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Original article

CLEANING METHOD OF WORKING VOLUMES OF HYDRAULIC CYLINDERS OF AGRICULTURAL MACHINES WITHOUT PRELIMINARY DISMANTLING

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Abstract

Background. More and more often lifting equipment is equipped with a hydraulic drive, which allows to develop the highest tractive force. However, this type of drive is prone to a reduction in the speed of the mechanism due to possible clogging of the working fluid. The performance of the hydraulic system directly depends on the cleanliness of the working fluid, which is operated in the equipment or machine. Dirt, the presence of air, as well as the presence of metal particles formed as a result of rubbing parts, all this negatively affects the service life and reliability of the hydraulic system. The paper describes a bench method of cleaning the working volume of the hydraulic cylinder without preliminary dismantling. The principal hydraulic scheme with a detailed description of the washing system operation is offered. The possibility of dispersing the flushing fluid flow by air bubbles is described.

Purpose. The purpose of the research is a method of cleaning the working volumes of hydraulic cylinders of agricultural machines without preliminary dismantling

Materials and methods. In most cases, the hydraulic system is flushed with the help of special stands. The flushing stand itself is a rather complex system of interaction of hydraulic units

The design feature of the developed unit is the pressurized supply of a gas-liquid mixture. It consists of air bubbles and washing liquid.

For the formation of air bubbles in the liquid a cavitator is installed. The flushing liquid is fed to the cavitator due to the pressure generated on the surface of the flushing liquid by the compressor. In parallel from the compressor there is a branch with air to the cavitator. As a result, from the cavitator the gas-liquid mixture enters one of the cavities of the double-acting hydraulic cylinder. After the piston takes the opposite extreme position, the hydraulic valve is switched, and the gas-liquid mixture enters the next cavity. The process is then repeated. After the cavity has been cleaned, the contaminants are removed by draining with the spent flushing fluid.

Results. Flushing unit with the use of air bubbles significantly increases the viscosity of the flushing fluid, and this reduces the rate of settling only flushed contaminants in the cavity of the product, which improves the removal of contaminants through the spigots.

In particular, for the mentioned parameters of the cylinder gas bubbles should be the size of 5 mm, the speed of surfacing of which is 12.3 mm/s, which justifies the need to fill/empty the cavity of the hydraulic cylinder within 10 seconds, at the same time for flushing the hydraulic system create a flow of fluid with a Reynolds number of at least 4000, and the nominal pressure in the hydraulic cylinder is 18 MPa.

Conclusion. The developed basic hydraulic scheme and the proposed design of the flushing stand provide high efficiency of the cleaning process. In addition, the calculations and experiments confirm the correctness of the selected parameters and schemes, which makes this method promising for wide application in industry.

Keywords: hydraulic cylinder; cleaning of the working volume; dispersing of the flushing liquid

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Научная статья

СПОСОБ ОЧИСТКИ РАБОЧИХ ОБЪЕМОВ ГИДРОЦИЛИНДРОВ СЕЛЬСКОХОЗЯЙСТВЕННЫХ МАШИН БЕЗ ПРЕДВАРИТЕЛЬНОГО ДЕМОНТАЖА

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Аннотация

Обоснование. Все чаще грузоподъемную технику оснащают гидравлическим приводом, который позволяет развивать наибольшее тяговое усилие. Однако данный вид приводов склонен к снижению скорости работы механизма по причине возможного засорения рабочей жидкости. Работоспособность гидравлической системы напрямую зависит от чистоты рабочей жидкости, которая эксплуатируется в оборудовании или машине. Грязь, наличие воздуха, а также наличие металлических частиц, образованных в результате трущихся деталей, все это негативно сказывается на сроке службы и надежности гидросистемы. В работе описан стендовый способ очистки рабочего объема гидроцилиндра без предварительного демонтажа. Предложена принципиальная гидравлическая схема с подробным описанием работы промывочной системы. Описана возможность диспергирования потока промывочной жидкости пузырьками воздуха

Цель. Цель исследования заключается в способе очистки рабочих объемов гидроцилиндров сельскохозяйственных машин без предварительного демонтажа

Материалы и методы. В большинстве случаев гидросистему промывают с помощью специальных стендов. Сам промывочный стенд представляет собой достаточно сложную систему взаимодействия гидравлических агрегатов

Конструктивной особенностью разрабатываемой установки является подача под давлением газожидкостной смеси. Она состоит из пузырей воздуха и промывочной жидкости.

Для образования пузырьков воздуха в жидкости установлен кавитатор. Промывочная жидкость подается к кавитатору за счет давления, образованного на поверхности промывочной жидкости компрессором. Параллельно от компрессора идет ветка с воздухом к кавитатору. В результате от кавитатора газожидкостная смесь поступает в одну из полостей гидроцилиндра двойного действия. После того как поршень принимает противоположнее крайнее положение, происходит переключение гидрораспределителя, и газожидкостная смесь поступает в следующую полость. Далее процесс повторяется. После очистки полости, загрязнения удаляются путем слива вместе с отработанной промывочной жидкостью.

Результаты. Промывочная установка с применением пузырьков воздуха существенно увеличивает вязкость промывочной жидкости, а это снижает скорость оседания только смытых загрязнений в полости изделия, что улучшает выведение загрязнений через патрубки.

В частности, для упомянутых параметров цилиндра пузырьки газа должны быть размерами 5 мм, скорость всплытия которых 12,3 мм/с, что обосновывает необходимость заполнения/опорожнения полости гидроцилиндра в течение 10 секунд, при это для промывки гидросистемы создают поток жидкости с числом Рейнольдса не менее 4000, а номинальное давление в гидроцилиндре составляет 18 Мпа.

Заключение. Разработанная принципиальная гидравлическая схема и предложенная конструкция промывочного стенда обеспечивают высокую эффективность процесса очистки. Кроме того, проведенные расчеты и эксперименты подтверждают правильность выбранных параметров и схем, что делает этот метод перспективным для широкого применения в промышленности.

Ключевые слова: гидроцилиндр; очистка рабочего объема; диспергирование промывочной жидкости

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Introduction

Reliability, serviceability and durability of hydraulic system elements directly depend on the cleanliness of internal surfaces and working fluid [1-7]. Installation – dismantling of the hydraulic system is an expensive and time-consuming operation. In industry, the level of cleanliness of internal surfaces of hydraulic units is regulated by the state standard GOST 17216-2001. This standard also establishes the classification of industrial cleanliness for those fluids that are used during the operation of the unit or aggregate, as well as equipment or machinery.

Previously, the method of flushing with a stationary flow was actively used to clean the hydraulic system [8-12]. However, this method has a number of significant disadvantages, which further negatively affected the stage of controlling the degree of cleanliness of the system. Thus, for example, there were known cases when from the contaminated system after cleaning the degree of cleanliness of the working fluid was higher than when it was poured into the system. This is explained by the fact that the cleanliness of the fluid is controlled at a reduced flow rate, and the process itself is characterized not by cleaning, but on the contrary – contamination of the unit, due to the fact that particles settle on the inner surface.

This problem is actual in the operation of truck cranes. In this case, the hydraulic cylinders of the crane's support extension are subjected to contamination of the internal cavity. Standard cleaning with washing machines as a rule does not give a proper level of cleanliness, and on internal hollow parts, about 90% of dirt and metal chips are removed, and residual deposits of dirt in the spigots in such cleaning is almost impossible to remove [13-16].

In accordance with this, to achieve the required level of surface cleanliness it is necessary to dismantle the part, and then to clean it by immersing the hydraulic cylinder in an ultrasonic bath, which implies a preliminary process of dismantling the hydraulic cylinder, consisting of several stages, including unscrewing the nuts from the hydraulic cylinder socket and rod cavity pipeline nut, removal of the cotter pin, washer; removal of the rod pipeline; disconnection of the rod eye and, finally, removal of the hydraulic cylinder from the outrigger.

As can be seen, the dismantling of the hydraulic cylinder is a rather labor-intensive process. Based on the above, it is proposed to use a washing stand for washing the internal cavity of the hydraulic cylinder.

Materials and methods

In most cases, the hydraulic system is flushed with the help of special stands. The flushing stand itself is a rather complex system of interaction of hydraulic units.

The design feature of the developed unit is the pressurized supply of a gas-liquid mixture. It consists of air bubbles and washing liquid.

For the formation of air bubbles in the liquid a cavitator is installed. The flushing liquid is fed to the cavitator due to the pressure generated on the surface of the flushing liquid by the compressor. In parallel from the compressor there is a branch with air to the cavitator. As a result, from the cavitator the gas-liquid mixture enters one of the cavities of the double-acting hydraulic cylinder. After the piston takes the opposite extreme position, the hydraulic valve is switched, and the gas-liquid mixture enters the next cavity. The process is then repeated. After the cavity has been cleaned, the contaminants are removed by draining with the spent flushing fluid.

Flushing is carried out by cyclic movement of the piston to the extreme positions and alternate supply of gas-liquid flow of washing fluid into the cavities of the hydraulic cylinder. The principle scheme of operation of the flushing stand is shown in Fig. 2.

The peculiarity of hydraulic cylinder flushing by the developed method is in the pressurized supply of gas-liquid mixture consisting of flushing liquid and air bubbles into the system.

The flushing stand provides for the possibility of dispersing the flushing liquid flow by air bubbles. Air bubbles moving in the fluid flow eventually collapse, releasing a large amount of kinetic energy. This process is explained by the physics of cavitation. When a cavitation bubble collapses, it emits a wave accompanied by hydraulic shocks, thus destroying the crystal lattice of contaminants on the walls of hollow parts and assemblies.

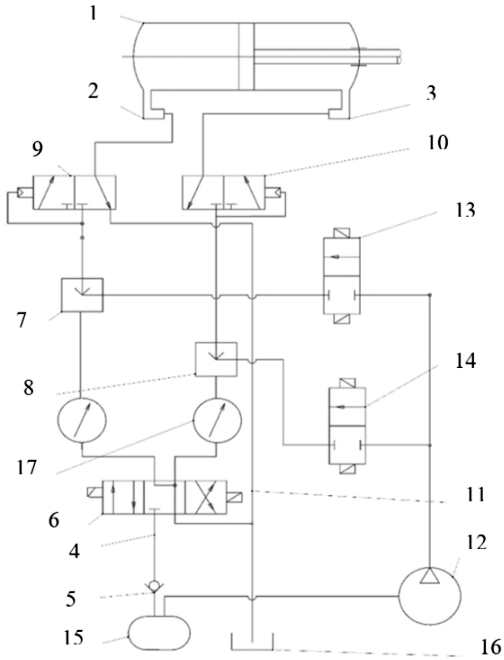

Fig. 1. Hydraulic schematic diagram: 1 – hydraulic cylinder, 2 – piston cavity connector, 3 – stem cavity connector, 4 – discharge line, 5 – check valve, 6 – hydraulic distributor, 7 – piston cavity cavitator, 8 – stem cavity cavitator, 9, 10 – overflow valve, 11 – drain line, 12 – compressor, 13 – piston cavity valve, 14 – stem cavity valve, 15 – flushing fluid tank, 16 – drain tank, 17 – manometer.

The flushing liquid enters the hydraulic system due to the pressure created on the surface of the liquid by the compressor, so that the supply process is pressurized. In parallel to the supply of the flushing liquid, gas bubbles are introduced into the flow under pressure by means of a connection. As a result of the interaction of the above components, a gas-liquid mixture is formed.

Moving through the high-pressure hoses, the flow enters one of the cavities of the double-acting hydraulic cylinder, which drives the piston. After filling the cavity and moving the piston to the opposite extreme position, the distributor is switched and the liquid is redirected to the other cavity of the hydraulic cylinder. The process is repeated. As a result of the above manipulations, the hydraulic cylinder cavities are cleaned and contaminants are removed by draining, together with the flushing fluid.

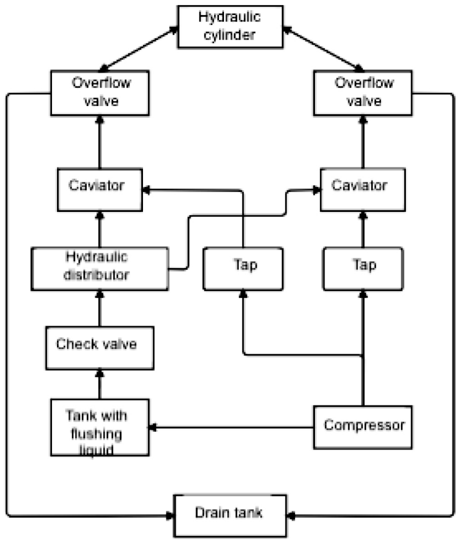

Fig. 2. Schematic diagram of the flushing stand

This method will almost completely remove deposits of contamination on the walls of the cylinder [13].

It is important to consider the size of the introduced bubbles. By their nature, air bubbles are quite unstable and tend to separate from the fluid in the hydraulic cylinder cavity. Therefore, the air is introduced into the system at a rate so that the size of the bubbles, resist instantaneous separation from the liquid.

Necessary sizes of bubbles are determined by the known dependences of the speed of surfacing of bubbles on their sizes

Thus, the speed of surfacing of a single bubble, graphically can be represented as a dependency $V = f(d_п)$ (Fig. 3).

The first region is characterized by the following indications - bubble diameter does not exceed 1.5 mm, bubble motion is similar to a solid sphere, since it is carried out under laminar flow conditions.

In the second region, the diameter of bubbles varies from 1.5 to 6 mm, it is characterized by the absence of a tendency to increase the velocity, because due to the oscillation of the bubble shape, its cross-sectional area increases.

The third region is characterized by the destruction of the gas bubble, since the velocity does not increase, with constant fluctuations in the shape of the bubble. [14]

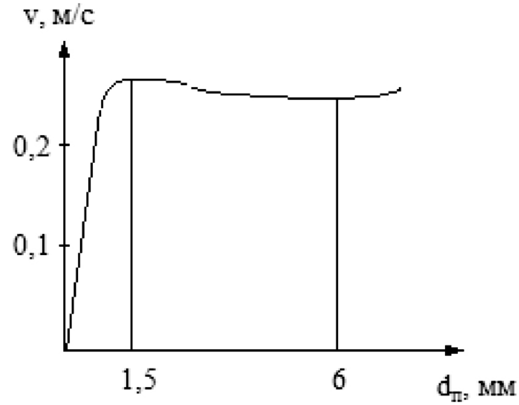

Fig. 3. Dependence of the floating velocity of a single bubble

Based on the graph, it can be observed that the optimal bubble popping speed, in terms of bench performance is within 0.25 m/s.

Thus, the topic of bubble motion in liquid is raised by G. Kotkin in the article "Pop-up air bubble and Archimedes' law". He compares the motion of bubbles in a liquid medium with the motion of weights connected by a thread and thrown over a stationary block. One of these blocks takes the role of a bubble with mass m, and the other takes the role of water, and its mass will be M, hence the pushing force will be the thread T.

Then Newton's second law will take the following form:

$$m \cdot a = T - m \cdot g \qquad (1)$$

If the load is held, then the tension of the thread will characterize the weight of the load mg. However, if we substitute the above equality into the equation, we can come to a false conclusion about the huge acceleration of the bubble.

The solution to this error will be the necessity to consider the motion of the weight of mass m and the motion of the "displaced" water.

In the booth is predominantly turbulent flow, which is created directly by the bubbles themselves. Reducing the resistance of the medium is achieved by communicating the fluid continuous flow direction of the bubbles popping.

Based on the above, it can be concluded that the surfacing velocity of a group of bubbles is much higher than that of a single bubble.

The surfacing velocity of the bubble flow can be described by the equation:

$$V_p = 1{,}74\sqrt{d_p \cdot g} \qquad (1)$$

where d_p – average bubble size. In the case of a polydisperse system under mass bubbling, the characteristic bubble size is rather difficult to determine and can be calculated using the formula:

$$V_p = 1{,}5\left(\frac{\sigma g \Delta\rho}{\rho_z^2}\right)^{0{,}25} \quad (1)$$

For example, the following calculation example is given in the patent "Methods of flushing hollow products". When washing a power hydraulic cylinder with a piston diameter of 125 mm and the time of filling and draining the liquid from the cavity of 5 s, the diameter of bubbles should be 0.2 mm or less, because the speed of surfacing of such bubbles (2 mm/s) prevents their separation in the cylinder cavity, and during the time of 5 s even in the absence of agitation, the bubble manages to float by 10 mm, i.e. by 0.1 of the piston diameter.

Flushing unit with the use of air bubbles significantly increases the viscosity of the flushing fluid, and this reduces the rate of settling only flushed contaminants in the cavity of the product, which improves the removal of contaminants through the spigots.

In particular, for the mentioned parameters of the cylinder gas bubbles should be the size of 5 mm, the speed of surfacing of which is 12.3 mm/s, which justifies the need to fill/empty the cavity of the hydraulic cylinder within 10 seconds, at the same time for flushing the hydraulic system create a flow of fluid with a Reynolds number of at least 4000, and the nominal pressure in the hydraulic cylinder is 18 MPa.

Results

The article describes a new method of cleaning the working volumes of hydraulic cylinders without the need for preliminary dismantling, based on the use of a flushing stand. This method makes it possible to effectively clean the internal cavities of hydraulic cylinders from various contaminants, including metal chips and other solid particles, which makes it possible to significantly extend the service life of the equipment and increase its reliability. Cleaning is carried out with the help of a gas-liquid mixture containing air bubbles, which contribute to the destruction of the crystal lattice of contaminants and their effective removal from the system. The developed basic hydraulic scheme and the proposed design of the flushing stand provide high efficiency of the cleaning process. In addition, the calculations and experiments confirm the correctness of the selected parameters and schemes, which makes this method promising for wide application in industry.

Conflict of interest information. The authors declare that they have no conflict of interest.

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