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To cite this article: V I Posmetyev *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **483** 012107

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Energy saving of hydraulic drives of machines due to increase of effectiveness of hydraulic cylinders cuffs according to the results of simulation modeling

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Abstract. Analysis of the results of studies of traditional sealing dynamic connections has revealed shortcomings and peculiarities of their design, which must be taken into account when selecting and justifying the design operating parameters of promising sealing dynamic connections. The proposed design of sealing dynamic connections allows increasing the efficiency of a hydraulic cylinder by 8-12%, facilitating the launch of hydraulic actuators of forest machines at freezing temperatures, increasing the durability of a hydraulic cylinder and reducing the complexity of maintenance of a hydraulic cylinder by reducing the number of assembly and disassembly work associated with unscheduled replacement of sealing dynamic connections.

1. Introduction

The efficiency of forestry units is significantly influenced by the use of advanced designs of sealing dynamic connections (SDC) further cuffs, in the hydraulic drives and energy recovery systems. At present, mainly sealing elements made of rubber in the form of rings and cuffs are used in mobile connections of hydraulic drives of forest and agricultural machines at present. In this case, rubbers are made, as a rule, of SKN (MRTU 38-5-1166-64) and SKF (MRTU-38-5-6056-65) raw rubber. The designs of these compounds are regulated by 6969-54, 9833-73 and 14896-74 State Standards. However, the lack of reliability of such movable seals leads to numerous failures of hydraulic drives of machines and equipment. The main drawbacks of standard rubber sealing elements are the high coefficient of friction (0.1-0.4), as well as the high dependence of the change in the elastic properties and elasticity of such elements on the temperature differential. These drawbacks are the main cause of low efficiency, and, in some cases, complete loss of hydraulic actuators efficiency of FM.

2. Materials and methods

Analysis of research results of traditional SDCs has revealed the shortcomings and peculiarities of their structures, which must be taken into account when selecting and justifying the design and operational parameters of prospective SDCs. In this regard, basic requirements for prospective SDCs structures for HC of forest machines have been developed at the initial stage of the study. Such SDCs must:

- Minimize the effect of varying pressure of actuating fluid on the tightness of the connection, as well as on the amount of force on the rod;

- Ensure reliable tightness when using low-viscosity actuating fluids, as well as with long-term nominal (15-20 MPa) and short-term maximum (25-40 MPa) pressure values in HC;

- Reduce the effort of the pistons and rods moving to minimum values;

- Prevent significant increase in the resistance force when moving HC pistons at speeds up to 5-10 m/s;

- Work stably at low and high ambient temperatures ($-40 - + 60^{\circ}\text{C}$) [3];

- Ensure leak tightness in HC up to 0.008 MPa;



Have geometrical parameters not exceeding the similar values laid down in the State standards and standard specifications;

Be compact, technological in design, inexpensive to manufacture and easy to operate.

In this regard, using the described ADS model of hydraulic drives of forest machines, a study has been carried out on the basis of simulation modeling and computer experiments to evaluate the effectiveness of standard and new sealings for various operating modes [1-3].

3. Results of research

The results of computer experiments has showed that if the cuff is rigid and nonmovable (figure 1, a), then the working fluid gradually enters the gap between the cuff and the inner wall of the hydraulic cylinder. However, since the cuff is elastic and movable (figure 1, b), then when the fluid pressure increases in the left part of the cuff, it deforms and rises, resting against the inner wall of the hydraulic cylinder (HC); it increases tightness of dynamic application and reduces the possibility of leakage of working fluid.

Analysis of the simulation results has also showed that the shape of the cuff and, accordingly, the compaction efficiency, significantly depends on the pressure difference between the working fluid on the left and on the right sides. The cuff is in substantially symmetrical state about the vertical axis at equal pressures on its both sides of the cuff (figure 2, a). With a small pressure difference (less than 1 MPa) the cuff is pressed against the inner surface of the HC and prevents penetration of the working

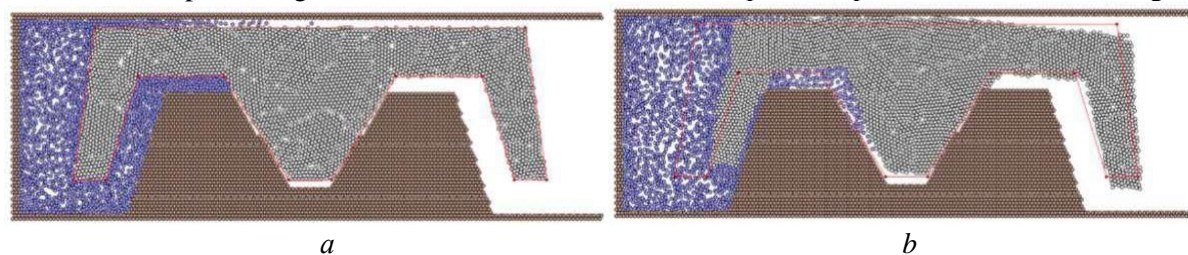


Figure 1. Visual comparison of the effectiveness of sealing with tight and elastic cuff: *a* – leakage of the working fluid through tight cuff; *b* - effective compaction due to the bending of the cuff of elastic material

fluid into the low-pressure cavity of HC (figure 2, *b*).

Although the degree of compression is small, the pressure of the working fluid is also small for the occurrence of significant throttling into the remaining gap. With a large pressure difference (about 10-20 MPa), the cuff not only presses stronger against the inner surface of HC, but it simultaneously presses against the skewed wall of the piston with the same force, which causes wedging of the middle part of the cuff and reliable sealing both in its upper and lower parts (figure 2, *c*).

At very high pressures in the hydraulic drive (about 40-60 MPa), the elasticity of the seal (cuff), made of traditional materials, can lead to its crush and (or) destruction (figure 2, *d*). Therefore, cuffs for high-pressure HC must be made of elastic materials with a high modulus of elasticity and protected from destruction with the help of additional elements of highly durable polymeric materials. In addition, it is possible to exclude the crush by changing the geometrical parameters of the cuff (more massive cuff in a whole, or a smaller gap size between the thrust metallic shaped ring of the piston and the inner surface of HC [4-6].

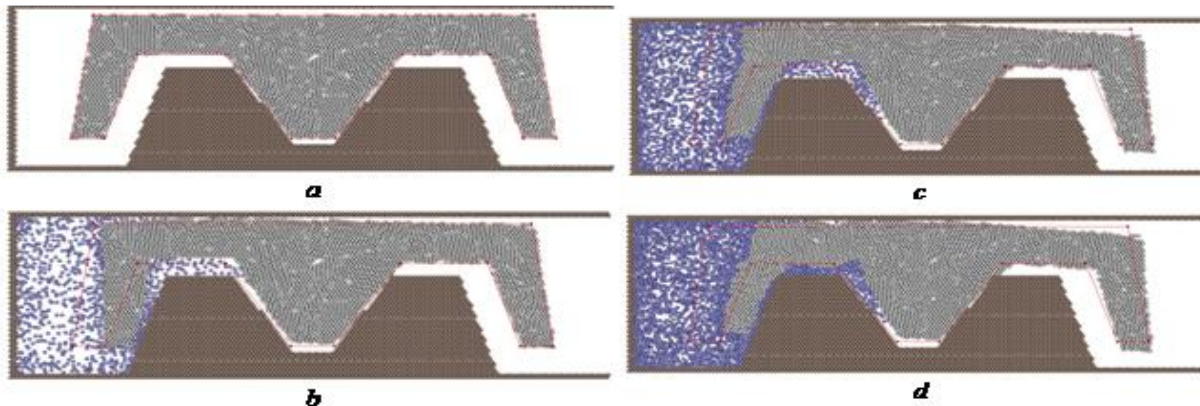


Figure 2. The condition of the cuff at different pressures of the working fluid: *a* – the main state of the cuff in case of equality of pressure on both sides of the piston; state of the cuff when the pressure in the piston cavity changes; *b* – 1 MPa; *c* – start of cuff deformation at a pressure of 10 MPa; *d* – crush of the cuff at a pressure of 50 MPa

The results of simulation and laboratory-field experiments of the investigated SDC, obtained for the three main parameters - linear leakage Q_l of the working fluid, inertia of the response t_r and overall efficiency of HC η_o are presented in figure 3. An analysis of the obtained data indicates the following [7-8].

The values of all three fixed parameters largely depend on changes in the ambient temperature and, especially, in freezing $0 \dots -10$ and low $0 \dots +10$ °C temperatures. At the same time, the intensity of reducing the values of the parameters in the direction of performance deterioration of SDC is approximately 1.5-2.0 times higher than at $T > 10$ °C. This difficult drawback of both SDCs, typical for all types of SDCs, is especially evident in spring and autumn periods, which should be taken into account by machine operators, working with forest machines on forest objects at low ambient temperatures.

The leakage Q_l of the working fluid of the new SDCs does not exceed the leakage of the standard seal (figure 3, a), which indicates that it is sufficiently tight over the whole range of possible ambient temperatures.

Delayed action t_r of HC with new SDC is 1.6 times less than that of the delayed action standard SDC (figure 3, b). Due to this, both hydraulic actuators themselves and working bodies of the FTT are much less susceptible to dynamic loads during operation of forest machines on cuttings. The efficiency of the new

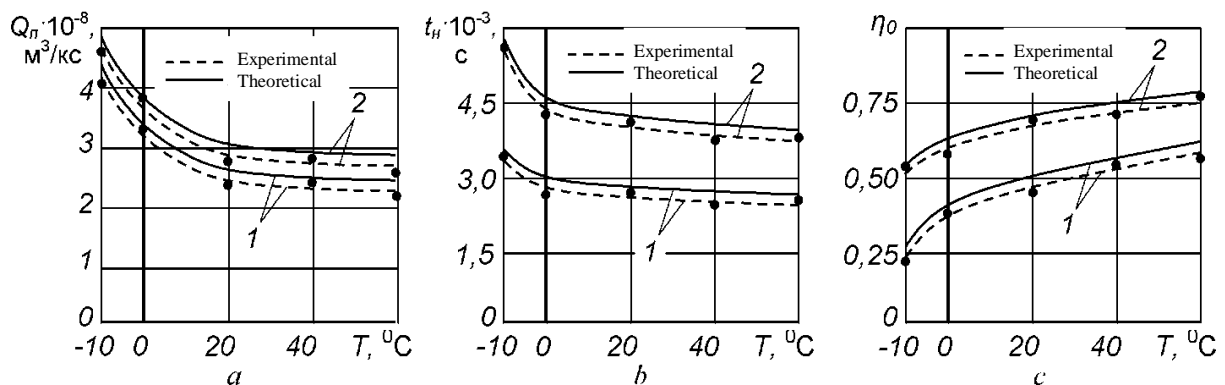


Figure 3. Dependences of the specific linear leakage Q_l of the working fluid, inertia of the response t_r and overall efficiency of HC η_o of the hydraulic cylinder on the working fluid temperature T for the studied sealing elements: 1 and 2 – curves of new and standard SDCs, respectively

SDC has increased two times due to decayed action of the operation of HC, and also due to the use of a polyurethane cuff in the new SDC, which has a much lower coefficient of friction in comparison with the standard rubber cuff (figure 3, c) [13-14].

4. Discussion and conclusions

The failures associated with hydraulic systems of tractors are mainly caused by the loss of movable seals tightness of the hydraulic cylinders rods and pistons of the mounted devices and working machines, the wear of spools and valves. The reason for these failures, as a rule, is untimely replacement of worn seals in hydraulic drives, actuating fluid and flushing of tractor hydraulic systems. Unjustified downtime for the repair of tractors adversely affects the intermittency of the mounted system and the quality of works performed at forest sites.

Thus, the results of the analysis show that the use of SDC new design ensures an increase in the efficiency of hydraulic actuators and forest machines by reducing the leakage of the working fluid and the inertia of HC operation [9-12].

In addition to the noted ones, an important positive quality of the proposed SDC structures is the ability of their cuffs to slightly rotate with the pistons in the cylinder during the operation of HC. Presumably, this should ensure more uniform wear of SDC sealing elements and antifriction layers of pistons during long-term operation of HC and, consequently, increase durability and stability of HCs in general. The proposed SDC designs make it possible to increase the efficiency of HCs approximately by 8-12% in comparison with traditional ones, to facilitate the launch of hydraulic drives of forest machines at low temperatures, to increase the durability of HCs and to reduce the complexity of HC maintenance by reducing the number of installation and dismantling works associated with unscheduled SDA replacement.

5. Acknowledgements

“The reported study was funded by Council for Grants President Russian Federation according to the research project № MK-6621.2018.8”.

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