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Comparative Analysis of the Lip Seal in Hydraulic Power Cylinder

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Keywords: finite element method, modeling, hydraulic power cylinder, hermetic sealing,seal.

Abstract. The natureofthe hydraulic power cylinderseal assembly operation with high working fluid pressure, different geometrical parameters oflip-type seal, is revealed. The method of hermetic sealingprocess modelingaccording to the simplifiedmodelusing finite element method is considered.

Introduction

Operating capacity of power cylinders, including hydraulic jacks and hydraulic legs of power supports, is determined according to the capacity of the leap seal in piston – working cylinder clearance, as well as to the sealed clearance size. This paper provides a comparative operation analysis of three seals, manufactured according to GOST 6678-72, GOST 14896-84 and GOST 6969-54; they differ in form and geometrical parameters.

Work Description

Sealing parameters in sealed clearance were assessed according to the axially symmetrical parametric finite-element model of a sealed assembly, input characteristics of this model included geometrical parameters of the lip seal and piston groove (height, width, curvature radius of a seal, groove edge rounding radius of the piston); sealed clearance, material properties of a seal and the cylinder, working fluid pressure [1, 2].

When modeling lip seals regular lattice of finite elements was used [3], which improves the accuracy of calculations and convergence probability of finite-element solution.

Required density and finite element parameters were selected with reference to the density index [4, 5, 6], determined according to obtained equivalent stress values, this index enables evaluation of maximum possible absolute error of obtained equivalent stress values.

Oil-water sludge was used as working fluid; sealing pressure equaled 50 MPa. Since the lip seal of hydraulic legs is manufactured of low-compressible material its behavior is better to be described by Mooney-Rivlin model with two parameters [7].

In terms of the model, calculation comprised two phases: first, deformed state of lip seal was modeled after assembling of hydraulic cylinder; second, it was modeled under the dependence on working fluid effect in the form of distributed load on internal seal surfaces [8–10]. Mises stress distribution in the cross section and that of contact stress on sealed surfaces are illustrated by Figures 1-3 for considered lip seals.

a b

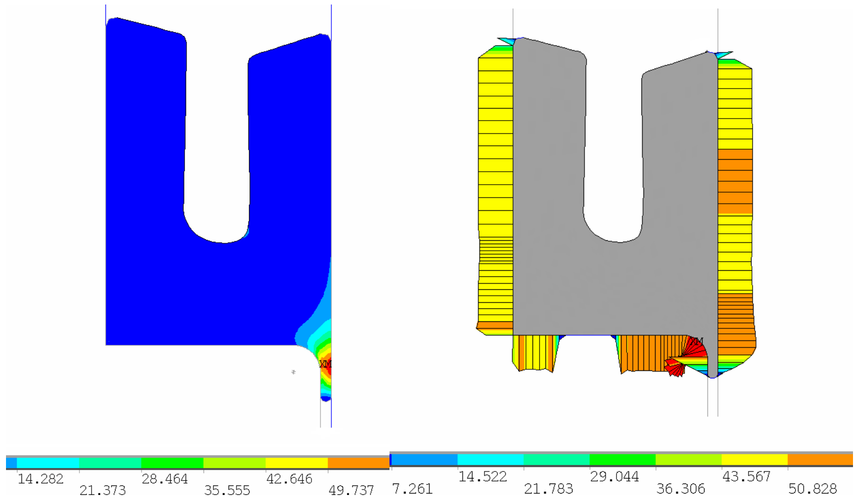

Fig. 1. Misesstress, MPa (a) and contact stress, MPa (b) for lipGOST 6678-72 at working fluid pressure P=50 MPa

a b

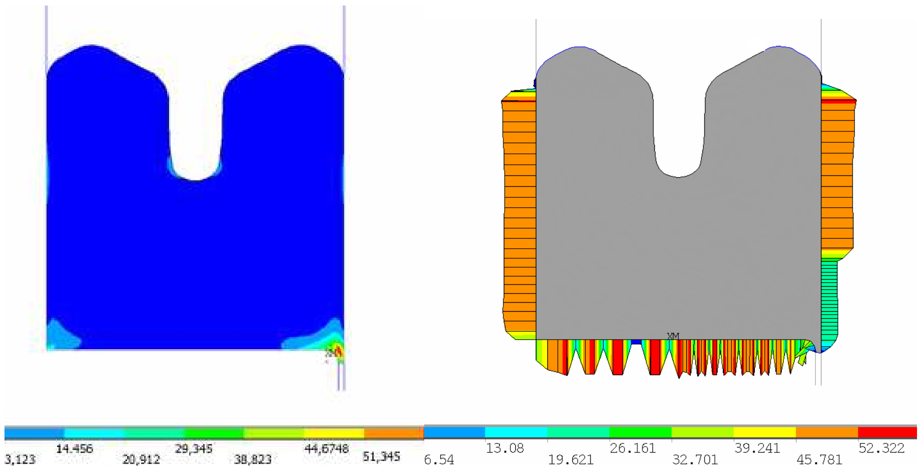

Fig. 2. Mises stress,MPa (a) and contact stress,MPa (b) for lipGOST 14896-84 at working fluid pressureP=50 MPa

a b

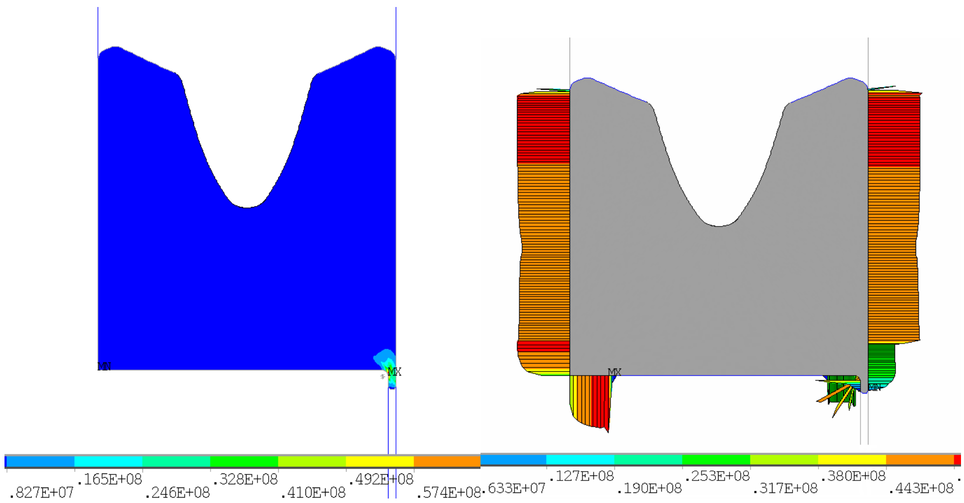

Fig. 3. Misesstress, Pa (a) and contact stress, Pa (b) for lip GOST 6969-54 at working fluid pressureP=50 MPa

Seal elements, tightened and pressed down by working pressure of fluid are to fit close to adjacent assembly elements for providing secure fluid blocking. Sealing elements are to pass into all caused by machining irregularities of sealed surfaces. A while-moving clearance is to be avoided in order to prevent fluid leakage. Therefore, the following criteria are offered for assessment of seal operation parameters [11, 12]:

- *Safety factor of seal* $[n] = \dfrac{[\sigma]}{\sigma_{max}}$,

where σ_{max} and $[\sigma]$- respectively, maximum and admissible equivalent stress in the seal, MPa;

- *Value of pressed out seal material into the clearance* L_s, mm;
- *Relative value of pressed out material into the clearance, equial to the preceding value rated to the clearance* $K_з = \dfrac{L_s}{\delta}$;
- *Maximum contact pressure on the sealed surface* $p_к^{max}$, MPa;
- *Koefficient of working fluid blocking* $К_{зп} = \dfrac{\overline{p}_к}{p}$,

where $\overline{p}_к$ – mean contact stress on the sealed surface, MPa; p – working fluid pressure, MPa.
Values of criteria, calculated in accordance with the developed parametrical model, for various lips are listed in Table, piston diameter is 220 mm, clearance is δ=0.25 mm.

Table 1. Values of seal criteria in the sealed clearance (250 mcm)

Seal type	Safety factor $n_{зп}$	Pressing-out into clearance $L_з$, mm	Pressing-out rated to the clearance $K_з$	Maximum contact stress $p_к^{max}$, MPa	Coefficient of working fluid blocking $K_{зп}$
GOST 6678-72	3.1	1.06	4.2	56.7	1.13
GOST 14896-84	4.9	0.75	3.0	48.9	0.97
GOST 6969-54	3.9	0.63	2.5	57.1	1.14

Given in Table 1 data demonstrate that values of seal operation are within the following limits:

- Safetycoefficient – 3.1 to 4.9;
- Coefficient of working fluid blocking – 0.97 to 1.14;
- Maximum contact stress – 48.9 to 57.1 MPa;
- Pressing-out into the clearance – 0.63 mm to 1.06 mm;
- Pressing-out related to the clearance – 2.6 to 4.2.

Numerical values of criteria help to evaluate lip seal operation comprehensively in a particular assembly of power hydraulic cylinder. On the basis of obtained data analysis the conclusion is drawn performance of the seal meeting the requirements of GOST 6969–54 is the best one in terms of working fluid blocking and its behavior in the working cylinder – piston clearance.
Table makes it evident seal operation in the sealed clearance is fully assessed according to the value of seal material pressed-out into the clearance L_s. and pressing-out related to the clearance $K_з$.

Conclusions

The following regularities and lip behavior character in the clearance are stated on the basis of calculations according to the mentioned above models:

- Pressing-out into the clearance and other equivalent stress vary linearly in direct proportion to the edge curvature radius of piston groove, sealed clearance, working fluid pressure and in inverse proportion to seal rounding radius;
- Maximum equivalent stress is located quite near the edge of piston groove (Fig. 4);

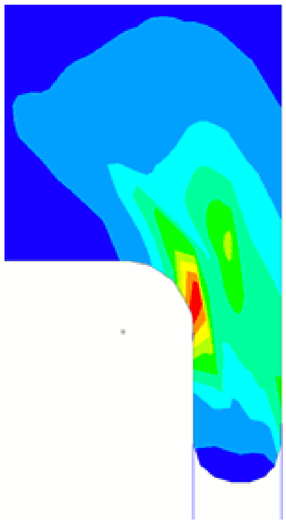

Fig. 4. Mode of deformation of seal near the clearance

- Increased height of lip causes slightly reducing (within the limits 0.001 mm per 1 mm of height) value of pressing-out into the clearance, whereas internal stress rises (0.1 MPa per 1 mm of height);
- Pressure increased by 10 MPa causes rising value of pressing-out into the clearance by 0.1 mm, as well as internal stress by 5 MPa.

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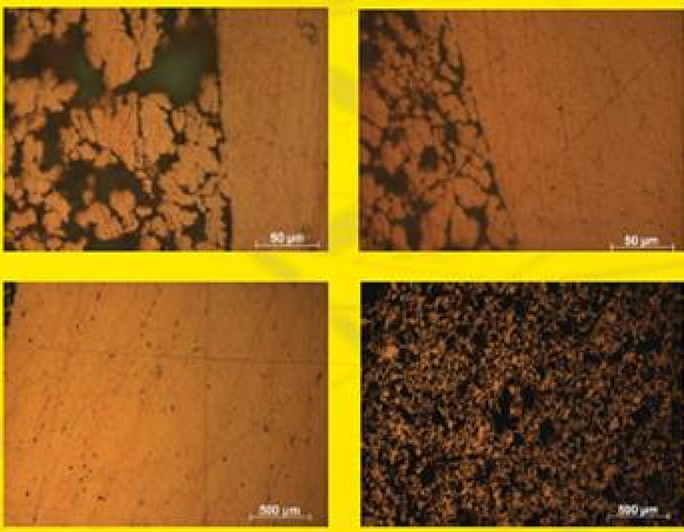

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