DOI 10.18454/PMI.2016.5.651

Oil and gas

UDC 621.6

INVESTIGATION OF POLYMER MATERIAL OF THE WORKING CAMERA-CHANNEL OF THE MAGNETIC PUMPS FOR HEAVY OIL

M.A.VASILYEVA[1], S.VÖTH[2]
[1] *Saint-Petersburg Mining University, Russia*
[2] *Technische Hochschule Georg Agricola, Bochum, Germany*

The article contains results the study of the basic properties of fluorinated polymers used as matrix in the manufacture of magnetically active elastomers (MAE). MAE belong to the group of so-called smart materials, they can be used in the creation of new techniques and technologies. Environments, which is in contact with an element of the MAE, specifically high viscosity asphaltenic oil impose substantial restrictions on the choice of the polymer matrix for its production, taking into consideration the influence of the material selected to modify the rheological properties of the resultant material.

The use of magnetically active materials in the system instead of a roller system, pressing on the tube with the substance, and to push it forward will significantly expand the range of application of such equipment. Additionally, the magnetic treatment reduces the viscosity, the limit shear stress and the activation energy of the viscous flow of oil.

***Key words*:** peristaltic transport, composite materials, magnetoactive elastomer, polymers, oil.

***How to cite this article*:** Vasil'eva M.A., Vöth S. Investigation of polymer material of the working camera-channel of the magnetic pumps for heavy oil. Zapiski Gornogo institute. 2016. Vol.221, p.651-654. DOI 10.18454/PMI.2016.4.651

Introduction. Magnetoactiveelastomers (MAE) comprise an extensive class of materials based on various viscoelastic matrices, including natural and synthetic rubber, silicone, polyurethane, etc., with different volume fractions of the magnetic powder filler inside the matrix. Interactions between the matrix and the filler particles may be of varying strength, and it has an effect on the rheological and mechanical properties of the composite [9].

The combination of the magnetic properties of the filler and the elastic properties of the polymer matrix in magneto-elastics gives rise to a number of unique properties. In particular, mechanical and rheological properties of elastomeric materials containing the magnetizable particles may be reversibly changed under the action of an external magnetic field. The nature of the field dependence of the magnetorheological properties consistsin the existence of the dipole magnetic interaction between the particles and the magnetic moments of the particles with an external magnetic field [6].

Materials and methods. Research has shown that as a polymer matrix for the manufacture of MAE in contact with aggressive high viscosity substances can be used fluororubbers, fluorosilicones [4, 10].

Fluororubbersprepared by emulsion polymerization of vinylidene fluoride and hexafluoropropylene (R = CF3; FKM-26, Viton), VDF with trifluorochloroethylene (R = Cl; FKM-32), VDF with vinyl ether perfluoroethane (R = CF3O; FKM-260).

Rubber mixture (FKM-26, FKM-32) based on fluorine-containing rubbers are far superior hydrocarbon (natural, nitrile, acrylic, etc.) and intended for use in such harsh conditions that hydrocarbon and natural rubber does not stand up.In particular, the fluororubber to be stable in the environment of acids, aliphatic and aromatic chlorinated and non-chlorinated hydrocarbons, oils and greases, oil and gasoline, as well as most solvents except for ketones and esters. Also important advantage of FPM rubber products is an absolute and non-flammability.

Fluororubber is used for the production of a wide range of rubber products for the aerospace, automotive, chemical and engineering industries.

Another material which may be regarded as promising for the preparation on its basis MAE for transporting highly viscous substances are fluorosilicones.

Fluorosilicones (FVMQ) – it is silicone polymers, which, along with dimethyl, methylvinyl silicone containing methyl trifluoropropyl units. As a result, the material in addition to the properties typical of silicone polymers – resistance to high temperatures, oxidation and solar radiation, resistance to acid and alkaline solutions, good electrical insulation properties, and many others, gets more oil resistance and resistance to aggressive media – the properties characteristic of fluoropolymers polymers, such as Viton and FKM.During this frost fluorosilicone, unlike fluoroelastomers reaches minus 60 °C.

DOI 10.18454/PMI.2016.5.651

For the research as a polymer matrix for the manufacture of MAE were used FPM fluorosilicones of different brands that are used in industry. Samples were prepared by incorporating a magnetic powder Nb-Fe-B in the same proportion for all polymers. Mixing of the material to evenly distribute the filler material is carried out using a centrifuge. Tests were conducted on the chemical stability in aggressive environment at a temperature of 125 ° C for 72 hours for all the samples, and tensile test and thermal resistance (Table 1, 2).

Table 1

Physical and mechanical properties of FPM

Indicatorname	Value for rubber brands	
	FKM-26	FKM-32
Tensilestrength, MN/m^2	16-27	16-27
Elongation at break, %	250-500	120-200
Shore hardness	71	65
The upper temperature limit long-term operation, °C	250	200
The lower limit temperature continuous operation, °C	−25	−30
Mass loss, %, no more than	0.15	0.2
Mooney viscosity, cu	70-95	80-105

Table 2

Physical and mechanical properties of silicone rubber

Indicatorname	Value for rubber brands		
	FVMQ-55	FVMQ-70M	FVMQ-80M
Shore hardness	55+5	70±5	80±5
Condition Tensile, [MPa], within the	6-12	6-12	7-10
Elongation at break, not less then	300	200	100
The lower limit temperature continuous operation, °C	−60	−60	−60
Resistance to thermal aging (air, 150 °C, 72 h):			
the change of hardness, Shore hardness	0-3	0-2	0-1
change Tensile strength, %, not less then	0	0	0
change in elongation	0	0	0
Density, g/sm^3	1.19-1.23	1.41-1.45	1.46-1.53

Analysis. Different options have been proposed designs pumps that allow to transport highly concentrated and highly viscous substances [5, 8]. Their work is based on the change in the wave of internal cross-section of the working chamber by an external control signal. Observations of the peristaltic units convince us that the movement of substances in them due to the formation of waves of deformation at one end of the elongated flexible tube and moving them along it, i.e. as a running process of local deformation. The concept of "running wave of deformation" helps to explain the motion of viscous fluids and mixtures in flexible pipes whose walls are exposed to the wave deformation [7].

MAE is a promising material for the manufacture of the operating chamber of pumping units. This element is a drive to implement the peristaltic movements in the transportation of highly viscous and highly condensed substances. Unlike conventional elastomers also possess elastomeric properties, MAE, when used as a peristaltic pump operating chamber, do not require moving mechanical parts in the construction of the pump unit. Reduction of the operatingchamber, and as a result, the movement of portions of the transported substances caused by running magnetic field.

Environment with which contact element from MAE impose significant restrictions on the choice of polymer matrix for its manufacture. Thus it is necessary to take into account the effect of the selected material to change the rheological properties of the resulting material [3, 11].

To solve problems related to pumping high-viscosity fluids and highly condensed substances in various countries around the world are increasingly used peristaltic pumps [2].

Heavy oil and petroleum products are aggressive environments, so the material of the polymer matrix should be resistant to mineral acids, aliphatic and aromatic hydrocarbons, petrol, oil and grease. This addition is necessary to take into account the fact that in some parts of the production and transportation of used heat treatment oils.

DOI 10.18454/PMI.2016.5.651

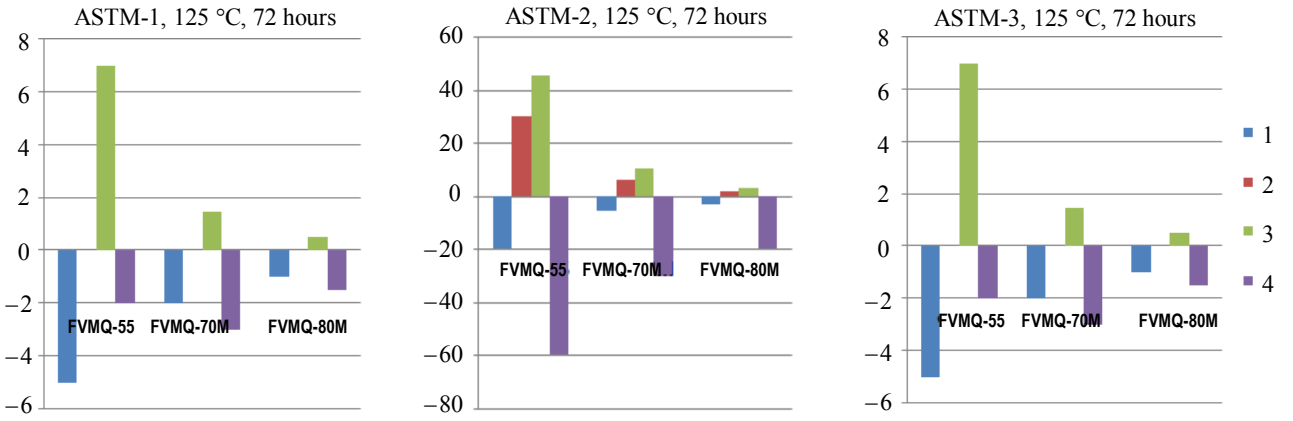


Fig.1. Resistance rubber in a relaxed state to liquid aggressive environments
1 – the change of hardness, shore a units; 2 – alteration in the mass, %; 3 – volume change, %; 4 – change the conditional tensile strength, %

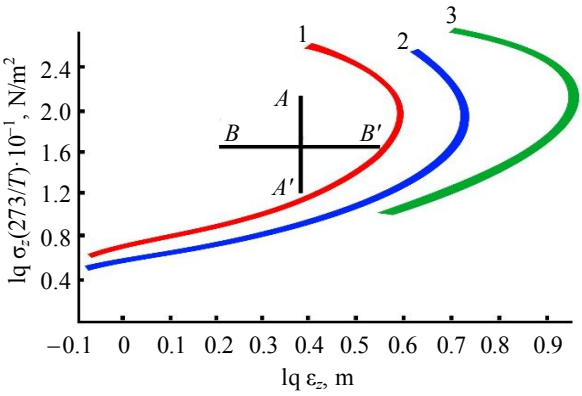


Fig.2. "The envelope breaks" given to $T = 0$ °C for the unfilled elastomers based on a variety of rubbers
1 – fluororubber; 2 – butylrubber; 3 – natural rubber;
A – the initial value σ, corresponding to a given value ε_z = const; AA' – relaxation time; B – the initial value of the deformation ε, corresponding to the specified value σ_z = const; BB' – delay time (0.1 MN/m^2)

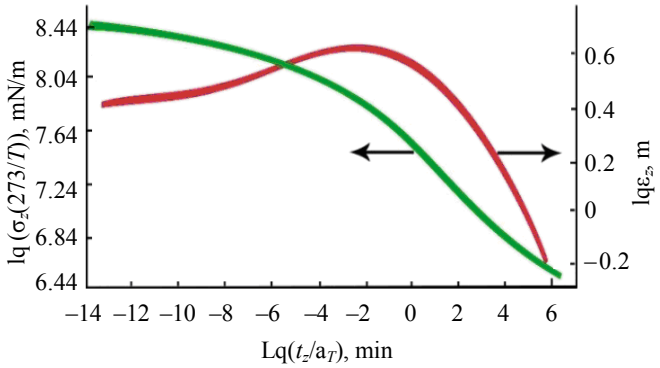


Fig.3. Dependencies reduced to $T = 0$ °C durability t_z/a_T from stress σ_z and deformation ε_z for FPM

The research results ability of the polymer to maintain strength and plastic properties after swelling in aggressive liquids in a relaxed state to change one or more physical and mechanical properties are displayed in Fig.1.

Results and Discussion. The most important feature of the strength properties of the polymer matrix magnetically elastomer – dependence on strain relaxation properties [1]. The method of the above variables on the basis of a series of tests at different temperatures and mechanical loading conditions can be generalized to obtain the relation between tensile strength (durability at a stretching) σ_z elongation at break ε_z for a selected temperature as curves "envelope breaks" (Fig.2). Counterclockwise motion corresponds to an increase or decrease in the rate of deformation temperature.

After reaching stress indicated by the point A', the ratio of stress and strain will comply with the limit values σ_z and ε_z, located on the "the envelope breaks" 1, corresponding "the envelope breaks" 1, i.e., failure occurs. Time t_z determines the durability of the sample of fluororubber in these conditions and is responsible relaxation time. By varying the temperature and time parameters, which can be recorded as the present value of longevity t_z/a_T (a_T–reduction factor), alter the ratio of discontinuous stress σ_z and strain ε_z. Thus, the strength characteristics are discussed in three-dimensional space these values $\sigma_z(T_{np}/T) - \varepsilon_T - t_z/a_T$.

Fig.3 shows the projection of the "envelope breaks" the plane $\sigma_z(273/T) - t_z/a_T$ and $\varepsilon_T - t_z/a_T$. In isothermal mode DC voltage curves of "given voltage" $\sigma_z(273/T)$ – "given time" t_z/a_T obtained experimental "laws of longevity" (the destruction time) $t = t_z/a_T = t_{пр}$ a function of stress. In the transition zone from the glassy state to a rubbery dependence satisfies the theoretical calculations (law Zhurkov – Busse):

DOI 10.18454/PMI.2016.5.651

$$t = B\exp\left(\frac{U_0 - \gamma\sigma}{kT}\right);$$

in the law of the plateau (highly elastic state) – a power law of Bartenev:

$$t = C\sigma - b\exp\left(\frac{U}{kT}\right),$$

where B, γ, C, b – constants; k – Boltzmann constant; U – "activation energy" ofthedestruction, equal 41,9-54,6 kJ/mol (10-13 kcal/mol); U_0 – true "activation energy" ofthedestruction of solid polymer, equal to the energy chemical bond rupture in the main chain of the macromolecule.

For polymers used in oil production equipment must have resistance to swelling in hydrocarbon oil, and the water contained in the reservoir fluid. When selecting polymers must be considered that resistance to swelling in oil products in a series of butadiene-nitrile rubber SKN-18 and SKN-26 and SKN-40 increases and decreases in hot water, respectively, reaching values of 3-5, 10-13 and 50-70%. When the equipment is operated at higher temperatures of 200 to 330 C is necessary to use polymers based on fluororubber SCF 26 or fluorosilicone rubber SKTFT-50, SKTFT 100. Research results rubbers ability to maintain strength and elastic properties after swelling in corrosive liquids in a relaxed state to change one or more of the physical and mechanical properties are displayed in Figure 3.

Conclusions. Researches of the basic properties, which should have a material used as a polymer matrix in the manufacture of the MAE for use it as a structural element of the peristaltic pump unit for transporting highly viscous and highly condensed substances, such as heavy oil asphaltene.

On the basis of the research the following conclusions:

• MAE is a promising material for realizing the peristaltic movements in the transportation of highly viscous and highly condensed substances.

• as polymer matrix for the manufacture of MAE in contact with aggressive high viscosity substances can be used fluorine-containing polymers.

Acknowledgments. *Fundingsources thatsupported theresearch: Russian Foundation for Basic Research, grant number 16-38-00169.*

REFERENCES

1. *Bonaldi F., Geymonat G., Krasucki F.* Modeling of smart materials with thermal effects: Dynamic and quasi-static evolution. Mathematical models & methods in applied sciences. 2015. N 25, p.2633-2667.

2. *Detsi E., Tolbert S., Punzhin S.* and all. Metallic muscles and beyond: nanofoams at work. Journal of materials science.2016. N 51, p.615-634.

3. *Iannotti V., Ausanio G., Lanotte L.* and all. Magneto-piezoresistivity in iron particle-filled silicone: An alternative outlook for reading magnetic field intensity and direction. 2016. N 10, p.65-71.

4. *Kaiser A., Winkler M., Krause S.* and all. Magnetoactive liquid crystal elastomer nanocomposites. Journal of materials chemistry. 2009. N 19, p.538-543.

5. *Nilsen F., Aaltio I., Ge Y.*, and all. Properties of the pulsed electric current sintered Ni-Mn-Ga-Co-WC composites. Journal of alloys and compounds. 2016. N 656, p.408-415.

6. *Niu C., Dong X., Qi M.* Enhanced Electrorheological Properties of Elastomers Containing TiO2/Urea Core-Shell Particles. ACS Applied Materials & Interfaces. 2015. N 7, p.24855-24863.

7. *Paul H. Ratz.* Mechanics of Vascular Smooth Muscle. Comprehensive physiology.2016. N 6, p.111-168.

8. *Seoane Rivero R., Bilbao Solaguren P., Gondra Zubieta K.* and all. Synthesis, kinetics of photo-dimerization/photocleavage and physical properties of coumarin-containing branched polyurethanes based on polycaprolactones. Express polymer letters. 2016. N 10, p.84-95.

9. *Sorokin V., Stepanov G., Shamonin M.* and all. Hysteresis of the viscoelastic properties and the normal force in magnetically and mechanically soft magnetoactive elastomers: Effects of filler composition, strain amplitude and magnetic field. Polymer.2015. N 76, p.191-202.

10. *Yoonessi M., Peck J., Bail J.* and all. Transparent Large-Strain Thermoplastic Polyurethane Magnetoactive Nanocomposites. ACS Applied Materials & Interfaces. 2011. N 3, p.2686-2693.

11. *Zewan Qi, Qi You, Yang Chen.* Nucleotide/Tb(3+) coordination polymer nanoparticles as luminescent sensor and scavenger for nitrite ion. Analytica chimica acta. 2016. N 902, p.168-73.

***Authors*: M.A.Vasilyeva,** *PhD in Engineering Sciences, Associate Professor, saturn.sun@mail.ru* (*Saint-Petersburg Mining University, Russia*), **S.Vöth,** *Dr.-Ing., Professor, Head of Center for Drive and Hoisting Technology* (*Technische Hochschule Georg Agricola, Bochum, Germany*).

The paper was accepted for publication on 20 April, 2016.