydraulic shock absorber. The throttles in shock absorber are formed by the functional apertures between piston and cylinder and between piston and rod. Also absorber consists of piston "throttle-valve" and bottom "throttle-valve" units. Characteristics of them were investigated. The dependencies are based on experimental data of flow rate coefficient from Reynolds numbers for fluids with different viscosities were calculated and represented. Data for a temperature range 13.5 ... 60.1 ° C of liquids were carried out. Design calculations using these characteristics provide more precision for determination the resistance force of the shock absorbers. Presented recommendations are able to reduce the temperature influence on characteristics of hydraulic shock absorbers.*

Keywords: *valve-throttle unit; hydraulic throttle; flow coefficient; temperature; shock absorber*

**Introduction**

The principle of hydraulic shock absorber based on the processes of fluid throttling [1, 2]. In case shock absorber reduces vibration of asymmetric loadings in it is used of two type "throttle-check valve" groups – on the piston (piston throttles) and on the bottom (base valve); and it works in two operating modes – "compressing" and "return" [3, 4] (Fig. 1). Each one of the groups provides appropriate work in two modes. Herewith in two-chambered shock absorber, fluid is extruded into reserve chamber through the base valve in the compressing mode. In return mode fluid backs into cylinder chamber. Flow directions and velocities are defined by opening or closing of check valves in throttling lines. Check valves are designed as flat round springs. They work depends on the shock absorber mode. One of them is pressed to the piston and closing appropriate throttle lines. Opposite one is opening and make ring-shaped aperture with value that depends on the current velocity of piston. Theoretically, fluid's velocities in throttle lines are due to shock absorber characteristics and operating modes. In practice, the shock absorber construction has two additional throttling apertures formed by cylindrical contact surfaces of piston, rod and cylinder. In contrast to turbulent flows in the throttles of the piston and in the base valve channels there are laminar flows in additional throttles, as usual. Also shock absorber work accompanied by transforming kinetic energy into heat. It influences on the fluid temperature [5]. The temperature changes can have bad influence on damping characteristics by differ flow modes and throttling in inner channels of shock absorber [6].

To ensure the planned characteristics of damping it necessary to take in account these features in design of shock absorbers. Presented researching is due to define the way of accounting these features.

**Goal of the work**

Increasing of accuracy of getting planned characteristics of shock absorbers by the way of taking into account, on the design stage, the degree of the influence of main and additional throttles depending on the temperature changes of fluid.

*Tasks:*

- define active throttles on shock absorber's working modes;
- experimental study of throttles' characteristics including influence of temperature changes of fluid in shock absorber;

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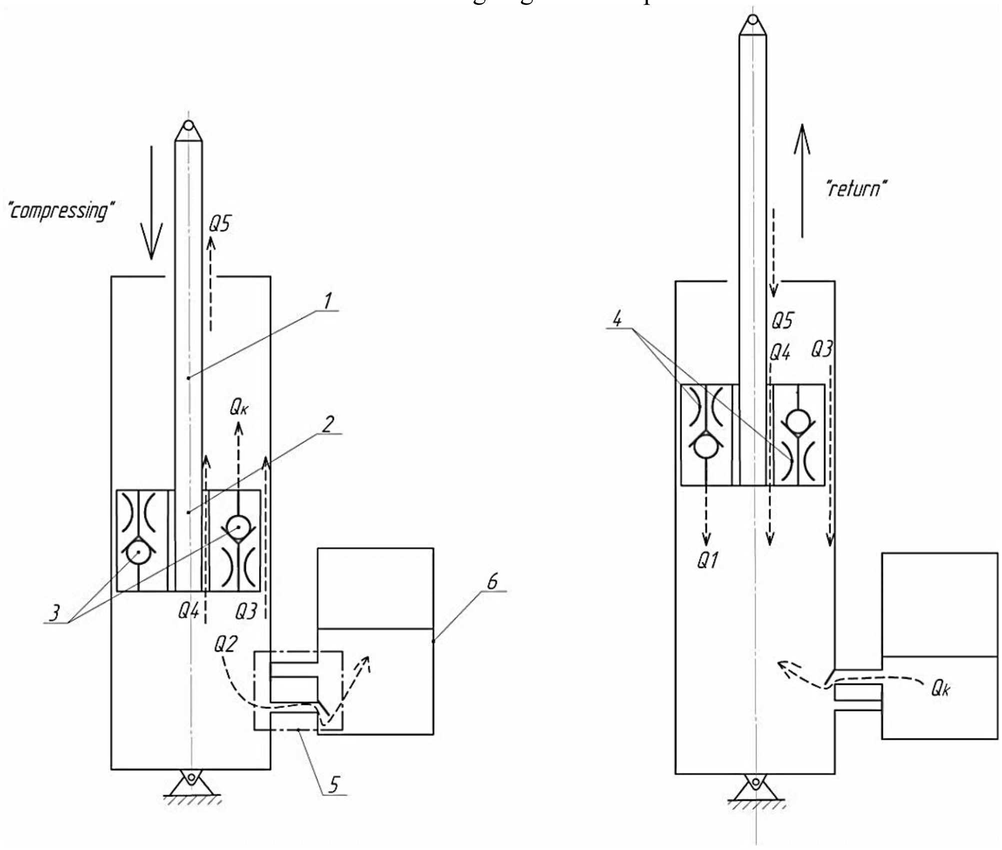
- make recommendations for shock absorbers designing to ensure planned characteristics.




*a* *b*

**Fig. 1. Simplified scheme of a hydraulic two-chambered shock absorber: *a*–flows in the "compressing mode" *b* - flows in the "return mode"**
**(1-rod, 2- piston, 3- check valves, 4-"throttle-check valve" groups, 5- base valve, 6- reserve chamber)**

*Definition of active throttles.*

Damping characteristics depend on flows' directions in throttle channels and throttles' resistance values. Analyses of operating modes and definition of active throttles in each mode were made. In the compressing mode the base valve and additional throttles formed between rod, piston and cylinder are active. In the return mode the piston throttles and additional throttles are active (Table 1).

Table 1

**Active throttles in shock absorber's modes**

| Operating modes | Function | | Impact of additional throttles | |
|---|---|---|---|---|
| | Piston throttles | Base valve | Piston-cylinder | Rod-piston |
| "Return" | Main throttling (turbulent) | bypass fluid (laminar) | Additional throttling (laminar) | Additional throttling (laminar) |
| "Compressing" | bypass liquid (laminar) | main throttling (turbulent) | Additional throttling (laminar) | Additional throttling (laminar) |

One of the main characteristics of the shock absorber is a resistance depended on velocity of the piston movement. Sizes and forms of throttle's apertures and liquid's parameters determine the damping resistance according to velocities of rod. Also viscosity of fluid is changed due to temperature changes while shock absorber works [6-7]. It leads to flow rate changes through the active throttles and total value for each mode can be defines as [1]:

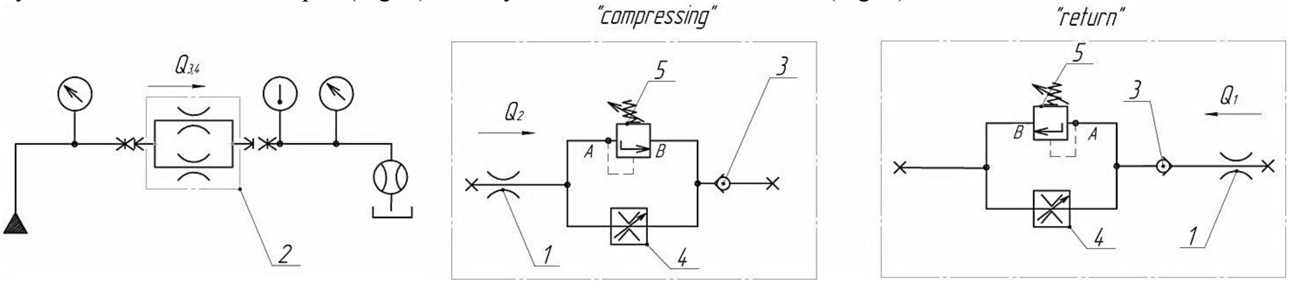
$$Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + .... + Q_n = \sum_{1}^{n} Q_i \,, \qquad (1)$$

where $Q_1 ... Q_n$ - is the flow rate through corresponding throttles. The degree of influence of each throttle type depends on the operating mode, temperature, design of throttles and flow mode.

For quantitative assessment of influence on throttling by fluid temperature changes the flow rate coefficients obtained experimentally were used.

**Researches**

To determine flow rate characteristics of additional throttles, experimental model of the piston with throttles and the base valve was designed and manufactured. Methodology of the study and the universal circuit diagram of the hydraulic stand were developed (Fig. 2), also hydraulic stand was assembled (Fig. 3).




*a* *d* *c*

**Fig. 2. Hydraulic circuit diagram of the experimental stand: *a*- diagram of studding additional throttles flow rates; *b*- diagram of studding the base valve flow rate; *c*- diagram of studding the piston throttles flow rate (1-local supplying channel resistances, 3- check valve; 4- hydraulic calibrated bores, 5- pressure check valve)**

Experiments were made in next order. According to working circumstances of shock absorber and operating mode a pressure differential for "throttle-valve" groups had been set and flow rate was measured. Pressure values were set up in range 0.1 – 2.5 MPa with discrete step ±0.05 MPa (+0.05 MPa increment for pressure settings from 0.1 to 2.5 MPa and -0.05 MPa decrement for pressure settings from 2.5 to 0.1 MPa). Flow rate measurements were made by a volumetric method. Temperature changes of fluid, due to throttling, were being observed in range 13.5 – 60.1 °C and were recorded with 1 °C step.

The dependence of the base valve flow rate coefficient on Reynold's numbers, based on the experimental data, was got. Dependencies for different viscosity values are shown on Figure 4.

Experimental studies of the piston throttles were made in the same way [8]. Although the dependencies of the piston throttles flow rate coefficient on Reynold's numbers look similar to results of the base valve studies, but it different in quantitative (Fig. 5). Results obtained for additional throttles are shown in Figure 6.

*Analysis of the results.*

**Fig. 3. Experimental stand for studding "throttle-valve" groups of hydraulic shock absorber (general view)**

The comparison of the dependences of the flow rate coefficients on the Reynolds numbers and the viscosity for the three types of throttles showed the following. In the range of Reynolds numbers from 200 to 1000 units for a temperature that corresponds to a working fluid viscosity of 0.000045 m ²/s, the value of changes in the flow rate coefficient in additional throttles exceeds the value of changes of the flow rate coefficient in the piston throttles by approximately 3 times. The same situation has been observed for flow rate coefficient in range Reynolds numbers 200…400 (Fig. 5, 6). For Reynolds numbers in range 200…400 the fluid with viscosity about 0.00015 m²/sec the value of the flow rate coefficient changes is 2 times greater in additional throttles than in the piston throttles. At temperature that corresponds to fluid viscosity 0.000045 m²/s and in range of Reynolds numbers from 200 to 1000 a value of the flow rate coefficient changes in additional throttles is about 20% greater than its value for the base valve. For the fluid with viscosity about 0.00015 m2/s and Reynolds numbers in range 200…400 the value of flow rate coefficient changes in additional throttles and in the base valve are almost identical (Fig. 4, 6) Described factors must be taken in account to ensure planned damping characteristics.

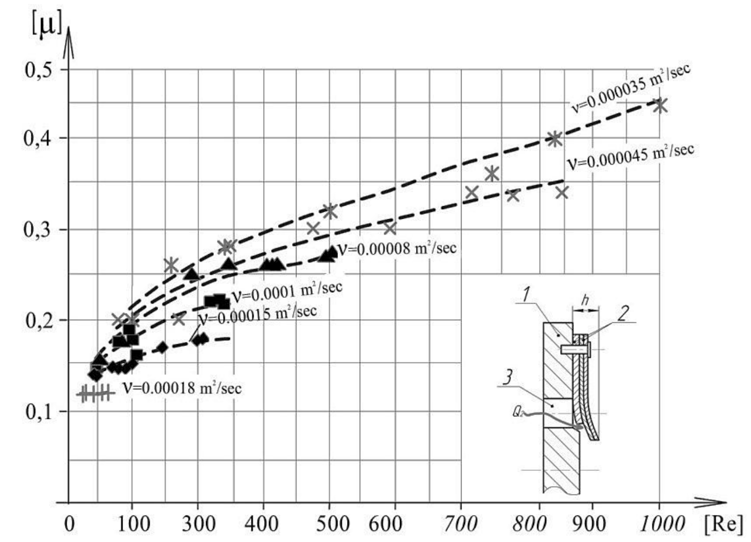



**Fig. 4. Dependencies of the base valve flow rate coefficient on Reynolds numbers for the HL-P fluid type**

Need to be noticed that influence of each throttle unit on damping characteristics is determined not only by values of the flow rate coefficient changes, but it's important to taking in account the throttle unit type, form and area ratio of apertures for each operating mode.

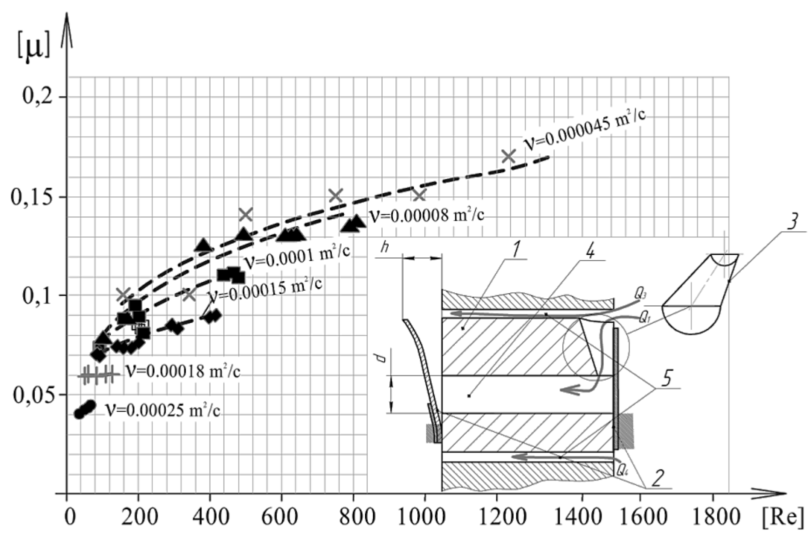



**Fig. 5. Dependencies of the working piston flow rate coefficient on Reynolds numbers for the HL-P fluid type**

The made calculation of areas for main and additional throttles allows taking into account impact of each one on the total flow rate that determines dampers resistance in operating modes (Table 2).

Table 2

**The share of the areas of the throttles when the total flow rate is determined**

| Operating mode (fluid temperature is 20 °C) | Quotient of the throttle areas, % | | | |
|---|---|---|---|---|
| | Main throttle groups | | Additional throttles | |
| | Piston | Base valve | Piston - cylinder | Rod - piston |
| "Return" | 60 | Does not effect on the damping resistance | 30 | 30 |
| "Compressing" | Does not effect on the damping resistance | 79.7 | 13.3 | 7 |

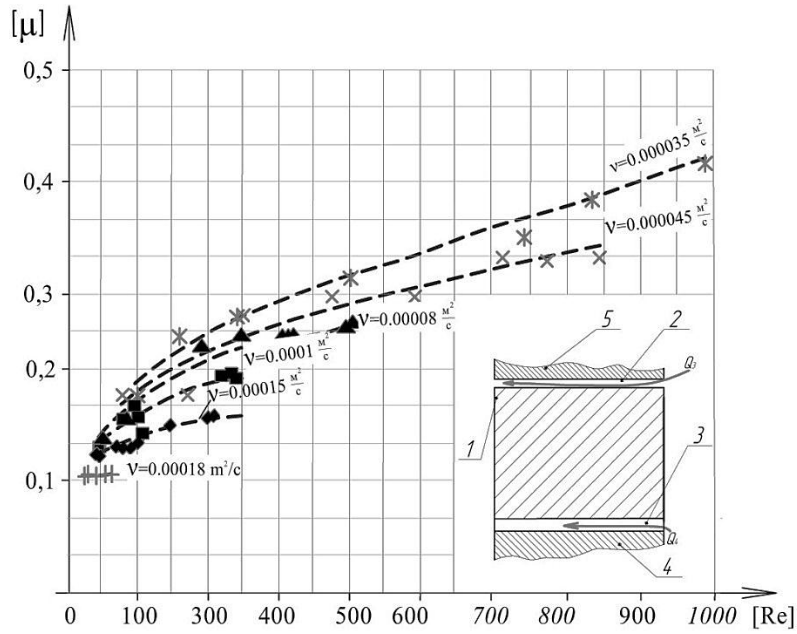



**Fig. 6. Dependencies of the additional throttles total flow rate coefficient on Reynolds numbers for the HL-P fluid type**

It's clear that influence of the additional throttles areas is 1.5 times less than influence of main ones in operating mode "return", in case providing the same values of the flow rate coefficients and same Reynolds numbers, according to the experimental data (Table 2). Herewith, in "compressing" mode with same values of the flow rate coefficient and Reynolds numbers, the influence of main throttles are almost 4 times greater than additional ones.

Taking into account obtained dependencies of the flow rate coefficients during design stage one might increases accuracy of the damping resistance and defines frames of its changes in given range of the fluid temperature changes.

The performed researches allow making the following recommendations for maintenance of stable characteristics of shock absorbers in conditions of changes of temperature of a working fluid.

The values of apertures formed by cylindrical surfaces of piston, rod and cylinder must be minimized. However, these values must to keep shock absorbers elements against jamming due to temperature increasing and longitudinal and transverse bending. According to the standard «СТСЭВ 14475» (USSR) functional apertures for the size group of pistons about 29.5 mm diameter are made in constraints: from -0.08 to -0.026 mm for aperture between piston and rod; from -0.03 to 0.063 mm for aperture between piston and cylinder. But precision measurements of the typical size group of typical shock absorber shows that values of functional apertures were bigger than determined in the standard for middle size of apertures and they were in range 0.01-0.1 mm. Possible reasons are the deviation from the standard requirements on manufacturing stage or the wear of the sealing surfaces during operation.

To ensure planned characteristics is recommended:

1. On design stage need to be set values of the piston throttles and the base valve throttling areas according to required damping characteristics taking into account dependencies of the flow rate coefficient on Reynolds numbers and operational range of the fluid temperature changes.

2. Providing size control for elements of "throttle-valve" groups on manufacturing stage.

3. Using fluoroplastic or hardwearing gaskets to minimize influences of apertures between piston and rod, piston and cylinder.

4. Using thermo-sensitive materials in gaskets to compensate wearing of surfaces.

5. Decreasing influence of the fluid temperature changes on viscosity by using synthetic oils (e.g. MGP-10, -12 or AGT-12T) or special additives.

6. Correcting areas of main throttles with special devices to compensate temperature changes in operating cycle of shock absorber [8-10].

**Conclusions**

1. The made experimental studies allowed to determinate quantitative influence of the fluid temperature changes on characteristics of the main and additional throttle units that providing the possibilities to increase accuracy of calculation dampers resistance.

2. In case taking into account, on design stage, proposed recommendations of decreasing temperature influence on the shock absorber work there is the possibility to provide increasing accuracy and stability of the planned characteristics.

## Характеристики дросельних елементів гідравлічного демпфера з врахуванням експлуатаційних змін температури робочої рідини

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***Анотація.*** *Роботу присвячено експериментальному дослідженню характеристик дросельних елементів гідравлічного демпфера. Досліджено дроселі, які утворено функціональними зазорами між поршнем та циліндром і поршнем та штоком, а також дроселі поршневого та донного клапанно-дросельних вузлів. На основі експериментальних даних розраховано і представлено залежності коефіцієнта витрати від чисел Рейнодльдса для різної в'язкості робочих рідин. Дані представлені для діапазону змін температури робочої рідини 13,5…60,1 ºС. Використання наведених характеристик для проектних розрахунків дозволяє більш точно визначати зусилля опору демпферів. Розроблені рекомендації дозволяють зменшити вплив температури на характеристики демпфера.*

Ключові слова: *клапанно-дросельний вузол; гідравлічний дросель; коефіцієнт витрати; температура; демпфер*

## Характеристики дроссельных элементов гидравлического демпфера с учетом эксплуатационных изменений температуры рабочей жидкости

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***Аннотация.*** *Работа посвящена экспериментальному исследованию характеристик дроссельных элементов гидравлического демпфера. Исследовано дроссели, которые образуются функциональными зазорами между поршнем и цилиндром, и поршнем, и штоком, а также дроссели поршневого и донного клапанно-дроссельных узлов. На основе экспериментальных данных рассчитаны и представлены зависимости коэффициентов расхода от числа Рейнодльдса для рабочей жидкости с вязкостями, соответствующими диапазону температур 13,5 ... 60,1 ° С. Использование приведенных зависимостей для проектных расчетов позволяет более точно определять усилия сопротивления демпферов. Разработанные рекомендации позволяют уменьшить влияние температуры на характеристики демпфера.*

Ключевые слова: *клапанно-дроссельный узел; гидравлический дроссель; коэффициент расхода; температура; демпфер*

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