Differential pressure sensor for hydraulic drive of traction vehicles

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Abstract. Hydraulic systems equipped with working bodies hydraulic drive are widely used in road construction, agricultural, reclamation, forestry, military-technical and other surface vehicles. Depending on the operating conditions and modes, hydraulic drive elements are subjected to self-destruction, for example, high-pressure hoses hydraulic system, which reduces the machines’ working life (resource), increases operating costs and worsens the environmental situation. There are various systems and methods for protecting the hydraulic drive to mitigate these negative consequences. The analysis of conditions, operating modes and factors affecting the machines’ hydraulic system state, methods and systems for protecting the hydraulic drive, the causes of high-pressure hoses of destruction and the negative impact of consequences on the environment shows that the problem of finding a new technical solution remains. A new design solution is proposed for protecting the hydraulic drive, which is equipped with two adjustable throttles, two reverse valves and a pressure drop sensor that includes a diaphragm forming the positive and negative chambers.

In most road construction, agricultural, reclamation, forestry, military-technical vehicles, and other surface-based traction vehicles, the operating pressure in the hydraulic systems is limited to 20 MPa. However, despite the measures taken to limit the pressure of most machines, often due to fatigue failure of high-pressure hoses, there is an unauthorized release of working fluid into the atmosphere up to 300 liters per release [1-4]. This leads to the unjustified operational and economic costs and serious environmental consequences.

The analysis of machines hydraulic drive protection existing methods [3-20] shows that their improvement problem relevance remains, since most of them when triggered losses are from 3 to 10 l., for example, the pneumoelectric protection system loses 6 ... 8 l., float protection system - up to 10 l. In the early author's works [16], the loss was reduced to 0.5...1.2 l, and for [17,18] – 0.17 l, which also cannot meet the requirements of the environmental safety.

The analogue’s [19] low hydraulic drive protection efficiency is due to the presence of a complex system of hydraulically connected to 3- and 5- linear hydraulic control valves, creating the oscillatory process of the spool, which does not provide full pressure drop when draining, and [20] after the malfunction, it is necessary to carry out the setting of the adjustable throttle, and the stabilization of the control signal requires bulky circuit automatic switching of the hydraulic control valve in the working position.

Based on the analysis of shortcomings [19,20], theoretical and experimental studies were carried out, a project proposal was developed, a draft and layout study was made, a prototype was
manufactured and bench tests were conducted. According to the research results, the design provides full protection of the hydraulic drive, and the technical solution was patented [21] (Figure 1).

The hydraulic drive includes a hydraulic tank 1, a pump 2, a hydraulic line 3, a controlled throttle 4, a trilinear two-position hydraulic control valve 5, a drain hydraulic line 6, an adjustable throttle 7 and a pressure drop sensor 8, which consists of a housing 9, a diaphragm 12, dividing into a positive A and negative B chambers and a cover 10, secured by a screw joint 11 and a plunger 13, made with an internal cylindrical cavity C and a rod 14, connected by a screw attachment 15 with the diaphragm 12. The plunger 13 has holes 16, through which the cavity C of the plunger is connected with the positive chamber A of the pressure drop sensor 8. The sensor housing 9 has channels: D, connected with the positive chamber A, equipped with a nozzle 17 and E of the control signal, equipped with a nozzle 18 located at a distance \( t \) equal to the full stroke of the plunger. The cover 10 has a channel K connected with the negative chamber B, equipped with a nozzle 19. The negative chamber B of the cover 10 has an adjustment screw 20 and a spring 21.

The positive chamber A via the channel D and the adjustable throttle 22 is connected with the pressure hydraulic line 3 before the adjustable throttle, and the negative chamber B via the channel K is connected to the pressure hydraulic line 3 after the adjustable throttle 4.

The hydraulic drive is also equipped with a hydraulic lock 23, with input P, output F and control U cavities, two reverse valves 24 and 25 and two shut-off valves 26 and 27. The U cavity through the reverse valve 24 and the nozzle 18 connects with the channel E control signal of the pressure drop sensor 8 and through a reverse valve 26 connected to the discharge line 6. The input cavity P of the hydraulic lock 23 is connected to the discharge hydraulic line 3 to trilinear two-position directional control valve 5. The output cavity F of the hydraulic lock 23 is connected with the control cavity U trilinear two-position directional control valve 5 and simultaneously through a reverse valve 27 connected to the discharge line 6 and through a reverse valve 25 connected to the cavity.

In the hydraulic drive working state, the shut-off valves 26 and 27 are closed. With the help of the adjusting screw 20, the pressure drop sensor 8 is adjusted to the maximum pressure drop on the adjustable throttle 4 and, respectively, the channels A and B, corresponding to the movement of the working fluid in the pressure line 3 when it is destroyed.

In the hydraulic drive operation normal mode, the working fluid is pumped by the pump 2 through the pressure hydraulic line 3 through the pressure P and output F cavities of the trilinear on-off directional control valve 5, an adjustable throttle 4 and then into the working cavity of the drive. In this case, the flow of the working fluid in the pressure line 3 creates a pressure drop across the throttle 4 and, accordingly, between the positive A and negative B chambers of the pressure drop sensor 8. As the result, the plunger 13 by the diaphragm 12 through the rod 14 from the pressure difference between the working fluids in chambers A and B will move to the right, overcoming the force of the spring 21, while the fluid flow during the drive working and idling creates a slight pressure drop between the chambers A and B. The strut from such a pressure drop on the diaphragm 12 is compensated by the spring 21. The channel E in such a pressure drop corresponding to the hydraulic drive operation normal mode remains always closed, the plunger 13 and the control signal in the form of hydraulic fluid pressure from the positive chamber A through the plunger cavity C 23 into the channel E is not fed. The adjustable throttle 22, allows to smooth out the fluctuation of the pressure drop during the operation, as well as the jump in pressure drop when the pump 2 is turned on.

When the pressure hoses are destroyed, the pressure creates a significant pressure drop on the adjustable throttle 4 and, accordingly, in the chambers A and B of the sensor. As the result, the plunger 13, under the action of the diaphragm 12, moves to the right by a distance \( t \) of its full stroke and the control signal channel E opens, the hydraulic control signal being transmitted through the nozzle 18 and the reverse valve 24 to the control cavity U of the hydraulic lock 23. The check valve 25 prevents the plunger oscillates when the pressure drop changes.

The control signal from the pressure drop sensor 8 opens the hydraulic lock 23. In this case, the pressure of the working fluid from the pressure hydraulic line 3 of the pump 2 through the open inlet cavity P of the hydraulic lock 23 and then its output cavity F is supplied in parallel through the reverse
valve 25 to the control cavity U of the hydraulic lock 23 and to the control cavity U of a trilinear on-off hydraulic control valve 5, which instantly closes the discharge hydraulic line 3 and at the same time connects the pressure cavity P with the drain cavity L, through which the working fluid discharge is carried out from the pressure line of the pump 2 through the adjustable throttle 7 to the drain line 6 and into the hydraulic tank 1 until the hydraulic drive emergency condition is eliminated.

After the hydraulic lock 23 opening, the working fluid from the pressure hydraulic line 3 is fed into the hydraulic lock 23 inlet cavity P and through the reverse valve 25 to the hydraulic lock 23 control cavity U. Such a feedback scheme of the hydraulic lock 23 will make it possible to obtain and remember a stable control signal for activating the locking device - a trilinear two-way valve 5 not related to the pressure drop sensor 8 operation. The stable control hydraulic signal level is provided by the adjustable throttle 7 installed on the drain line 6. The adjustable throttle 7, as an adjustable load device at the outlet of the pump 2 when it is operated to drain in the hydraulic drive emergency state,

**Figure 1.** Traction vehicles hydraulic drive pressure drop sensor.
allows to get the pressure equal to the control signal pressure required value in the control cavity U of the trilinear on-off valve 5 in the hydraulic line 3 in the area from pump 2 to the trilinear two-way hydraulic control valve 5.

When the trilinear on-off hydraulic control valve 5 is shut, the pressure in the pressure hydraulic line 3 after it will approach atmospheric pressure, and the pressure in the positive A and negative B chambers of the pressure drop sensor 8 will be the same and the plunger 13 will move to the left by the force of the spring 21 closing the channel E.

An uncontrolled reverse valve 24 installed on the connection line between the channel E and the cavity U of the hydraulic lock 23 prevents the working fluid supply from the output cavity F of the hydraulic lock 23 to the channel E of the pressure drop sensor 8 control signal and then through the positive chamber A to the pressure hydraulic line 3 at the moment of shut-off device - a trilinear on-off hydraulic control valve 5 actuation a for draining the working fluid from pressure hydraulic line 3.

To restore the initial state of the hydraulic drive after eliminating the emergency condition connected with the pressure hoses destruction, the control hydraulic signal is removed by shut-off valves 26 and 27 opening. The pressure in the hydraulic lock 23 control cavities U and the trilinear two-way hydraulic control valve 5 instantly drops, and the trilinear two-position hydraulic control valve 5 connects the pressure cavity P with the outlet cavity F for supplying the working fluid to the hydraulic drive and closes the drain cavity L while draining into the hydraulic tank 1. After this, the valves 26 and 27 are closed.

As the result of studying the machines hydraulic drives conditions and operating modes, the analysis of the hydraulic drive protecting existing means a technical solution was developed (Figure 1), which allows to increase the efficiency of the hydraulic drive protection system from the unauthorized discharge of the working fluid from the hydraulic system during the destruction of pressure hoses, to stabilize control signal, versatility of hydraulic drive, operational reliability and environmental safety of its use.

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