

Modeling of Hydraulic Power Cylinder Seal Assembly Operation

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Abstract: The nature of the hydraulic power cylinder seal assembly operation with high working fluid pressure, different geometrical parameters of lip-type seal, is revealed. The method of hermetic sealing process modeling according to the simplified model using finite element method is considered.

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

1. Introduction

Sealing property of hydraulic power cylinders, which include hydraulic jacks and powered support props, is determined by the size of the gap between the piston and working cylinder, as well as by the operation of lip-type seal in this gap.

This paper presents comparative assessment of performance of three seals, made according to the State Standard 6678-72, State Standard 14896-84 and State Standard 6969-54, which differ in shape and geometrical dimensions.

2. Work Description

The assessment of seal parameters of the sealed gap was made on parametric axisymmetric finite element model of the seal assembly; the initial parameters being geometric dimensions of lip-type seal and lip seal groove of the piston; sealable gap, material properties, the working fluid pressure.

As the working fluid was adopted water-in-oil emulsion, sealing pressure—50 MPa. Since the lip-type seal of hydraulic powered props lip is made of

low-compressibility material, the Mooney-Rivlin model with two parameters is most suitable to describe its behavior.

According to the model the calculation was carried out in two stages: on the first stage the deformed state of lip-type seal after the cylinder assembly was simulated (Fig.1); on the second stage— from the working fluid effect in the form of distributed load on the internal sealing surfaces (Fig. 2).

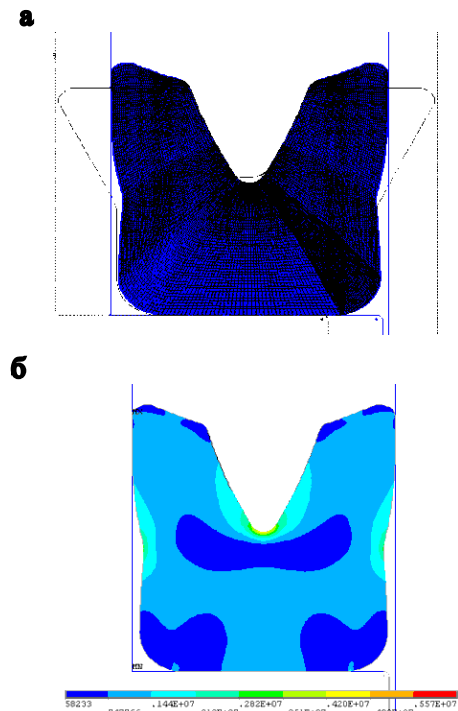


Fig. 1: Deformations (a) and load distribution according to Mises (b) in the lip-type seal on the basis of State Standard 6969-54 after assembly.

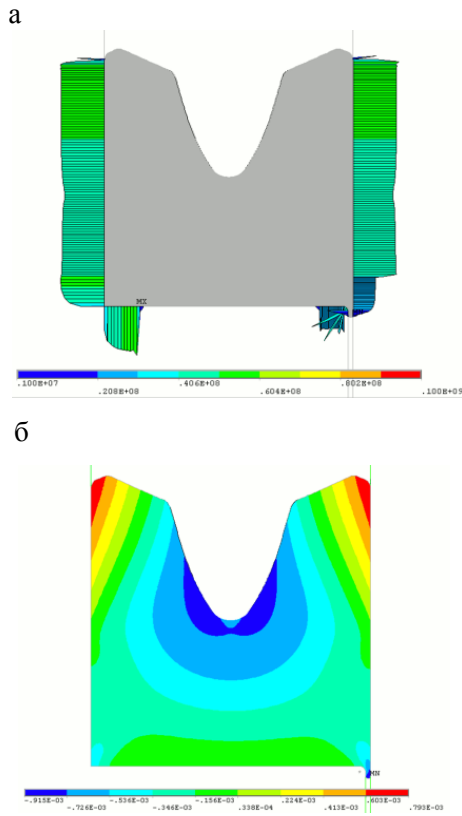


Fig. 2: Axial movement (a) и contact pressure (б) in the lip-type seal on the basis of State Standard at working fluid pressure 50 MPa.

For reliable liquid blockage the seal parts should adjoin tightly the details conjugate to them by means of preload and the working liquid pressure. The sealing parts must fit all mechanical regularities and to prevent the formation of the gap

through which the fluid could leak when moving. On this basis, the following criteria for assessment of the parameters of the seal operation are proposed [1]:

- seal load factor $[n] = \frac{[\sigma]}{\sigma_{\max}}$

where σ_{\max} and $[\sigma]$ and maximum and allowable equivalent loads in the seal respectively, MPa; value of seal material pressing-out into the gap L_s , mm; relative value of seal material pressing-out into the gap, equal to the previous value,

relative to the gap $K_3 = \frac{L_s}{\delta}$; maximum

contact pressure across the sealable surface p_{κ}^{\max} , MPa;

- working fluid blockage coefficient

$$K_{3II} = \frac{\bar{p}_{\kappa}}{p},$$

where \bar{p}_{κ} – average contact pressure

across the sealable surface, MPa;

p – working fluid pressure, MPa.

Criteria values calculated using the developed parametric model for various types of lip-type seal when the piston diameters of 220mm and gap size is of $\delta = 0.25\text{mm}$ are shown in Table 1.

Table 1: Seal operation criteria values in the sealed gap

Seal type	Load factor n_{3II}	Pressing-out into the gap L_s , mm	Pressing-out, relative to the gap K_3	maximum contact pressure p_{κ}^{\max} , MPa	working fluid blockage coefficient K_{3II}
State Standard 6678-72	3.1	1.06	4.2	56.7	1.13
State Standard 14896-84	4.9	0.75	3.0	48.9	0.97
State Standard 6969-54	3.9	0.63	2.5	57.1	1.14

As the table shows, the value of seal material pressing-out into the gap and Pressing-out, relative to the gap the give the most complete assessment of seal operation in the sealed gap.

The evaluation of operation of the seal in the gap between the piston and the cylinder using the finite element method is a laborious process [2, 3]. This is due, primarily, to the nonlinearity of the outer surface of the seal and the related additional complexity of creating a regular finite element mesh, as well as to with large model formations (especially

in the gap), which reduce the probability of the solution convergence.

In order to eliminate these difficulties the simplified model of lip-type seal was developed (Fig.3), which differs from the real one in the absence of "antennae". The accuracy of the results obtained on the basis of the simplified model in the gap area does not differ from the results obtained on the basis of a real model; at the height of the model being not lower then (B_{up}) the height of the main body of the lip-type seal. The error in the calculation is about 0.05 %.

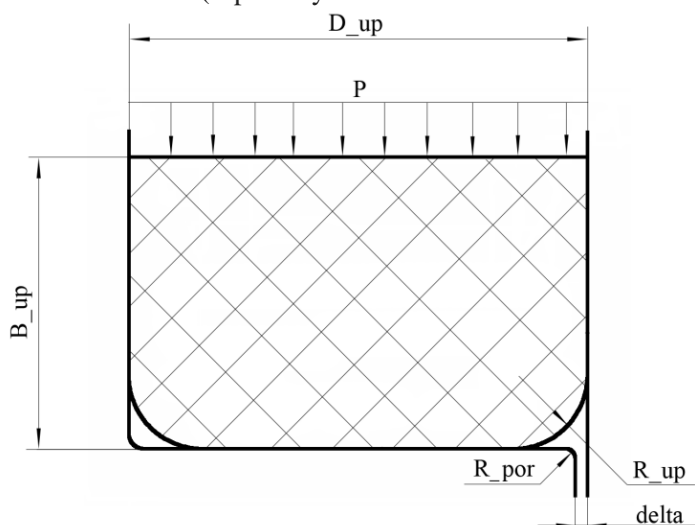


Fig. 3: The simplified model of seal assembly of hydraulic powered support prop

The developed model allows taking into account the following parameters (Fig. 3):

- geometrical dimensions: height (B_{up}), width (D_{up}), seal rounding radius (R_{up}), spherical radius of the groove edges of the piston (R_{por});
- sealed gap (δ);
- properties of the seal material;
- the fluid pressure in piston cavity of the hydraulic powered support prop (P).

3. Conclusions

On the basis of the calculations using the simplified models the basic regularities and the mode of lip-type seal behavior in the gap are found:

- pressing out into the gap and equivalent loads vary according to the linear relationship in direct proportion to the spherical radius of the groove edges of the piston (R_{por}), sealed gap, the fluid pressure and inversely to the spherical radius of the seal (R_{up});
- the maximum equivalent loads are in the immediate vicinity to the edges of the groove of the piston (Fig. 4);
- the height increase lead to a slight decrease (within 0.001 mm per 1mm of height) of the quantity of pressing out into the gap, wherein the internal load increases (0.1 MPa per 1mm of height);
- the 10MPa pressure increase results in an 0.1 mm increase of the value of the

pressing out into the gap and 5MPa increase of the internal load.

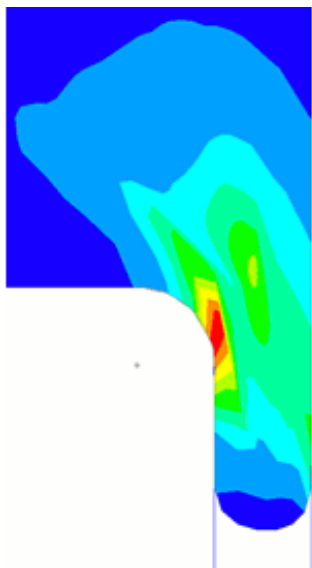


Fig. 4: Mode of deformation of the seal bear the gap

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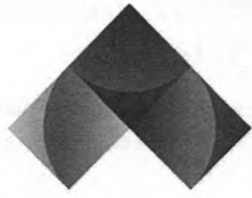
MINING 2014



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Mining, Green and Safety***

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Taishan Academic Forum – Project on Mine Disaster Prevention and Control

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- Shandong University of Science and Technology, China
- Shandong Administration of Coal Industry, China

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Foreword

Mining technology is an important issue on resource exploitation, which is related to mine production security and energy supply. In order to promote the scientific and technological progress and international exchanges of the mining technology, the Taishan Academic Forum – Project on Mine Disaster Prevention and Control is to be held on Oct. 17-20, 2014, in Qingdao, China. The aim of the symposium is to summarize the modern coal industry achievements, in safety green mining methods and the related fields. There will be experts and scholars to attend the meeting, from the coal industry enterprises, universities, research institutions and other related fields of China and Russia.

The main topics of the symposium include: safety green mining methods, mine construction and modernization, the mining theories, methods and technology, the construction safety of mining and underground engineering, the operation and management of mining and underground engineering, etc.

The symposium is organized by the Education Department of Shandong Province, Shandong University of Science and Technology, Coal Industry Bureau of Shandong Province. It is undertaken by Institute of Mining and Safety Engineering, Shandong University of Science and Technology and State Key Laboratory of Mine Disaster Prevention and Control.

We are convinced that the symposium is going to play an important role in the development of the coal mining technology and international communication. Heartfelt thanks are extended to domestic and overseas scholars who have given great supports to this conference and all the authors who have presented the papers.

Weijia Guo, China
Yunliang Tan, China
Yongjie Yang, China
Shasha Yan, China
Dongmei Huang, China

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