Research of the driven capacity of pushers with rubber pads for oil equipment

Anatoly Asheichik 1a*, Arkadiy Samsonenko 1b
1Peter the Great St. Petersburg Polytechnic University, Russia
E-mail: aaseichik52@mail.ru, barkadiy.samsonenko@mail.ru

Abstract. The paper discusses the choice of the optimal shape and dimensions of pushers with rubber pads for injection heads intended for pushing cables into an oil well. To optimize the size and shape of the pushers, the finite element method was used. The obtained results were checked experimentally on a specially designed stand. The results of experiments on the evaluation of a number of rubber compositions according to their tribological properties and tractive capacity are presented.

Keywords: cable-pusher, rubber coating, injector head, oil well, finite element method, tribological properties, traction

Introduction

There is a currently important problem of increasing the amount of oil production for majority of functioning oil wells. There are some different technical solutions, but analysis of the oil well’s condition should be performed. In order to perform analysis of oil well’s condition and its probable repair the measuring system is delivered into an oil well by a special cable-pusher [1]. Delivery of a cable-pusher is performed from a special marine vessel, where the supply of a cable (up to 6000 m) and all the controlling system are located. Pushing cables is performed by a mechanical device (injector head).

Aim of this research is to choose the optimal shape and dimensions of pushers with rubber pads for injector heads intended for pushing cables into an oil well by using finite element method (FEM). Optimal constructions of rubber pads that were obtained theoretically were supposed to be checked experimentally against their tribological properties and tractive capability.

Design of an injector head intended for pushing cables into an oil well is shown on Fig. 1. The chain gear is used in this construction [2]. Pushers 2 are hingedly attached to the chain. Movement to the pushers is transmitted by a star gear 3. Clamping pressure is realized by pressure rollers 6. Frictional material 4 is glued onto a surface of pushers’ (pads’) metal surface 5. This material’s friction coefficient with a pushed cable 1 must be as high as possible. Overall dimension in height of an injector head is more than 2 meters. Furthermore, in a critical condition it provides maximum pushing load up to 4 tons, speed of cable’s movement 0,15 m/s. Thus, a friction coefficient in an injector head between cable’s surface and pad’s frictional material must be as high as possible.

Schematic design of a pad is shown on a Fig. 2.

Finding an optimal shape of groove’s profile in rubber is necessary in order to provide maximum pushing load. This shape should provide uniform stress distribution on a rubber’s surface in places of its contact with a cable. As rubber is a material with nonlinear properties, this problem can be solved only with using finite element method (FEM). Software STAR was used for a numerical analysis [3]. Experimental data about nonlinear properties of rubber and friction coefficient changes depending on cable’s surface pressure was also used [4-8].
Results

Finite-element model of cable’s contact with the surface of a rubber pad’s was developed with to using finite element method (FEM) (Fig. 3).

Figure 1  Design of an injector head intended for pushing cables into an oil well
7 mm, 8 mm, 9 mm, 11 mm diameter, and trapezoidal grooves were examined when searching for optimal groove’s diameter for a 9 mm cable. Analysis of stress distribution in a contact area showed that 7 mm, 8 mm, and 9 mm grooves have higher stress concentration factor than an 11 mm groove. Trapezoidal grooves have non-uniform stress distribution. It is also important to note that for 7 mm, 8 mm, and 9 mm diameter grooves there is no possibility of residual oil’s outsqueezing from the contact area along the entire contact with the 9 mm diameter cable.

Figure 2
Construction of a pad (pusher)

Figure 3
Compression of a rubber pad by a cable and stress distribution in a contact area

Model of the cable compressing a rubber pad and stress distribution in a contact area for an 11 mm diameter groove is shown on Fig. 3. Chosen shape of the groove and its dimensions allowed to adjust contact stresses on a contact’s surface and lower highest contact stresses (Fig. 4).
It can be seen that swelling of rubber occurs from Fig. 3. and Fig. 4. This leads to a stress concentration (Fig. 4.) that leads to further fast fracture of an injector head’s pads while in operation. This defect can be eliminated by changing the pads’ shape. For that 3 mm radius recesses should be cut out on a side surface of rubber. Besides that, center of groove in a pad should be moved for 4 mm relatively to the top surface, and groove’s diameter should be increased from 11 mm to 12 mm. Principal deviator’s stress field of a rubber pad for that case is shown of a Fig. 5.
Change of rubber pads’ tractive capability depending on pressing the cable in was studied theoretically (FEM) and checked experimentally using the specially created for that purpose stand (Fig. 6). Base of a stand is a pressure machine with 3 tons of a maximum loading. Pushing cable 1 with a diameter of 9 mm is compressed by two rubber pads 2 between a press’ moving table 4 and press’ slider 3. Clamp’s load \( F_n \) is measured by a ring dynamometer 5. Accuracy of this load is 30 N. Axial load \( F_a \) is measured by a dynamometer 7, which pulls a cable 1 through a clamp 6. Vertical displacement of upper plate is measured by an indicator 9 with an accuracy of 0.01 mm. A cable was moistened with water with marine salt before the experiment.

Rubber pad with a rubber insert and groove of optimal shape is shown on a Fig. 7. Normal load’s change depending on pressing the cable into a rubber pad (displacement) experiment result and data that has been got with a numerical method (a solid line) are shown on a Fig. 8.

Experimental dependence of axial (tractive) load for one pair of pads on normal (radial) load for two types of cables without antifriction coating and with Xylan coating are shown on Fig. 9. Analysis of results shows that from tractive load point of view appearance of antifriction coating requires high normal loading for achieving desired 620 N axial (tractive) load, however, existence of such coating improves life time of rubber seals that are contacting with the cable [9-11].
Figure 6  A stand for experimenting tractive capability of rubber pads

Figure 7  Rubber pad with a rubber insert and groove of optimal shape
Summary

Therefore, FEM calculations allowed to find an optimal shape of a groove and its dimensions that assures uniform distribution of contact stresses along the contact surface of a rubber pad with a cable and achieves minimum stresses within the rubber element. Stand experiments showed that obtained with FEM shape of a pad and its dimensions assure maximum load of pushing the cable into an oil well.
References

[1] Asheichik A.A., Bahrami M.R. Investigation of antifriction feature of graflon under friction in seawater. Procedia Engineering, 2017, Vol. 206, P.642-646.

[2] Bashkarev A.Ya., Zaborsky E.V., Smirnov N.A. Traction chains with polymer coatings. Mashinosstroitel, 1980, No 5, P.3. (rus.)

[3] Golubev I, Naumov A, Michailov V. Developing finite element model of the friction stir welding for temperature calculation. METAL 2014 - 23rd International Conference on Metallurgy and Materials, Conference Proceedings. 2014: 1242-8.

[4] Rudskoy A.I., Tolochko O.V., Kol’tsova TS, Nasibulin AG. Synthesis of carbon nanofibers on the surface of particles of aluminum powder. Metal science and heat treatment. 2014 Jan 1;55(9-10):564-8. DOI: 10.1007/s11041-014-9670-8

[5] Larionova T, Koltsova T, Fadin Y, Tolochko O. Friction and wear of copper–carbon nanofibers compact composites prepared by chemical vapor deposition. Wear. 2014 Nov 15;319(1-2):118-22. DOI: 10.1016/j.wear.2014.07.020

[6] Tsemenko V.N., Tolochko O.V., Kol’tsova T.S., Ganin S.V., Mikhailov V.G. Fabrication, Structure and Properties of a Composite from Aluminum Matrix Reinforced with Carbon Nanofibers. Metal Science and Heat Treatment. 2018 May: 24-31. DOI: 10.1007/s11041-018-0235-0

[7] Nasibulina L.I., Koltsova T.S., Joentakanen T., Nasibulin A.G., Tolochko O.V., Malm J.E., Karppinen M.J., Kauppinen E.I. Direct synthesis of carbon nanofibers on the surface of copper powder. Carbon. 2010 Dec 1;48(15):4559-62. DOI: 10.1016/j.carbon.2010.07.028

[8] Skotnikova M.A., Tsvetkova G.V., Krylov N.A. Tribological properties of nanostructured diffusion layers of metal coatings. Key Engineering Materials. 2017 Jan 1;721: 446-450. DOI: 10.4028/www.scientific.net/KEM.721.446

[9] Breki A.D., Didenko A.L., Kudryavtsev V.V., Vasilyeva E.S., Tolochko O.V., Kolmakov A.G., Gvozdev A.E., Provotorov D.A., Starikov N.E., Fadin Y.A. Synthesis and dry sliding behavior of composite coating with (R–OOO) FT polyimide matrix and tungsten disulfide nanoparticle filler. Inorganic materials: Applied Research. 2017 Jan 1;8(1): 32-6.DOI: 10.1134/S2075113317010063

[10] Makarov E.S., Gvozdev A.E., Zhuravlev G.M., Sergeev A.N., Minaev I.V., Breki A.D., Malii D.V. Application of plasticity theory of dilating media to sealing processes of powders of metallic systems. Chebyshevskii Sbornik. 2017;18(4): 269-85.DOI: 10.22405/2226-8383-2017-4-268-284

[11] Breki AD, Aleksandrov SE, Tyurikov KS, Kolmakov AG, Gvozdev AE, Kalinin AA. Antifriction Properties of Plasma-Chemical Coatings Based on SiO 2 with MoS 2 Nanoparticles under Conditions of Spinning Friction on ShKh15 Steel. Inorganic Materials: Applied Research.2018 Jul 1;9(4): 714-8.DOI: 10.1134/S2075113318040081