ISSN 1392–1207. MECHANIKA. 2023 Volume 29(1): 19–26

Design of Three-stage Sealing Structure and Investigation of Sealing Performance for 7000 Fracturing Plunger Pump

Mingjun DU*, Jianqiu XI, Youping LIU***, Yongjun HOU*, Huachuan LI***, Xiaopeng YANG****, Zhixi WANG*****, Qiping DAI******, Ping DUAN***, Mingjian ZHAO***, Shikai JIANG*****

**School of Mechatronics Engineering, Southwest Petroleum University, Chengdu, 610500, China, E-mail: dmj9213@163.com*

***BOMCO Chengdu Equipment Manufacturing CoMPany, Chengdu 610052, China, E-mail: xijq_sc@cnpc.com.cn*

****Sichuan BOMCO Special Vehicle Manufacture Co., Ltd. Guanghan, 618300, China, E-mail: lzzlyp@163.com*

*****Changqing Downhole Service CoMPany of CNPC Chuanqing Drilling Engineering Co., LTD., Xian, 710018, China, E-mail: _yangxiaop @cnpc.com.cn*

******Downhole Service CoMPany of CNPC Chuanqing Drilling Engineering Co., LTD, Chengdu, 610051, China, E-mail: 182426257@qq.com*

*******CNPC National Engineering Research Center for Oil and Gas Drilling Equipment Co., Ltd., Baoji, 721002, China, E-mail: 1226614600@qq.com.*

crossref http://dx.doi.org/10.5755/j02.mech.31091

1. Introduction

With the rapid development of the exploitation technology of shale gas and other unconventional gas resources in China, many domestic scholars have carried out tremendous researches on its exploitation technology [1]. And Hydraulic fracturing technology has been used in the oil production process [2]. Hydraulic fracturing technology is an important measure for development and stimulation in low-permeability reservoir. And which is one of the effective measures to enhance oil recovery [3, 4]. As drilling wells is continually buried deeply, with high viscosity, and difficult to development, fracturing techniques are increasingly intensified with their technical progresses [5, 6]. However, the plunger pump in the fracturing truck is one of the key equipment in fracturing technology [7, 8]. Large fracturing equipment in the fracturing truck has made statistically significant progress on its design and technology in recent years, which gradually breaks the blockade on new techniques and the technological monopoly of foreign manufacturers [9, 10]. The fracturing pump in our country are developing rapidly toward the way of high pressure, large displacement and the versatility. Jereh company has developed 4500 turbine fracturing truck, which can be used in the large fracturing operations of high-difficult work and high-pressure wells, such as shale gas wells across rugged terrain. Honghua Group Limited has testing and developing large fracturing truck equipped with model 6000 pressure pump. To meet requirements of drilling operation with long time, high pressure, large displacement, Jereh company developed the manufacturing of new-generation of 7000 fracturing truck. The plunger pump operation with different rotational speed and pressure is stable and reliable in performance, and under the same discharge with different types of pumps, the reciprocating frequency of plunger pump of 7000 fracturing truck is getting smaller, the service life of accessories is getting longer.

The fracturing pump is one of the key equipment of the fracturing truck, and which mainly includes hydraulic end and power end [11]. Where its power end is mainly transmits the power of the system to the hydraulic end [12], and its hydraulic end is mainly inhale low-pressure liquid, the low-pressure liquid is converted to high-pressure liquid by reciprocating movements of the plunger pump. Hence, hydraulic end parts of the fracturing pump are extremely fragile, and it plays a key role in stable operation of the fracturing pump. The plunger pump takes higher demand for its sealing performance due to the action of high-pressure fluid and reciprocating motion of plunger pump in hydraulic end [13,14]. During the running process of the steady-state plunger pump, high-pressure fluid in the plunger pump acts on the end surface of the piston and the internal surfaces of the pump body. If the external surfaces of the piston are not contact with the internal surfaces of the pump body, the sealing performance of the system will decrease, which will cause a lot of carrying cuttings in high-pressure fluid from flowing freely to the contact surface, and reduce the service life of the piston and the pump body. Simultaneously, fluid pressure between the external surfaces of the piston and the internal surfaces of the pump body will decreased, and it is difficult to gather enough strain for transmission of fluid. Even seriously affect the drilling efficiency in the operation of drilling for oil [15]. Therefore, how to improve the sealing performance of the piston and the pump body becomes a new hot spot of the fracturing pump [16-19]. And aimed at 7000 fracturing plunger pump with the characters of high stress, large displacement and long operation time, we designed a new structure of three-stage sealing structure and investigation of sealing performance for 7000 fracturing plunger pump.

2. Model and sealing principle of three-stage sealing structure

The design of three-stage sealing structure for 7000 fracturing plunger pump is shown in Fig. 1. And its plane schematic diagram is shown in Fig. 2. The sealing structure consists of a support ring, three rubber rings, a junk ring, a pump head, a packing gland nut, a plunger, a supporting ring, etc. The rubber ring *1* and two rubber ring *2* are parallel installed between the support ring and the pump head. Three rubber rings of three-stage sealing structure to work in turn are adopted for improving the device sealing performance. Under the action of fluid pressure, a pressure difference is transmitted to the second and third rubber ring in turn when sealing failure of the first rubber ring is appear during the running process of 7000 fracturing plunger pump. Simultaneously, the second and third rubber ring play an important role in different levels of good sealing effect, and the sealing assembly life is improved. In addition, the sealing principle of three-stage sealing structure in hydraulic end of the plungers that a contacting pressure along the radius direction will be generated between the piston and the pump bod when three rubber rings are assembled; Then, through the adjustable wrench is clamped at the position of the radial hole of the packing gland nut, and after the rotary packing gland nut is locked, the support ring exerts an axial load to those rubber ring. Meanwhile, three rubber rings exert a contact force along the radius direction to the piston and the pump bod, and the contact force can be used to implement completely sealed when the liquid tank into the pump; When the liquid is discharged by the fracturing plunger pump, the high stress in the pump head acts on the support ring, and those rubber ring further will exert an axial compression to make a radial contact force between the rubber rings and the plunger, the pump head increases, which can better achieve high-pressure sealing. Therefore, the rubber rings and the plunger, the pump head are assembled by an interference fit, and the plunger is only moving in a straight line; the supporting ring is one of important parts in the seal assembly; the function of the support ring is to form an initial compression for the sealing rings to make it and the sealing surface functioning fully contact.

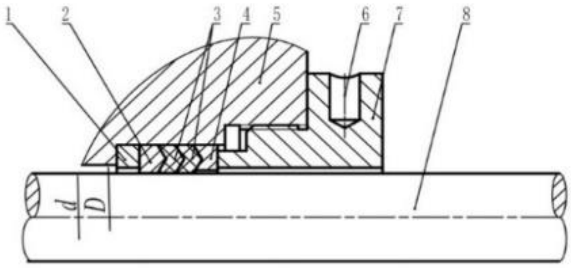


Fig. 1 Hydraulic end three-stage sealing device design of 7000 fracturing plunger pump: *1* - Support ring; *2* - Rubber ring *1*; *3* - Rubber ring *2*; *4* - Junk ring; *5* - Pump head; *6* - Radial hole; *7* - Packing gland nut; *8* - Plunger

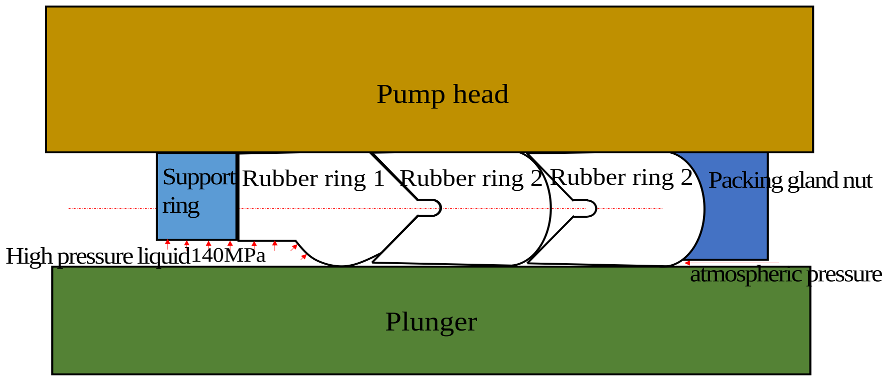


Fig. 2 Plane schematic diagram of Hydraulic end three-stage sealing device design

3. Theories and Methods

3.1. Constitutive model of Rubber Material

The rubber rings using three-stage sealing for 7000 fracturing plunger pump can be model as a class of incompressible hyperelastic materials. But it may appear distorted under the influence of external forces. In recent years, many domestic and international scholars proposed a number of constitutive models of rubber, and which generally fall into two basic categories [20]: the phenomenological model based on a new strain energy function and the statistical model based on molecular chain grid. There are a number of the most representative model in the phenomenological model, the main ones being Mooney-Rivlin model, Yeoh model, Valanis-Landel model, Ogden model, etc. However, there are a number of the most representative model in the statistical model based on molecular chain grid, the main ones being Treloar model, the 8 chain model of the Arruda-Boyce, etc. In the paper, the Mooney-Rivlin model is selected to explore mechanical characteristics of those rubber rings. And the strain energy density function can be expressed as following [22]:

$$W = C_1\left(I_1 - 3\right) + C_2\left(I_2 - 3\right), \tag{1}$$

where: W is the modified strain energy density; C_1 and C_2 are correction coefficient of the constitution model for Mooney-Rivlin; I_1 and I_2 are the first and second invariants of stress tensor, respectively.

The stress-strain relation can be expressed as [22]:

$$\sigma = \frac{\partial W}{\partial \varepsilon}. \tag{2}$$

According to rubber compression test [23], those material parameters in Mooney-Rivlin model can be obtained: C_1 =3.2 MPa, C_2 =4.021 MPa, ρ =1140 kg·m^{-1}.

3.2. Finite element analysis hypothesis

The rubber is noted for their material nonlinear, geometry nonlinear and contact nonlinear. So It is necessary for studying the sealing performance to make the following assumptions [23, 24]:

1. Rubber material is assumed to be transversely isotropic and fully elastic;

2. Rubber material has the same physical characteristics with a tensile and compressive behavior, creep;

3. The longitudinal compression of sealing ring is caused by its normal constraints;

4. The volume of sealing ring is not affected by its creep;

5. The effects of time and temperature on mechanical properties of sealing ring are ignored.

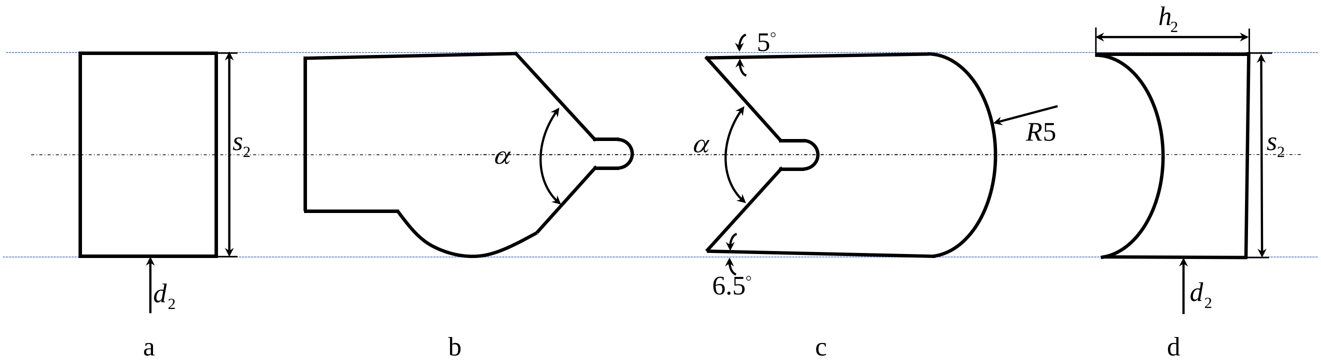


Fig. 3 Plane detail drawings of hydraulic end three-stage sealing device: a) Support ring; b) Rubber ring; c) Rubber ring; d) Packing gland nut

3.3. Computational model of three-stage sealing structure

Plane detail drawings of hydraulic end three-stage sealing device for 7000 Fracturing Plunger Pump are shown in Fig. 3, and its structural parameter are shown in Table 1. We restrict d =125 mm, and obtain the structure size of support ring, rubber ring, junk ring, pump head, packing gland nut, and plunger based on sealing design manual [25]. According to geometry and boundary conditions of three-stage sealing structure of 7000 fracturing plunger pump, a two-dimensional axisymmetric finite element model including support ring, rubber ring, junk ring, pump head, packing gland nut, plunger is built, as shown in Fig. 4. Materials of those rubber rings are HNBR type, and materials of plunger, pump head and support ring are 1Cr18Ni9Ti, Poisson's ratio is 0.3, the elastic module is 184 GPa, the density is 7800 kg·m^{-1}. We fixed one end of the packing gland nut, outer end of pump head and the axis of plunger. The fluid pressure P was applied in the right of support ring and the clearance area between support ring 1 and plunger. And four-node quadrilateral bilinear axisymmetric elements (CAX4R) were used for modeling all the bodies, as shown in Fig. 4. The contact relationships among rubber ring, pump head and plunger are established. A frictionless contact form is applied between pump head and plunger. As its physical characteristics has similar stiffness, it requires adopting symmetrical contact type, the contact algorithm is adopted by using Lagrangian method, and the contact stiffness between pump head and plunger is forced to update by using detection mode of Gauss point. A contact penalty algorithm with a friction coefficient 0.25 was employed to simulate the interactions between the rubber ring and pump head, the rubber ring and plunger.

Table 1

Sealing structure parameters

Part name	Mark	Value
Plunger	External diameter d, mm	125
Block	Inner diameter D, mm	145
Support ring	d_2, mm	125.6
	S_2, mm	9.4
Packing gland nut	d_2, mm	125.6
	S_2, mm	9.4
	h_2, mm	10

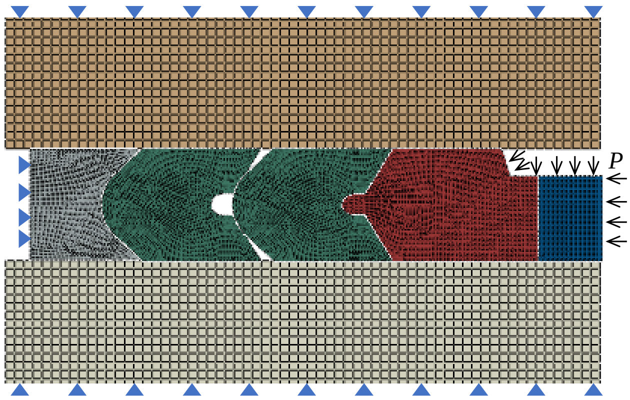


Fig. 4 Finite element models

In this paper, the sealing performance of three-stage sealing structure for 7000 fracturing plunger pump was investigated. First, the pressure of a high-pressure fluid is assumed as 140 MPa, a low pressure fluid is assumed as 70 MPa accordingly, and the fracturing plunger pump is suffered an atmosphere (0.101325 MPa). Then, applying different displacement amplitude on the right of the support ring is applied to simulate the axial preloading force during installation of the system.

4. Three-stage sealing performance

4.1. Fluid pressure

Considering that the displacement amplitude 7mm on the right of the support ring is applied to simulate the axial preloading force during initial installation, and the fluid pressure ranging 70 MPa –140 MPa was considered in the paper. The stress distribution of three rubber ring under different fluid pressure are shown in Figs. 5 - 7, respectively. It can be found that deformation and stress distribution of rubber rings are different under the action of different of fluid pressure. Owing to structurally symmetry of rubber ring *2*, its equivalent stress is basically distributed symmetrically. However, the structure of rubber ring *1* is unsymmetrical, its equivalent stress is basically distributed symmetrically is irregular changing under the action of fluid pressure and the support ring. When the liquid tank into the pump, the rubber ring *1* contacts with the surfaces of the adjacent rubber ring *2* more closely under the action of fluid pressure, and the rubber ring *2* contacts with the surfaces of the other rubber ring *2* by the transfer of pressure energy, as shown in Fig. 4. When the rubber ring *1* is pushing the rubber ring during the running process of 7000 fracturing plunger pump, their contacting zone slowly increases with the fluid pressure increases. The rubber ring *2* on the left is stretched in the open direction under the action of load, and it will produce good sealing effects. Also, the results show that the high stress areas appear around the corner of the rubber rings *2*. Meanwhile, the stress distributions and the maximum stress of each rubber ring increases with the fluid pressure increases. Hence, the fatigue failure of those rubber rings easily appears around its edges and corners. Compared with the stress distribution of different rubber rings under the action of same fluid Pressure, it can be seen that the maximum stress of rubber ring *2* on the left near the support ring is relatively large. Because the material of the support ring has the characters of higher stiffness caused axial compression force of sealing parts is accumulate at the rubber ring *2*. The maximum contact pressure of three rubber rings for Figs. 5 - 7 are shown in Fig. 8. When the liquids flow into the pump cavity with a certain pressure, three rubber rings will in intimate contact with pump head, junk ring and plunger. Different contact force between those rubber rings, and rubber ring and junk ring, plunger can prevent those liquids from the pump cavity to the outside. According to the sealing theory and the principle of force balance, the sealing performance of the system will reliable when the maximum contact pressure is not less than the internal pressure of the working fluid. It can be seen from Fig. 8 that the maximum contact force of the system is greater than the internal pressure of the working fluid under different working fluid pressures. And the structure of three rubber rings can ensure that the seal rings work in turn, which can achieve a better sealing effect.

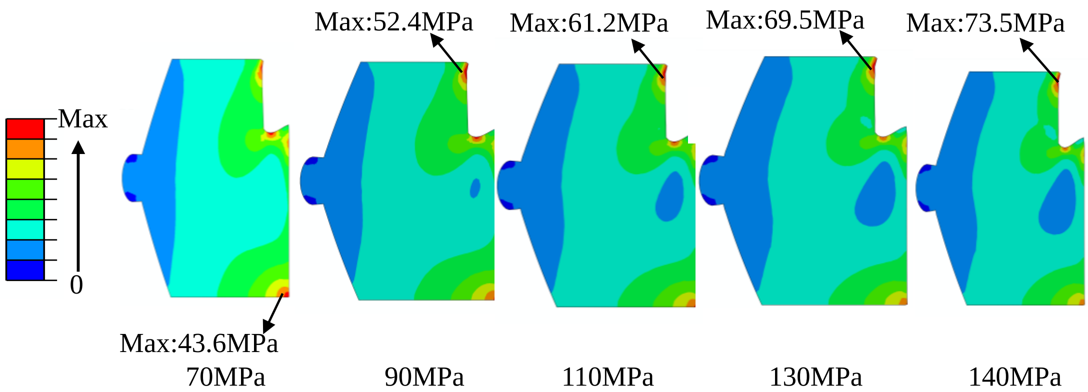


Fig. 5 The stress distribution of rubber ring *1* under different working pressure

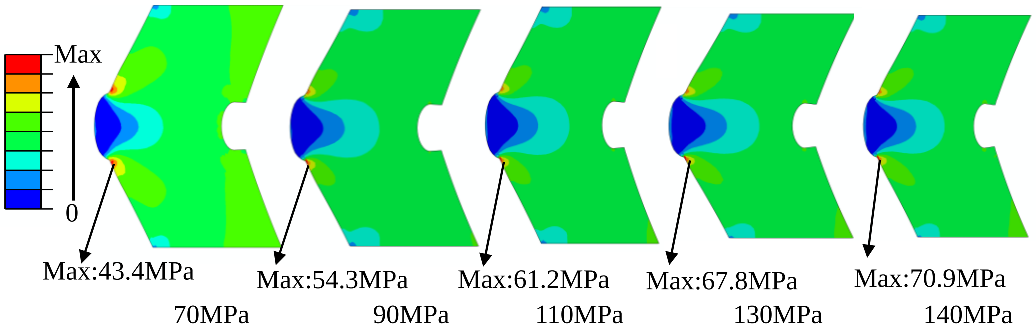


Fig. 6 The stress distribution of rubber ring *2* on the right under different working pressure

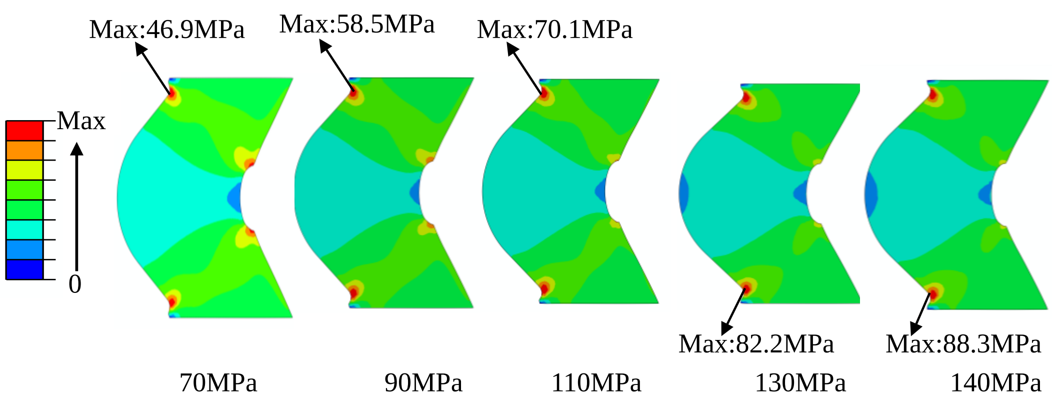


Fig. 7 The stress distribution of rubber ring *2* on the left under different working pressure

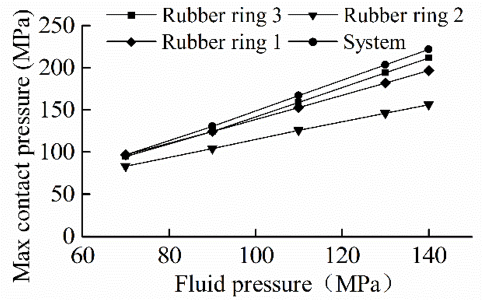


Fig. 8 Maximum contact pressure of rubber ring under different working pressure

4.2. Axial mounting preloads

Under the action of high-pressure fluid (140 MPa) in the hydraulic end, the effect of axial mounting preloads on the sealing performances of three-stage sealing structure for 7000 fracturing plunger pump are explored. When the displacement amplitudes are set to 3 mm, 5 mm, 7 mm, respectively, the stress distribution and the maximum contact pressure of three rubber rings are shown in Fig. 9, Figs. 10 and 11. The results show that rubber rings open in its lip with the increasing of axial mounting preloads, which caused that three rubber rings are in intimate contact with pump head, support ring and plunger. And the increases at double of contact pressure of rubber rings with different mounting preloads, three-stage sealing structure with better sealing performance is implemented to 7000 fracturing plunger pump. However, mises stress distributions of three rubber rings are similar under different axial mounting preloads during the running process of the system. As shown in Fig. 12, the contact pressure of each rubber ring along the edges is nonlinear under the action of high-pressure fluid when the displacement amplitudes are set to 3 mm, 5 mm, 7 mm, respectively. Because the high-pressure fluid directly is acting directly on the end of the rubber ring *1*, the contact force of the upper edge of the rubber ring *1* near its lip is gradually decreased, and the high stress areas appears on contact region between the rubber ring *1* and support ring. The maximum contact force appears at the corner of the rubber ring where the plunger and the support ring are in contact, simultaneously. Since the contact region of rubber ring *1* and adjacent rubber ring *2* is symmetrical, the contact force on the left side of rubber ring *1* is distributed symmetrically, as shown in Fig. 12, a. Due to the axial preloading force during the installation process of three-stage sealing structure, arcuate surfaces of the rubber ring *2* is in intimate contact with the lip of the other rubber ring *2*. With fluid loading continue to increase, the contact area between the rubber ring *2* on the left and the rubber ring *2* on the right increases, and the rubber ring *2* on the right open in its lip, which caused that those rubber rings are in intimate contact with support ring and plunger, and three-stage sealing structure plays an important role in 7000 fracturing plunger pump. In addition, due to the symmetrical structure of rubber rings *2*, the stress distribution and the contact pressure of three rubber rings are also symmetrical. And the maximum contact force appears at the corner of the rubber rings. It can be seen from Fig. 12 that the contact stress of the system is directly related to fluid loading during the running process of the system.

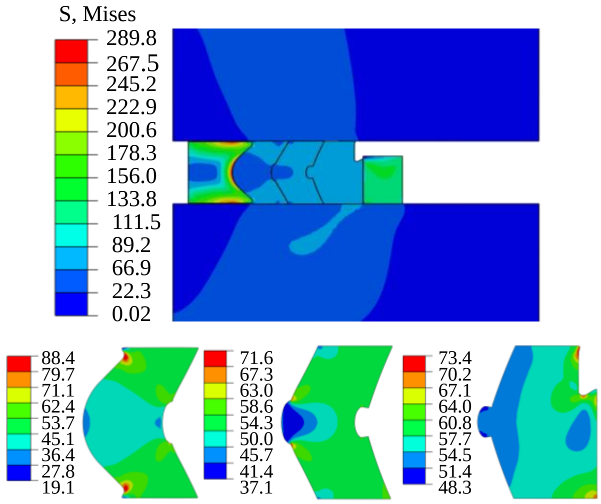


Fig. 9 The stress distribution of 7000 fracturing plunger pump with 3 mm displacement of the junk ring

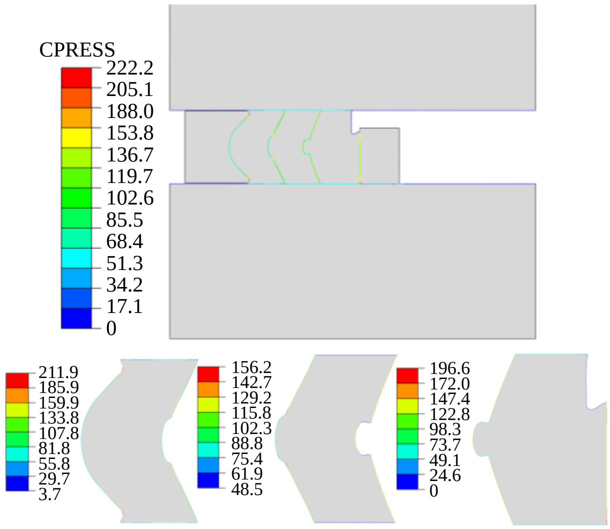


Fig. 10 Contact stress of 7000 fracturing plunger pump with 3 mm displacement of the junk ring

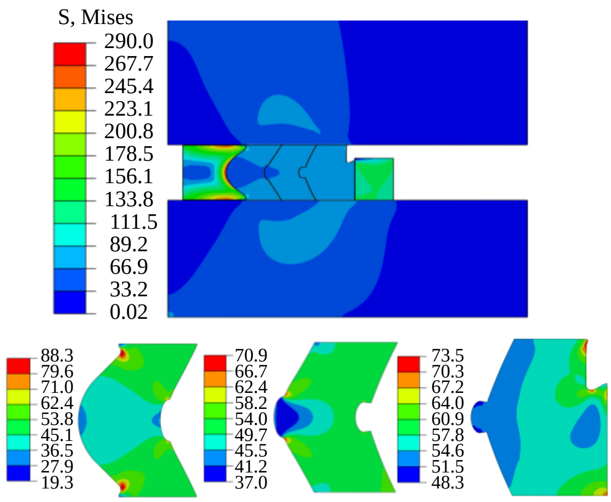
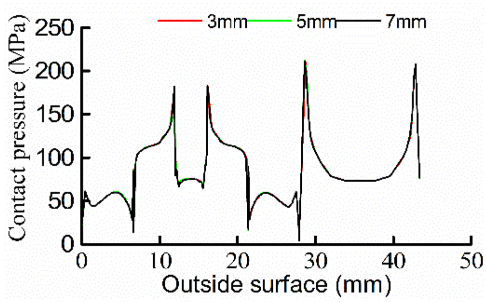
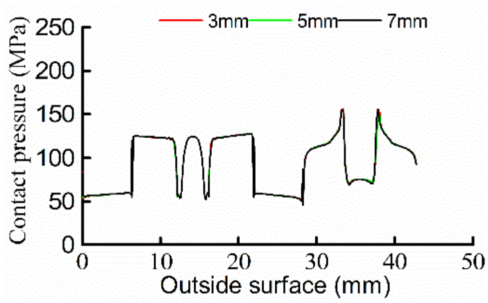


Fig. 11 The stress distribution of 7000 fracturing plunger pump with 7 mm displacement of the junk ring

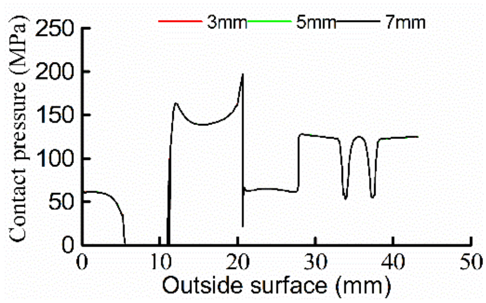
Figs. 13 and 14 show the mises stress distributions and the contact stress of the three-stage sealing structure when a low-pressure fluid load (70 MPa) is applied to hydraulic end of 7000 fracturing plunger pump. Obviously, the amplitude of its mises stress distributions and contact stress decrease when compared to results for high-pressure fluid, and the high stress area are consistent with results of high-pressure fluid.



a) Stress amplitude of rubber ring 1



b) Stress amplitude of rubber ring 2 on the right



c) Stress amplitude of rubber ring 2 on the left

Fig. 12 Contact stress of 7000 fracturing plunger pump with different displacement of the junk ring

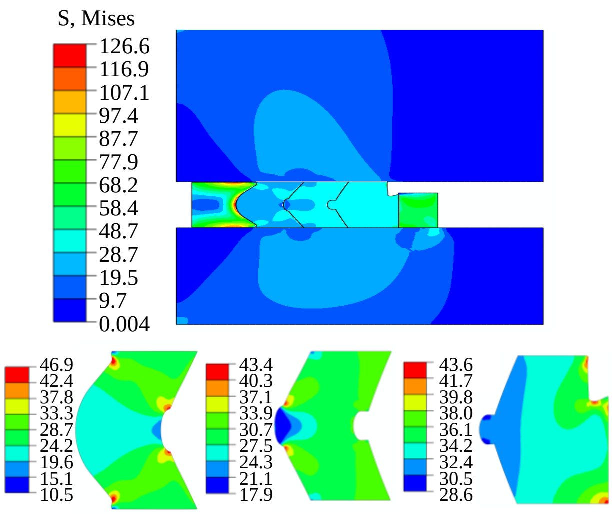


Fig. 13 The stress distribution of 7000 fracturing plunger pump under the action of a low pressure fluid (70 MPa)

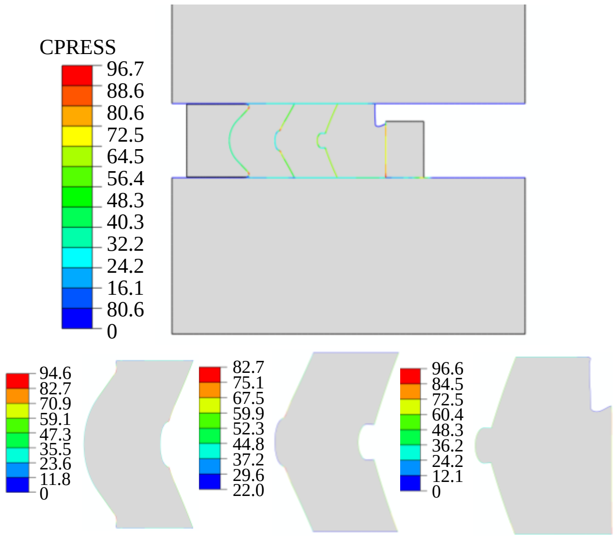


Fig. 14 Contact stress of 7000 fracturing plunger pump under the action of a low pressure fluid (70 MPa)

5. Conclusions

A better seal performance of 7000 Fracturing Plunger Pump can be obtained by the design of three-stage sealing device. Therefore, the structure of three-stage sealing device is meaningful to engineering fields. The maximum contact force of the system is greater than the internal pressure of the working fluid. And three-stage sealing structure can ensure that the seal rings work in turn, which can achieve a better sealing effect. The maximum stress area of the rubber rings appears at the corner of the structure, which easily leads to premature failure of the rubber rings, such as bite failure, fatigue failure, etc.

Fluid pressure in hydraulic end and axial mounting preloads of three rubber rings have great influence on the mises stress distributions and the contact stress of the system, its peak value increases with the increasing of axial mounting preloads. But the peak value of the mises stress distributions and the contact stress are directly related to fluid loading in hydraulic. The peak value of the mises stress distributions and the contact stress for three rubber rings increases with the increasing of fluid loading. Due to the symmetrical structure of rubber rings *2*, the stress distribution and the contact pressure of three rubber rings are also symmetrical. Therefore, the material of the rubber rings and the structure design of three-stage sealing are the key to sealing performance of 7000 fracturing plunger pump.

6. Acknowledgments

This study was supported by the Sichuan Science and Technology Support Project (No. 2020YFG0260) and CNPC Science and Technology Project (2019F-30).

References

1. **Gigorev, G. A.; Afanaseva, T. A**. 2012. Prospects for industrial development of unconventional gas resources in Russia. Petroleum Geology. Theoretical and Applied Studies 7(2):1-16.
2. **Deng, Q.; Zhao, F.; Li, H**.; et al. 2021. Technology and practice of the roof-caving of hydraulic fracturing in a

fully mechanized caving face, Thermal Science 25(3): 2117-2126.
http://dx.doi.org/10.2298/TSCI191104096D.

3. **Zhang, H. W.; Zhang, T.; Zhang, W. J**.; et al. 2021. New sealing techniques for hydraulic fracturing experiment of rock under high temperature and /high pressure conditions, Journal of Northeastern University (Natural Science) 42(03): 422-427 (in Chinese). http://dx.doi.org/10.12068/j.issn.1005-026.2021.03.018.
4. **Ye, W. J.; Cheng, K. S.; Zhan, C. C**.; et al. 2021. Analysis of flow field characteristics and optimization of structural parameters for distributing valve in high-pressure fracturing pump, Journal of Wuhan University of Science and Technology 44(03):2 07-212(in Chinese). http://dx.doi.org/10.3969/j.issn.1674-3644.2021.03.007.
5. **Wang, L**. 2019. Current situation and trend of oil and gas development technology in China, Petrochemical technology 26(09): 218-219 (in Chinese). http://dx.doi.org/10.3969/j.issn.1006-0235.2019.09.129.
6. **Lv, X. Q**. 2017. Analysis of development history and development trend of deep-sea oil drilling equipment. Science and technology innovation and application (18): 108 (in Chinese).
7. **Li, L.; Zhang, B.; Fan, C**.; et al. 2019. Stress analysis and strength test of 2500 fracturing truck frame, 5th International Conference on Mechanical and Aeronautical Engineering (ICMAE). http://dx.doi.org/ 10.1088/1757-899X/751/1/012057.
8. **Wang, X**. 2012. Topology optimization and analysis of sub-frame of 2500HP fracturing truck, 2nd International Conference on Advanced Engineering Materials and Technology (AEMT), p. 3226-3229. http://dx.doi.org/10.4028/www.scie-tific.net/AMR.538-541.3226.
9. **Landelle, A.; Tauveron, N.; Revellin, R**,; et al. 2017. Performance investigation of reciprocating pump running with organic fluid for organic Rankine cycle, Applied Thermal Engineering 113: 962-969. http://dx.doi.org/10.1016/j.applthermaleng.2016.11.096.
10. **Huang, Y. Q.; Nie, S. L.; Ji, H**.; et al. 2017. Development and optimization of a Linear-Motor-Driven water hydraulic piston pump, Transactions of the Canadian Society for Mechanical Engineering, 41(2): 227-248. http://dx.doi.org/ 10.1139/tcsme-2017-1016.
11. **Zhang, R. H.; Cheng, J. R.; Yang, J. H**. 2013. Theory and design of special pumps (in Chinese). http://dx.doi.org/ 978-7-5170-1473-7.
12. **Yang, T**. 2011. Research on power end components of radial reciprocating Pump. Wuhan University of Technology (in Chinese). http://dx.doi.org/ 10.7666/d.D473134.
13. **Huang, Z. Q.; Zhou, X. R.; Yang, Q. M**,; et al. 2000. Study on piston seal pair of fracturing pump, Journal of Southwest Petroleum Institute (03):88-90 (in Chinese). http://dx.doi.org/10.3863/j.issn.1000-2634.2000.03.024.
14. **Hang, W.; Fu, Y. K.; W, J. J**.; et al. 2020. Optimal design of flow field of parallel-plate reactor based on response surface methodology and CFD, Chemical machinery 47(05): 5 94-600 (in Chinese).
15. **Ji, R.; Liu, Y.; Xu, C**.; et al. 2017. Novel method for the hybrid composite electroplating of the upstream pumping mechanical seal, International Journal of Advanced Manufacturing Technology 89(5-8): 1875-1886. http://dx.doi.org/10.1007/s00170-016-9244-6.
16. **Zhu, W. B.; Zhou, X.R.; Cheng, Y**.; et al. 2006. Study on performance and mechanism of reciprocating seal of fracturing pump, Natural Gas Industry (01): 60-62 (in Chinese). http://dx.doi.org/10.3969/j.issn.1673-59X.2007.05.001.
17. **Wu, W**. 2018. Research on sealing performance of packer cartridge based on super viscoelastic characteristics of rubber. Southwest Petroleum University (in Chinese).
18. **Du, J.; Liu, X**. 2017. Sealing failure analysis of drilling mud pump plunger V-seal ring based on FEM, Chinses Journal of Applied Mechanics 34(04): 698-703 (in Chinese). http://dx.doi.org/ 10.11776/cjam.34.04.B062.
19. **Lee, S. P.; Kang, K. W**. 2019. Deformation analysis of rubber seal assembly considering uncertainties in mechanical properties, Journal of Mechanical Science and Technology 33(7): 3345-3353. http://dx.doi.org/10.1007/s12206-019-0629-y.
20. **Fried, I.; Johnson, A. R**. 1988. Nonlinear computation of axisymmetric solid rubber deformation, Computer Methods in Applied Mechanics and Engineering 67(2): 241-253. http://dx.doi.org/10.1016/0045-7825(88)90128-4.
21. **Hu, Y.; Zhang, J.; Chen, L**. 2020. Design and seal performance analysis of bionic sealing ring for dynamic seal, Mechanika 26(4): 338-345. http://dx.doi.org/ 10.5755/j01.mech.26.4.23264.
22. **Zhang J.; Xie J.** 2018. Investigation of static and dynamic seal performances of a rubber O-ring, Journal of Tribology-Transactions of the Asme 140(4).
23. **Xu, X.; Yao, X.; Dong, Y**.; et al. 2021. Mechanical behaviors of non-orthogonal fabric rubber seal, Composite Structures, p. 259. http://dx.doi.org/10.1016/j.compstruct.2020.113453.
24. **Liang, B.; Yang, X.; Wang, Z**.; et al. 2019. Influence of randomness in rubber materials parameters on the reliability of rubber O-ring seal. Materials 12(9). http://dx.doi.org/10.3390/ma12091566.
25. **Wo, L.; Song, W. X.; Zhang, E. Z**. 1990. Seals and seals manual(in Chinese).

M. Du, J. Xi, Y. Liu, Y. Hou, H. Li, X. Yang, Z. Wang, Q. Dai, P. Duan, M. Zhao, S. Jiang

DESIGN OF THREE-STAGE SEALING STRUCTURE AND INVESTIGATION OF SEALING ERFORMANCE FOR 7000 FRACTURING PLUNGER PUMP

S u m m a r y

As a key component of the drilling mud pump, the plunger seal often has problems such as seal failure in reconstruction of low-permeability sandstone reservoirs and the development of unconventional reservoirs, which, in turn, leads to low efficiency of drilling mud pumps and even great potential safety hazard. Based on this, we design a three-stage sealing device at the hydraulic head for the 7000 fracturing plunger pump, and analyzes the sealing performance of the system. The effects of different working loads of the hydraulic head and axial pre-tightening force on the contact force of the seal ring and the stress distribution in the seal ring are explored, and the sealing effect of the three-stage seal of the fracturing plunger pump is confirmed. The results show that the peak stress and the peak contact pressure of the three rubber rings increases with the increasing of the working load of the hydraulic head; the peak stress and the peak contact stress of the three rubber rings during the installation process increase with the increase of the installation pre-tightening force. But the equivalent stress peak and the contact stress peak are directly related the fluid load under the action of the working fluid load; the maximum contact force of the rubber during the sealing process of the system is greater than that of the system working medium under different working fluid pressures. With internal pressure, the three sealing rubber rings can play a sealing role to varying degrees in sequence, and increasing the total life of the sealing body.

Keywords: 7000 fracturing plunger pump, the sealing performance, the seal ring; the contact pressure, working life.

Received April 05, 2022
Accepted January 27, 2023