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ХІМІЧНЕ МАТЕРІАЛОЗНАВСТВО

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Problem of Selection of Lubricants for ethelene High-Pressure Compressors.

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Technology of obtaining and properties of ethylene compositions with different content of oils inside is researched. It is shown viscous-mechanical properties of polyethylene during addition of different quantity of lubricants. The results of researches of physics-mechanics and dielectric properties of polyethylene, synthesized during ingress of naphtene, with addition of 0,15% of different oils and thermooxidants.

Key words: polyethylene, oils, composition, polyglycol, dielectrical properties, thermooxidants, compressors.

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Проблема вибору та властивостей мастильних матеріалів для етеленових компресорів надвисокого тиску.

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Досліджено технологію отримання та властивості етиленових композицій з різним вмістом мастил всередині. Показано в'язко-механічні властивості поліетилену при додаванні різної кількості мастильних матеріалів. Приведені результати досліджень фізико-механічних та діелектричних властивостей поліетилену, що синтезований при надходженні нафтенового масла, з додаванням 0,15% різних мастил та термооксидантів.

Ключові слова: поліетилен, мастила, композиції, полігліколі, діелектричні властивості, термооксиданти, компресори

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1. Statement of a question of Selection of Lubricants for ethelene High-Pressure Compressors.

Introduction

Maty investigations are known that apply to the question of solving the problem of lubricants selection for ethylene high-pressure compressors [1-8].

About 60 % of high-pressure polyethylene is used for making products by the method of moulding and pressurizaticn-containers for food industry, products of domestic chemistry and childrens toys, 20 % - for making special films, which are stable to thermo and photooxidation, films of capacitors and cable isolation with the heightened demands to the thermal aging and dielectric properties.

One of the most important problems of the making is selection the high quality oil for lubrication gaskets of cylinders or shafts of ethylene compressor. Delivering of fluid lubricant to the friction pair is realized either by injection it into the gas (phase of the suction- when using gaskets with the pistons rings) or by feeding it through the openings of gaskets element drilling (when glad gaskets are used) [2-9].

According to [9], in compressors at the compression up to 22-40 MPa specific loadings of the gasket's elements reaches 7-10 MPa. In ethylene compressors gas compresses from 25 up to 1 10-120 MPa on the first degree and from 110-120 MPa up to 180-250 (and even to 350) MPa on the second degree. There fore, gasket elements of compressors experience during lubrication influence of the limit specific loadings from the hydrodynamic to limit regime and even to seizure. In ethylene compressors friction pair are used:

- the plunger made from the nitrided steel 38 XMKDA or with coating of Wolfram carbide ; gasket elements made from the bronze Bp OCH 7-13-1;
- the bush of the cylinder made from the carbide of Wolfram (type BK-6), gasket rings made from the special alloyed cast iron or made from the bronze Bp OO 10-1.

The demands to wear resistance of surfaces are: intensity of wearing counterface from alloy BK-6 is ought to be not higher than 0,02 rnkm/hour or 0,05 mm for 2500 hours of compressors work.

Pressure of pumping is 200-300 MPa, temperature of gas at the end of process reaches 373K, average velocity of piston - up to 2,5 m/s. Consumption of the oil for 1 t final product - polyethylene for different compressors is from 0,7-0,9 to 4,7-6,5 kg.

Properties and nature of oils determine quality indicators of polyethylene and reliability of work of seal pistons and plungers of ethylene compressors. For lubrication of friction pair of these compressors mineral (naphthene - «white» oils), polybutene and polyglycol oils are used [2; 3].

Materials

Specifications to oils are: transparence, colourlessness, absence of sediment and mechanic impurities, viscosity (not less than) ~ 450 cs at 293K, 200 cs at 323K, 50cs at 373K; flash temperature must be higher than 293K from the maximal allowable (373-383 K), but better not lower than 473K; temperature of solidification - not higher than 273K; acid number -not more than 0,4 mg KOH/g; alkali number 0 mg KOH/g; content of moisture not more than 0,1 %; ashes -0 %; point of turbidity of 1 % solution -not more than 353K [15- 19].

According to manufacturers naphtene and polyglycol oils for the most quantity indicators satisfy these requirements. (Tabl. 1) [16-19].

Physic-and-chetnical properties and quantity of oil which ingresses in polyethylene determine its properties and use for cable isolation, products, which contact with food etc [16- 19].

Methods of testing

Content of oil appreciably has an influence on such quality indicators as resistance to thermal aging and cracking and photooxidation processes, tangent of angle of dielectrical loss, dielectrical penetrability, breakdown electrical stress, sanitarian-hygienical properties. Content of oil in polyethylene is estimated by IR-spectroscopy (graduated by solution in $CC1_4$), tangent of angle of dielectric loss (frequency 10^3, 10^4, 10^6 hertz), dielectric penetrability (frequency 10^6 hertz). And also indexes of flow of plastics (g in 10 min.), changes of bound of strength and flow during tension, relative extension during breakage are found [10-15].

STATE STANDARD 16337-77 (for polyethylene) and STATE STANDARD 16336-77 (for compositions of polyethylene) determine demands to physic-and-chemical properties of polyethylene. Dielectrical properties of polyethylene and its composition are determined by:

- tangent of angle of dielectrical loss- STATE STANDARD 22372-77;
- electrical strength at variable voltage (frequency 50 hertz) – TATESTANDARD 64333-71;
- dielectrical penetrability (frequency 10^5 hertz) – STATE STANDARD 22372-71;
- resistance to thermal aging – STATE STANDARD 16336-77.

Block-effect (sticking of films together) and content of extraction substances which an; in initial polyethylene and which educe from it during secondary processing relate to quality indicators of polyethylene too. Content of these substances is estimated by excess of organic substance during lubrication of ethylene compressors with mineral oil and by using light mineral oils as solvents during peroxidative initiation of polymerization of ethylene.

Feasibility study of supplying of lubrication of seal elements relates not only to quality of polyethylene but to time wasted of compressor's equipment for repair (up to 2-7 days a year), which for high productivity producers (synthesis of polyethylene) turns as substantial economical losses. More over it is necessary to add that after every seal replacement necessity (100-300 hours) of feeding through lubricators excess of oil (for runningin of friction pair) comes into existence. Polyethylene made in this period contents of substantial quantity of oil that is not up to the requirements (for cable isolation) [10-19].

Results and discussion

Aim of work: consists in scientific search of lubricants for lubrication seal elements of ethylenes high-pressure compressors, which are compatible with polyethylene. Tasks:

1. Studying of viscous-and-thermal properties of naphtene and polyglycol oils and selecting characteristics that the most complete characterize these properties.
2. Studying of antifriction properties of naphtene and polyglycol oils and finding indices, which the most complete characterize, these properties.
3. Studying of oils compatibility with polyethylene on the grounds of changes of physic-mechanical, rheological and dielectric properties of composition [4-7].

Solubility of fuel oil in ethylene

Initial gas during production of polyethylene is dry polyethylene (99,0-99,9 %), the rest- impurities (propylene, ethane, methane, hydrogen, nitrogen and others non-aggressive gases). Content of 0-_t is strictly controlled; even signs of it provoke polymerization of ethylene before reactor.

When finding the solution of lubricating of ethylene compressors it is important to take to account that temperature raising of gas leads to increasing of oils solubility in ethylene, but minimum of solubility displaces in side of higher pressure [10-12]. By mounting to high lubricating ability it is possible to bring down temperature in contact zone where maximum solubility of oil in ethylene is seen.

Besides that, according to [2; 10; 12; 13] in general case increasing of molecular mass of oils leads to increasing of pressure intervaf where minimum of solubility is seen. Increasing of the molecular mass for the one homological row of hydrocarbons leads to decreasing of its solubility in ethylene. Hence, it is necessary to aspire to use oils with enough large molecular mass and viscosity.

It is known that isomers have better solubility in gases than substances with normal structure and mutual solubility of fuels and gases increases with approaching of theirs physic and chemical properties. Thus oils with ethylene or others hydrocarbon chains have better solubility in ethylene.

Maximum solubility of oil in ethylene (at temperature up to 323-373 K and pressure up to 200-300 MPa) is sufficiently substantial and is, depending on nature of oil, from 300 to 3000 g/mm^3 of ethylene (recalculation on normal physic conditions), which is from 0,25 to 2,5 kg on 1l of compressed ethylene [10; 12; 14].

Increased mutual solubility of gas and oil (vaseline, naphtene, polybutene) will decrease operational properties of oils and lead to little term of capacity for work of seals.

Proceed from this information for lubricating of ethylene compressors it is necessary to use oils with big molecular mass and normal structure only then effect of raising antifriction properties because of increasing of viscosity will be reached.

Table 1

Characteristic of properties of naphtene and polyglicol oils (information of producers)

Index	Rieslla-33	NKM-40	NKM-70	Laprol 2502-2-70	Orites-270 DS
Density,kg/m^3 at 293 K at 303 K	 884 878	 873 867	 884 878	 1078	 1080
Coefficient of refraction of light (293 K)	1,4820	1,4794	1,4800	-	-
Viscosity kinematic, cs at 293 K at 303 K at 373 K	 126 42,4 8,8	 80,2 39,3 9,8	 180 70,4 12,8	 417 182 54	 462 186 46,8
Acid number, mg KOH/g	0,007	0,006	0,006	0,019	0,016
Temperature of solidification, K	255	255	260	-	≤270
Temperature, K in closer crucible in open crucible	 475 494	 470 488	 478 498	 489 523	 493 523
Content of water, %	0	0	0	0,1	0,1
Content of mechanic impurities, %	0	0	0	0	0

Limitation of lubricating and expenditure of oils

One of ways of finding solutions of economy of fuel-lubricating substances and lowering quantity of oil which ingresses in ethylene is limitation of expenditure of oil during friction and wear of adjoining surfaces. Industrial experiment on finding optimum expenditure of oils Orites-270 DS, Risella-33 and Laprol-2502 was realized on ethylene compressors of plants of firms ICI with auto-clave and «Polymir» with tubular reactor [1; 2]. These plants were differing by construction and productivity of ethylene compressors: productivity of plant «Polymir» four times higher than productivity of ICI plant.

Change of oil Risella-33 to polyglycol oil Laprol-2502 and lowering its supply from 4,8 to 0,8 kg/hour on II cascade compressors (plant of ICI firm) lead to decreasing (two time) of term of capacity for work of seal elements from bronze, content of oil in polyethylene was about 0,05% and polyethylene by resistance to thermal aging, influence of oxygen, sanitarian-hygienical, dielectrical and antiblocking properties was close to STATE STANDARD 16337-77. In that case when content of polyglycol oil Orites-270 DS in polyethylene was 0,02-0,04 % commodity polyethylene was up to the requirements of STATE STANDARD and world standards [1].

When feeding of polyglzcol oils Orites-270 DS and Laprol-2502 on compressors of II cascade (plant «Polimir») was lowered from 41,5 to 14 kg/hour accordingly content of oil in polyethylene increased three-four times and was 0,09-0,15 % and 0,06-0,08 % accordingly for Orites-27- DS and 0,10-0,12 % for oil Laprol-2502 к but this did not solve problem of obtain polyethylene for cable isolation (content of polyglicol oils in polyethylem; up to 0,02-0,04 %)/ Productivity of plant increased by 2,6 times and term of capacity for work of seal element form bronze decreased by piston rings of I degree compressors (before experiment 6 months) and 6-8 months by stuffing-box seals of II degree compressors (before experiment 12 months) [1-6].

Thus use of naphtene oils leads to lowering of coefficient of ethylene compressors and use of polyglicol oil - quality indexes of polyethylene.

Trends in finding solution of lubricating of ethylene compressors are:

- decreasing of quantity of polyglicol oil which ingresses into polyethylene;
- increasing of viscosity and loading ability and improvement of viscous-and-thermal characteristics of naphtene and polyglicol oils;
- replacement of seal elements riiade from bronze on high-quality durable polymeric materials (type of graphelon) [1,5-18].

In spite of constructive works on lowering of contaminations of oils in ethylene and accordingly lowering its content in polyethylene, work on creation of new synthetic lubricants and lubricating compositions which could provide increasing of reliability and term of service of seals of II cascade compressors and which do not have negative influence on properties of polyethylene, especially for cable isolation is still actual.

Proceeded from this information, for lubrication of ethylene compressors is necessary to use oils with big molecular mass and normal structure, only then effect of raising of antifriction properties because of viscosity increasing could be reached.

Using of oils in industries

In industry producers use naphtene oils which are made practically by one technology and which have similar physic-mechanic properties and which are different by trademark of firms-producers: Risella-33 (Shell, ELF Aquitaine- France), Vitorex-334, Esso-Christo, 5350 (Mitsui, Japan), KPL-201 (British. Petroleum, Great Britain, Austrian branch- Technol, and Holland branch), NKM-40 (NPZ, Russia) etc (Tabl. 2). To synthetic oils show preference all key compressors firms: «Burckadt» (Switzeland), «Esslingen» (Germany), «Hitachi» (Japan), «Dresser-Clark» (USA), «Nuovo-Pignone» (Italy), «Ingersoll-Rand», «Technocompressormash» of concern «Ukrrosmets 1» (Ukraine), fabrics named after Frunse (Ukraine) and «Borets» (Russia) etc [5-6].

However, naphtene oils when ingressing into polyethylene do not lower quality indexes of polyethylene have shortcomings:

- substantial solubility of ethylene in oil and as a result substantial lowering of viscosity and others hydrodynamic properties force to feed for lubrication substantial quantity of oil;
- substantial solubility of oil in ethylene which leads to substantial ingress of oil into ethylene and as a result increasing of extracting substances and "smoking" of mass during processing of polyethylene into products and to scale formation on piston's surfaces;
- low loading ability which force to limit of ethylene plants little and medium productivity (term of seal service 1000-4000 hours).

With the object of viscosity increasing naphtene oils have lowmoleeular polyisobutylene and polybutene Polyvis (firm Cosden Petroleum Co.) with the molecular mass from 400 to 1500 [15-19]. Producers use as well highmolecular polyisobutylene [1; 2], methyl ether of methacrylic or acrylic acids [14], polyvynilbutyl ether [15]. Polyisobutylenes are more stable and do not polymerize under action of heat and pressure. Here wide diapason of viscosity change opens.

For increase of viscosity into naphtene oils Shella-Onclina-33 and Vitorex-334 0,7-0,8 % wax O-Vax is given.

However, feeding into mineral oils thickens in big quantity as a rule changes course of curve of viscosity dependence from pressure, which acquires more steep character at low temperatures. This can lead to corking of feeding lines of lubricants to cylinder seals and deteriorate lubricating conditions of friction surfaces. For removal this effects in practice use additional heating of oil in tanks and feeding lines of lubricators, and some times high-pressure pipes.

For lubricating of ethylene compressors producers use as well pure polybutene oils Oritex L 100 (firm ELF Aquitaine), polybutene oil (firm Witco and Houfix 200), white oil BP Olex WM2631, thicken by complex additive: for increase of viscosity-polyisobutylene, inhibitor of oxidation - 0,1 % solution of phenol compound, for increasing of antiwear properties - 0,1 % ether compound.

Firm Burkhadt for high productivity compressors uses pure polybutene oils Polybutene-8, Polybutene-12 (Chevron), Indopol L100 (Amoco-Fina firm) or their mixtures with naphtene oils (lubricant Sonne bom-1200-Witco Chemical Sonnebom firm- analogue Orites L66) [2].

Firms Ingersoll-Rand (USA), Dresser-Clark (USA), Burkhadt (Switzerland), Nuovo-Pignone (Italy), Esslingen (Deutschland), Hitachi (Japan) (when pressure of ethylene is up to 350 MPa) use thickening oils CL 1000 PH LA 3, CL 1200 PH LA 3, CL 1500 PH LA 3 (Witco firm, USA, Holland's branch).

At positive compatibility of naphtene, polybutene and thickening white oils with polyethylene theirs maximum limiting content in polyethylene -0,1 % normalizes.

Increasing of individual capacity of plants for synthesis of polyethylene lead to transition to synthetic :i oils. For large technological lines was required equipment, which guarantee high coefficient of using working times. One of the essential factors directed to this increasing was using synthetic lubricants with high antiwear and antiseizure properties.

These oils are:

- lowmoleeular Orites-88 (ELF, France);
- highmolecular Orites-27Q. DS (ELF, France) with ratio of ethylene and propylene oxides 72,8:27,2 (analogue of this oil Laprol 2502-2-70);
- BreoxCL 1300, BreoxCL 1400, BreoxCL 660 without additive and with additive Breox PC 1314, Breox PC 1315, Breox PC 1316 (British Petroleum Co.);
- Syntheso D 201, Syntheso D 201 N (with additive), Syntheso D 202 (Bochaco, Kliiber, Duetschland); lowviscous Ucon 75 H1400, Ucon PE-159 and highviscous Ucon PE-320, Ucon PE-350 (Union Carbide, USA);
- EXD 62/152H, EHD62/152 H with ratio of ethylene and propylene oxides 48:52 (Mobiol-Oil, USA);
- highviscous Polyol LG-56.

Polyglycol oils in comparing with naphtene have advantages:

- low solubility in ethylene and at saturation by ethylene viscosity, antiseizure and antiwear properties do not change;
- have high adhesion and adsorption properties to surfaces of metals, moisten theirs surfaces well, form on them durable bounding layers, which determines theirs high antiseizure and antiwear properties;
- change viscosity not much (when pressure increases); when pressure is high change viscosity not thus much that canal for feeding of oil in cylinders and pipes become corked;
- have high viscosity and declivity viscous-and thermal characteristic.

More over, according to firm Esslingen term of work of seal elements during lubrication with polyglycol oils 3-5 times bigger and increases from 1000-4000 hours for naphtene and polybutene oils to 5000-15000 for polyglycol oils, According to firm ELF expenditure for It of polyethylene during transition from lubricating with naphtene oils to lubricating with polyglycol Orites 270 DS decreased from 3-4 to.) ke/t.

At the same time from 0,02 to 0,15 % of oil ingress into polyethylene, which decreases durability of polyethylene to thermal aging and photooxidation processes, sanitarian-hygienical indexes and electroisolation properties.

Investigation of antifriction properties of naphtene and polyglycol oils during little loading with lubrication of pair bronze-WK-6 (WK-11) and graphelon-20-WK-6 (WK-11) [11-19].

Wearing of bronze (firm «Rranz»), Beryllium bronze Bp BHT-2,5-1-68, Tina-Stannum bronze Bp OC 12,2, Tina-phosphorous bronze Bp OO-10-land composition material on the base of aromatic polyamide phenilon C-2+20 % of graphite fiber from hydrocellulose (viscose) graphelon-20 was investigated on three-pin-disk friction machine.

Samples were made in shape of three fingers with diameter 6 mm and height 15 mm (last sphere 6,35 mm). Counterfaces were made by method of pressing and annealing of metal-ceramic bronze (wolfram group BK-6 and BK-11) as inserts with d_e = 45,0 mm, $d,$ = 25,0 mm and thickness 15 mm (HB 8200-8400 MPa; Ra_0 - *0,04 - 0,06* mkm). Normal loading on one specimen JV) = 67 N, velocity of sliding 1,3 m/s, time of investigation 4 hours (friction track 16,14 km), temperature 591 ± 275 K. Lubricant - polyglycols Laprol 2502-2-70, Laprol 2002 and naphtene oil Risella-33 [11-19].

Intensity of wearing was calculated by diameter of wear spot (wear capacity):

$$J = \frac{V}{N, S_{mm^3 N-m}} \quad (1)$$

where V – average volume of wear capacity on one sample [mm^3]; N - normal loading on one sample; S - wear track [m].

Results of the wear intensity J = (0,21-2,4)-10^s mm^J /N-m (Tabl. 3) were calculated by diameters of wear spot d_w = 0,754-1,461mm by which it is possible to estimate the limit of specific loading at the end of friction: 150-40 mPa.

As we can see from the Tabl.3, during little loadings (TV = 67 N) and relatively high sliding velocity (& = 1,3 м/s) for pair «bronze - BK-11» and «bronze - BK-6» preferences of polyglycol (statistic polymer of propylene and ethylene oxides Laprol-2502-2-70 and linear polypropyleneglycol Laprol 2002) oils to naphtene oil Risella-33 are not seen and on the contrary, for pair «graphelon-20-BK-H» and «graphelon-20-BK-6 polyglycols are more effective than naphtene oil.

Except samples of bronze (firm «Kranz») and Бр ОФ 10-1, for which intensity of wearing in friction on BK-11 during lubrication with polyglycols 1,09-1,55 time larger than on BK-6, for the rest of samples made frombronz.3 (Бр ОС 12-2andBpBbIT 2,5-1 -68) wearing on BK-6 1,02-1,48time bigger than onBK-11.

In general: wearing of samples made from bronze during lubrication with polyglycol oils 1,31-5,86 time

Table 2

Trademarks and producgrs of oils for ethylene compressors

Type	Trademark	Firm	Country
Mineral (naphtene)	Risella-33 (Shell-Ondina33)	ELF Aquitaine	France
	Risella-17	Mitsui	Japan
	Vitprex-334	Mitsui	Japan
	Esso-Christo 5350	Mitsui	Japan
	type Risella-33 Codex H23	Codex	Great Britain
	KPL-201	British Petroleum (austr. branch) (TECHNOOL)	(austr. branch)
	Sonnebom-1200	Witco Chemical Sonnebom	USA
	NKM-40	Moscow	Russia
	NKM-70	Moscow	Russia
	NKM-40	Jaroslav	Russia
	NKM-200	Jaroslav	Russia
Polybutene	Orites-270 MS	ELF Aquitaine	France
	(Orites-L 100)	Amoco-Fina	Finland
	Polybuthene-8	Amoco-Fina	Finland
	Chevron (Polybuthene-12)	Amoco-Fina	Finland
	IndopolL-100	Amoco-Fina	Finland
	Houfix-200	Amoco-Fina	Finland
	Polybutene for sucevnimide additives M=860	Amoco-Fina	Finland
	Polybutene Tredkat-99 M=460	Amoco-Fina	Finland
Mixture of polybutene and naphtene oils	Orites-125 MS	ELF Aquitaine	France
	Orites-L 100	Witco Chemical Sonnebom	USA (holland's branch)
	CL 1000 PHLA3		
	CL1200PHLA3		
	CL1500FHLA3		
	Witco CL-1000		
	Witco CL-1200		
	Witco CL-1500		
Polyglycol	Orites-125 DS	ELF Aquitaine	France
	Orites- 88 DS	ELF Aquitaine	France
	Orites-270 DS	ELF Aquitaine	France
	Orites-210 DS	«Dolymersyntes»	Russia
	Laprol 202	(Volodymyr)	Russia
	Laprol 602	(Volodymyr)	Russia
	Laprol 1002	(Volodymyr)	Russia
	Laprol 2002	(Volodymyr)	Russia
	Laprol 3002	(Volodymyr)	Russia
	Laprol 503	(Volodymyr)	Russia
	Laprol 3003	(Volodymyr)	Russia
	Laprol 3503-B 6	«Polymersynte»	Russia
	Laprol 5003-2-B 10	(Volodymyr)	Russia
	Laprol 5003-2-B12	(Volodymyr)	Russia
	Laprol 6500-2-B 18	(Volodymyr)	Russia
	Laprol 1601-4/2-50	Kliiber	Duetschland
	Laprol 1502-2-70	Kliiber	Duetschland
	Laprol 2502-2-70	Union Carbide	USA (austr. brc.nch)
	Laprol 4002-2-70	IPChl Baku	Azerbaijan

Continuation of Table 2

Trademarks and producgrs of oils for ethylene compressors

Type	Trademark	Firm	Country
Polyglycol	Ucon 50 HB 660 Poly-a-olephine EHD-62/152H Polyol LG 56	Mobil-oil Mobil-oil Mobil-oil Mobil-oil	USA USA USA USA
Polyglycol with additives	Breox CL 660 BreoxCL 1300 BreoxCL 1314 BreoxCL 1400 Breox PC 13150 Breox PC 1316 SynthesoD201 N Ucon PE-150 Ucon PE-350 Poly-oolephine, thickened with 4 % of polymer SKEP	British Petroleum British Petroleum British Petroleum British Petroleum Kliiber Union Carbide Union Carbide IPChl Baku IPChl Baku	Great Britain Great Britain Great Britain Great Britain Deutschland USA (austr. branch) Azerbaijan

during friction on BK-11 and 1,11-4,84 time during friction on BK-6 bigger than with naphtene oil.

For the future it is necessary to estimate the antiwear and antiseizure properties of oils by the results of investigations on the four-ball-friction machine [5-10] in the contact of working bodies of which the specific loadings 1350-7500 MPa can be reached.

Conclusions

Analysis of results shows that for lubrication of ethylene compressors is necessary to use oils with big molecular mass and normal structure, only then effect of raising of antifriction properties because of viscosity increasing could be reached.

Were tested properties of antifriction properties of naphtene and polyglycol oils during little loading with lubrication of pair bronze-WK-6 (WK-11) and graphelon-20-WK-6 (WK-11)

In general: wearing of samples made from bronze during lubrication with polyglycol oils 1,31-5,86 time during friction on BK-11 and 1,11-4,84 time during friction on BK-6 bigger than with naphtene oil.

Table 3

Antifriction properties of naphtene and polyglycol oils during investigation of pair samples (bronze, graphelom-20) counterface (metaiceramic material) during low loading

Lubricant	Sample	Wear intensity of the sample *J*, (0^8) $mm^3/(N\cdot m)$	
		counterface	
		BK-11	BK-6
Risella-33	Bronze (firm «Kranz»)	1,48	1,17
Laprol 2502-2-70	Bronze (firm «Kranz»)	2,40	2,05
Laprol 2002	Bronze (firm «Kranz»)	2,02	1,30
Risella-33	Bronze Бр ОФ 10-1	0,33	0,53
Laprol 2502-2-70	Bronze Бр ОФ 10-1	0,83	0,76
Laprol 2002	Bronze Бр ОФ 10-1	0,76	0,70
Risella-33	Bronze Бр ОС 12-2	0,32	0,53
Laprol 2502-2-70	Bronze Бр ОС 12-2	0,47	0,68
Laprol 2002	Bronze Бр ОС 12-2	0,42	0,62
Risella-33	Bronze Бр БНТ 2,5-1-68	0,21	0,32
Laprol 2502-2-70	Bronze Бр БНТ 2,5-1-68	1,05	1,55
Laprol 2002	Bronze Бр БНТ 2,5-1-68	1,23	1,26
Risella-33	Graphelon-20	1,50	1,56
Laprol 2502-2-70	Graphelon-20	1,24	1,17
Laprol 2002	Graphelon-20	0,95	0,77

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2. Characteristic of object of investigation.

Introduction

Properties and nature of oils determine quality indicators of polyethylene and reliability of work of seal pistons and plungers of ethylene compressors. For lubrication of friction pair of these compressors mineral (naphthene - «white» oils), polybutene and polyglycol oils are used.

These oils are:

- lowmolecular Orites-88 (ELF, France);
- highmolecular Ontes-270 DS (ELF, France) with ratio of ethylene and propylene oxides 72,8:27,2 (analogue of this oil Laprol 2502-2-70);
- Breox CL 1300, Breox CL 1400, Breox CL 6601, Breox PC 1314, Breox PC 1315, Breox PC 1316 (British Petroleum Co.);
- Syntheso D 201, Syntheso D 201 N(with npncaAKOio), Syntheso D 202 (Bochaco, Klüber, Duetschland);
- lowviscous Ucon 75 H1400, Ucon PE-159 and highviscous Ucon PE-320, Ucon PE-350 (Union Carbide);
- EXD 62/152H, EHD62/152 H with ratio of ethylene and propylene oxides 48:52 (Mobiol-Oil);
- highviscous Polyol LG-56.

Results and discussion

Polyalkylenglicols or polyglycols are the products of condensation of twoatom glycols. They are polyethers with long chains molecules of which contain two OH-groups. Polyethyleneglycol and polypropyleneglycol-products of condensation accordingly of ethyleneglycol and propyleneglycol have today the practical interest as lubricants.

I. Polyglycols:

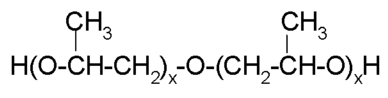
***1.Polyethyleneglycol*:**

$HO-[-CH_2-CH_2-O-]_n-H$

Average molecular mass 200-6000; n≈4-136.
PEG-200 (f), M=200; n≈4-5
PEG-400 (f), M=400; n≈9
PEG-600 (f), M=600; n≈13-14
PEG-1500 (s), M=1500; n≈34; $T_{cr.}$=318-324K
PEG-2000 (s), M=2000; n≈45-46; $T_{cr.}$=326-333K
PEG-4000 (s), M=4000; n≈90-91; $T_{cr.}$=328-333K
PEG-6000 (s), M=6000; n≈136; $T_{cr.}$=330-334K

Quality indexes of polyethyleneglycols produced by "Barva" are adduced in Tabl.1

2.Linear polypropyleneglycols*:*


(2)

These are twobased homopolymers of propylene oxide. Content of active final OH-groups is increasing when molecular mass of olygomers decreases. Trademarks of lubricants of this group are adduced in Tabl.2

Laprol 2002 is homopolymer of propylene oxides (molecular mass 2000), production of «Sumhaitchimprom», kinematic viscosity (298K~400 cs) [1-5].

Table 1

Quality indexes of polyethyleneglycols

Indexes	PEG-2000	PEG-1500	PEG-2000	PEG-4000	PEG-6000
Alkali number, mg KOH/g	-	65,0	51,9	26,01	18,4
T_{cryst}, K	-	318	321,5	326	327,5
pH 5% of watery solution	6,60	6,80	6,05	5,65	5,3
mass fraction of ashes, %	0,04	0,10	0,08	0,07	0,08
mass fraction of water, %	0,44	0,17	0,80	0,45	0,35

3.Statistic copolymers of propylene and ethylene oxides

$$HO\text{-}(\text{-}CH_2\text{-}CH_2\text{-}O\text{-})_x\text{-}(\text{-}CH_2\text{-}CH(CH_3)\text{-}O\text{-})_y\text{-}(CH_2\text{-}CH_2\text{-}O)_x\text{-}H \quad (3)$$

Trademarks of lubricants of this group are adduced [10-15]:

Laprol 1502-2-70 (M=1500, 70% of oxiethyl groups).

Laprol 2502-2-70 (M=2500, 70% of oxiethyl groups, kinematic viscosity at 303 K ~ 400-500 cs).

KSM (M=2500, 70% of oxiethyl groups).

Orites 125 DS (M=1 150, 72,8% of oxiethyl groups).

Orites 270 DS (M=2400, 72,8% of oxiethyl groups).

EHD 62/152 H (M=?; 48% of oxiethyl groups).

Breox CL-660 (the same polyglycol, but with additives).

Breox CL-1300 (the same polyglycol, but with additives).

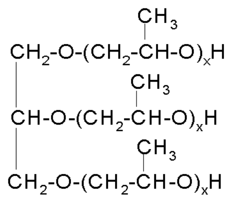
Breox CL-1400 (the same polyglycol, but with additives).

Hydropol-200 (f)- is statistic copolymer of ethylene and propylene oxides. M=7000-8000.

Trademarks of lubricants of this group are adduced in Tabl.3

4.Ramified polypropylene on the base of glycerine:

General formula:



Laprol 503: Average molecular mass M= 00, OH%=1,54; pH=6,4; η_{298K}=670 cp.; acid number, mg KOH/g=0,12 [6-8].

To this group belong as well oils Laprol-3003, 6003, Polyol LG-56 (M=3000) [6-8].

Table 2

Trademarks of lubricants of linear polypropyleneglycols

	Average molecular mass	OH, %	pH	η_{298K}	Acid number, mg KOH/g
Laprol 202	200	16,75	5,25	58	0,08
Laprol 602	600	5,55	5,60	86	0,08
Laprol 1002	1000	3,13	6,30	156	0,03
Laprol 2002	2000	1,50	5,85	316	0,07

Table 3

Trademarks of lubricants of statistic copolymers of propylene and ethylene oxides

	Average molecular mass	OH, %	pH	η_{298K}	Acid number, mg KOH/g
Laprol 1502	1500	2,20	5,5	260	0,05
Laprol 2502	2500	1,37	6,6	504	0,03
	T, K		η, cp	ρ, kg/m^3	ν, cs
Orites-270-DS	303 323		423 181	1080 1065	390 170

5.Blockcopolymers on the base of propylene and ethylene oxides on the base of glycerine with the placing of oxiethyl groups in the end of chain:

Laprol-3503-2-B 6 (M-3500, 6% of oxiethyl groups);

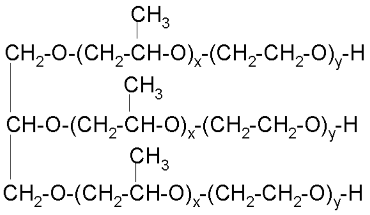
Laprol 5003-2B-10 (M=5000, 10% of oxiethyl groups);

Laprol 5003-2B-12 (M=5000, 12% of oxiethyl groups);

Laprol 6503-2B-18 (M=6500, 18% of oxiethyl groups);

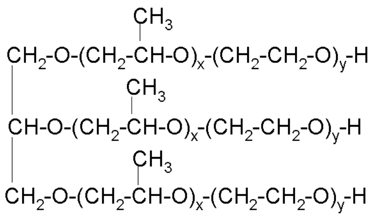
Laprol 5003: Average molecular mass M=5000; OH%=1,07; pH=6,45; η_{298K}=830 cp.; acid number, mg KOH/g=0,0;

Proxanol CL-3 (f). Blockcopolymer of propylene and ethylene oxides (M=3600). Proxanol-268 (s). Blockcopolymer of propylene and ethylene oxides (M=14000) [8-15].



x>y (5)

6.Statistic copolymers of propylene and ethylene oxides on the base of glycerin



y>x (6)

Laprol 3503-2-70 (analogue Syntheso D-201) - statistic copolymer on the base of glycerin and ethylene oxide (70% of ethylene oxide): OH%=1,54; pH=6,4; η_{298K}=670 cp. [6-8];

Laprol 3503-2-B5 – on the base of glycerine, the same molecular mass, but 65% of ethylene oxide and oxiethyl links are placed in the and of the chain: OH%=1,45; pH=6,3; η_{298K}=557 cp.;

Laprol 10003-2-70 -is statistic copolymer on the base of glycerin and ethylene oxide (70% of ethylene oxide): molecular mass 10000; OH%=0,47; pH=7,4; η_{298K}=6800 cp.;

Syntheso D-202 - statistic copolymer on the base of glycerin and ethylene oxide: density ρ (293 K)~1080 kg/m^3;

kinematic viscosity at 293 K~ 800 cs;
313 K~ 300 cs;
323 K~ 200 cs;
373 K~ 52 cs;

index of viscosity ~ 230; flash temperature $t_{fl.}$ >523K; temperature of solidification $t_{sol.}$ < 293K .

Syntheso D-201 (70% oxiethyl groups).

Indexes of quality of synthetic oils produced by IPChl (Baku, Azerbaijan) adduced in Tabl.4. [15-20];

Lubricating properties of different groups of polyglycols are adduced in Tabl.5, 6 [15-20].

Influences of final groups of polyglycol oils on the indexes of quality are adduced in Tabl. 7. [20-24].

Table 4

Indexes of synthetic oils, produced by IPChl Baku

Index	Indenter 1	Indenter 2	Indenter 3	Indenter 4
Viscosity, cSt:				
at 373 K	35,75	7,56	36,05	39,07
at 323 K	234,48	29,04	208,44	257,46
Index of viscosity:	115	135	131	120
Temperature, K:				
flashing	579	495	527	513
solidification	269	251	255	250
Density at 293K, kg/m^3	869,6	841,0	848,1	871,8

Indenter 1 - poly-a-olefine oil; indenter 2 - copolymer of ethylene and propylene; indenter 3 - copolymer of ethylene and propylene; indenter 4 - poly-a-olefine oil, thickened with polymer (SKEP)

Table 5

Lubricating properties of polyglycol oils

Oil	Molecular mass	Kinematic viscosity		
		at 313 K, cs	at 318 K, cs	at 353 K, cs
Linear polypropyleneglycols	200	25,8	19,8	4,3
	600	43,7	35,3	8,4
	1000	77,7	-	15,3
	2000	197,6	163,3	40,5
Ramified polypropyleneglycols on base of glycerin	500	110,4	76,6	12,3
	3000	265,8	-	45,8
	3000*	224,2	175,5	41,8
	3503	330,1	-	76,7
	3500**	300,0	-	52,0
Blockopolymer of ethylene and propylene oxides on the base of glycerin	5000	559,3	-	101,2

Continuation of Table 5

Statistic copolymers of propylene and ethylene oxides	1500 2500 2500***	132,3 268,9 -	- 230,0 237,3	31 60 59

* - Polyol LG-56, ** - Syntheso D201, *** - Orites-270 DS.

Table 6

Lubricating antifriction properties of polyglycol oils

Oil	Molecular mass	Boundary loading on ball, N	Diameter of wear spot, mm	Hydrodynamic effect, 10^{-14}, m^2
Linear polypropyleneglycols	200 600 1000 2000	238 242 246 262	0,62 0,53 0,51 0,49	0,528 0,589 - 2,16
Ramified polypropyleneglycols on the base of glycerin	500 3000 3000* 3503 3500**	226 320 308 - -	0,58 0,52 0,41 0,71 0,57	1,67 - 1,35 - -
Blockopolymer of ethylene and propylene oxides on the base of glycerin	5000	349	0,49	-
Statistic copolymers of propylene and ethylene oxides	1500 2500 2500***	361 402 447	0,73 0,68 0,64	- 8,09 6,96

* - Polyol LG-56, ** - Syntheso D201, *** - Orites-270 DS.

II.Naphtene oils.

Properties of the naphtene oils are adduced in Tabl.8 [15-20].

Dependence of dynamic and kinematic viscosities and density of oil Risella-33 on temperature is adduced below: T, K 303,323; η, cp 104,35,5; ρ, kg/m^3 873,861; ν, cs 120, 41,2.

Demands to the naphtene oils for ethylene compressor are adduced in Tabl.9 [15-20];.

III.Polybutene oils.

ethers; they do not dissolve in the most of high

Polybutene oil – is linear polymer with average

transparence viscous light-yellow fluid: ν_{50}=80-200 cs; ν_{100}=15-40cs; t_{fl}. (in opened crucible)=438; ρ

Polybutene – linear polymers with the molecular mass 500-1500. Most of moleculeks of polybutene contain only one final double bond with minimal quantity of cross bonds. This polymer is stable. Polybutene do not dry, do not become like paraffin or sticky even after long-duration storing. Important properties of polybutene are as well light colour, absolute transparence and absence of smell. Polybutenes are soluble in petroleum, in aliphatic and aromatic hydrocarbon chloride, in lubricating oils, polar solvents [1-5].

molecular mass from 400 to several thousands. This is

(293 K)=850-890 kg/m^3[1-5].

Table 7

Indexes of olygoethers indenters for synthetic oils

Index	Unit of measure	Indenter №1	Indenter №2	Indenter №3
Content of OH-groups	%	1,48	0,48	1,05
Content of moisture	%	0,10	0,042	0,10
Content of K^+	mg/kg	17,2	22,3	-
Acid number	mg/g	0,117	0,365	0,02
pH		6,20	5,35	6,70
Dynamic viscosity at 303K at 323K at 373 K	cs	 405,8 173,5 42,7	 290,8 129,8 33,1	 456,1 196,2 48,4
Turbidity point of 1% solution of polyether in water	K	>363	>363	>363

Indenter №1: olygoether L-2502-2-70 with final OH-groups;
Indenter №2: olygoether L-2502-2-70 with final OH- and butoxygroups;
Indenter №3: olygoether 11601-4/2-50 with final OH-group.

Table 8

Properties of naphtene oils

Oil	Density at 293K (ρ_4^{293}), kg/m^3	Kinematic viscosity at 310,8K(v), cs	Temperature of solidification ($T_{sol.}$), K	Flash temperature ($T_{fl.}$), K
Risella-17	867	9,91	223	407
Risella-33	884	76,5	255	480
Vitorex-350	859	15,8	264	497
Esso-Christo	879-889	76,6-81,0	253	491
NKM-40	873	67,1	255	468
NKM-70	884,3	70,39 (323 K) 11,77 (373 K)	260	473
5350	880,8	43,1 (323 K) 8,37 (373 K)	249	471
KPL-201	-	68,0 (323 K) 11,8 (373 K)	-	493
NMR-12	858,3	11,9 (323 K)	228	438

Table 9

Characteristic of naphtene oils for lubrication of ethylene high-pressure compressors

Indexes	Requirements TC 38-101 434-74	Naphtene compressors oils		
		NKM-70	NKM-40	Risella-33
Density (ρ_4^{293}). kg/m^3	<880	884,3	873,0	884,2
Index of refraction (n_D^{293}).	<1480	1,4800	1,4794	1,4820
Specific dispersion *(F, C)*	-	97	98	98
Viscosity kinematic, cs at 323K at 373K	36-41	70,39 11,77	37,09 7,88	40,96 7,69
Viscosity index	-	85	-	-
Acid number, mg KOH/g	<0,01	0,006	0,006	0,007
Temperature, K of solidification of flashing in opened crucible	<263 >463	263 478	260 468	253 475
Colour with glass №2 on KH-51, mm	>270	270	270	270
Test of content of organic impurities	sustains	sustains	sustains	sustains
Content of water	-	-	-	-
Content of mechanical impurities	-	-	-	-

Lowmolecular polybutene for succynimide additives:

Molecular mass-860; Iodine number – 33,94 g of iodine/l00g of product; v_{100} =287,6cs; $t_{fl.}$(in opened crucible)=417; content of moisture -absen.; content of mechanical impurities $c_{mech.}$=0,06 %w; content of ions c_{Cl^-}=0,03 %w.; ρ(293K)=886 kg/m^3.

O-Vax: ρ(293K)$^=$1030kg/m^3; colour-light-yellow; point of dropfalling $t_{dr.}$=373K ; structure-solid; acid number 10-15; alkali number 111-133 [5-15].

IV.Polyvynilbutylether (PVBE): viscous fluid with light-yellow colour or colourless with specific smell, does not dry. Density 903-921 kg/m^3 , index of refraction 1,450-1,457; does not dissolve in water; relative viscosity of 1% solution in toluol 0,63-0,68; molecular mass 2500-5500; chemical formula[16-24].

$$CH_3\text{-}\underset{\displaystyle CH_3}{CH}\text{-}[\text{-}CH_2\text{-}\underset{\displaystyle CH_3}{CH}\text{-}]_n\text{-}CH_2\text{-}\underset{\displaystyle CH_3}{CH}\text{-}R \qquad (7)$$

Conclusions

Polyglicol oils in comparing with naphtene have advantages:

- low solubility in ethylene and npn saturation by

ethylene viscosity, antiseizure and antiwear properties do not change;

- low loading ability which force to limit of ethylene plants little and

medium productivity (term of seal service 1000-4000 hours).

More over, according to firm Esslingen term of work of seal elements during lubrication with polyglicol oils 3-5 time bigger and increases from 1000-4000 hours fo naphtene and polybutene oils to 5000-15000 for polyglicol oil, According to firm ELF expenditure for 11 of polyethylene during transition to lubricating from naphtene oils to polyglicol Orites 270 DS decreased from 3-4 to 1 kg/t.

At the same time from 0,02 to 0,15% of oil ingress into polyethylene, which decreases durability of polyethylene to thermal aging and photooxidation processes and electroisolation roperties.

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3. Investigation of Viscous-and-Thermal Properties of Lubricants

Introduction

It is known, that viscous-and-thermal characteristic of oils, which are used in high-pressure compressors, is one of the important operating properties of lubricant [1-6]. This determines by such basic reasons:

- For oils of one chemical group antiwear and antiseizure characteristics increase when viscosity increases. And also viscosity increases when pressure increases. For naphtene oils when pressure increases from 0,1 to 100 MPa, viscosity increases by 10-20 times.
- When temperature increases viscosity decreases, pressure influence on viscosity becomes less noticeable.
- Thus, value of viscosity change when pressure changes depends on composition, structure of molecule and temperature.

I. Experimental

Testing of viscosity-and-thermal characteristic were carried out on the viscosimeter ВПЖ-4 using standard methods.

Viscous-and-thermal properties of machines, naphtene, polybutene, polyglycol and others oils for ethylene high-pressure compressors were evaluated by:

- indexes of dynamic η_t and kinematic v_t viscosities in the diapason of the temperature 20-100° C with the viscosimeter ВПЖ-4 (Tabl. 1);
- thermal coefficients – correlations of viscosities at t_1 and t_2:

$$C_t = \frac{\nu_{t_1}}{\nu_{t_2}} \qquad (1)$$

where ν_{t_1}- kinematic viscosity at 45°C (C_1) or at 50°C (C_2);

ν_{t_2} - kinematic viscosity at 90°C (C_1) or at 100°C (C_2);

ν_{t_2} *for polybutenes $C_1 = \nu_{45^0}/\nu_{100^0}$);

- thermal coefficient of viscosity

$$TCV_1 = \frac{\nu_{t_1} - \nu_{t_2}}{\nu_{t_2}} \text{ or } TCV_2 = \frac{(\nu_{t_1} - \nu_{t_2})k}{\nu_{t_3}} \qquad (2)$$

for instance: for oils with low viscosity and medium viscosity

$$TCV_2 = \frac{\nu_{0^0} - \nu_{100^0}}{\nu_{50^0}} \qquad (3)$$

for oils with high viscosity

$$TCV_2 = \frac{\nu_{20^0} - \nu_{100^0}}{\nu_{50^0}} \cdot 1{,}25; \qquad (4)$$

in this work was used coefficient

$$TCV_2 = \frac{\nu_{30^0} - \nu_{90^0}}{\nu_{60^0}} \text{ and } C=1; \qquad (5)$$

- interval coefficient of viscosity

$$\Delta T = \frac{\nu_{t_1} - \nu_{t_2}}{t_2 - t_1} \qquad (6)$$

in this work was used coefficient

$$\Delta T = \frac{\nu_{30^0} - \nu_{90^0}}{t_{90^0} - t_{30^0}}, \qquad (7)$$

parameters *a* and *β* of curve *lg v = a + β lg t*,where *β* – tangent of obtuse angle of incline of straight

- line *lg v* = φ (*lg t)*, to the axis of abscissas; in the work were used more convenient dependences of viscosity on inverse
- parameters *a* and *β* of curve *lg v = a + β lg t*,where *β* – tangent of obtuse angle of incline of straight line *lg v* = φ (*lg t)*, to the axis of abscissas; in the work were used more convenient dependences of viscosity on inverse temperature for finding the acute angle:

$$\lg \nu_i = a_i + b_i \lg \frac{1}{t}. \qquad (8)$$

where $b_i = \frac{\lg \frac{\nu_{t_1}}{\nu_{t_2}}}{\lg \frac{t_1}{t_2}}$, i = 1,2,3; (9)

As criterions of assessment of viscous-and-thermal properties were chosen:

1. b_1 for t_1 =30°C, t_2 = 90°C ;
2. b_2 t_1 = 30°C, t_2 = 60°C ;
3. b_3 t_1 = 60°C, t_2 = 90°C ;
4. mean arithmetical

$$\bar{b} = \frac{\sum_{i=1}^{n} b_i}{n}; \qquad (10)$$

5. mean quadratic

$$\overline{b_q} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} b_i^2} \qquad (11)$$

6. mean quadratic deviation from the mean

arithmetical $S_{n-1} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(b_i - \bar{b}\right)^2}$ (12)

Oils with less value of indexes C_t, TCV and ΔT havegood viscous-and-thermal properties.

Declivity of viscous-and-thermal characteristic of oil was found by the tangent of acute angle of incline of straight line $\lg\eta = f\left(lg\frac{1}{T}\right)$ to the axis of abscissas: less value of coefficient b, less changes viscosity from temperature. This parameter was used as substitution to less definable index of viscosity.

Results of calculations of coefficients C_1, TCV_2, ΔT

Table 1

Comparable viscous-and-thermal characteristics of oils and lubricating compositions

Oil, additive	Kinematic viscosity at t°C, cs							
	20	30	40	45	50	60	90	100
Risella-33		126	68,5	49	42,4	27,7	10,4	8,8
Risella-17		18,9	13,9	12,3	10,5	7,8	4,1	4,02
Vitorex 334		132	78,9	49,7	42,9	26,3	11,3	9,13
Esso-CHristo		121	68,9	53,8	47,9	28,2	10,6	10,3
5350		131	69,2	42,5	39,3	29,0	11,9	8,7
Vaseline oil		78	50,4	44,6	34,9	23,8	9,9	7,74
NKM-40		80,2	56,6	47,8	39,3	26,8	10,6	9,79
NKM-70		148,4	83,2	65,07	52,72	36,26	15,9	12,82
Polybutene for succynimide additives		16321	7422	5830	3683	1961	374	288
Polybutene Tredkat-99		1799	1475	1074	759	464	146	53,7
Lowmolecular polybutene		61404	13842	12851	7277	1968	172	93,6
Risella-33+ Polybutene for succynimide additives 30		630	300	220	182	108	36,5	30,2
Risella-33+ Polybutene for succynimide additives 50		826	405	275	233	139	42,9	34,8
KPL 201	420	258,2	115	89	68	42,8	15,4	11,8
Witco CL 1000	824	378	194	143	104	61,86	23	20,6
Witco CL 1200	880	430	225	184	120	71	26	23
Witco CL 1500	1190	612	300,4	215	158	90	29,5	25
Orites 210 DS	650	462	280	237	186	135	59	46,8
Polyol LG 56		362	224	175	143	98	41,8	36,9
Orites (regen.)		443		226	177,2	130	60,3	49,7
Syntheso D201	800	461	300	245	200	140	62	52
Syntheso D201N	865	615	310	262,4	210	144,2	62,2	50
Syntheso D202	890	634,9	307	264,7	208	138,9	57,9	46
Breox CL 1300		409,9	250	205,4	171	125,8	63,2	52,8
Breox 1400		485	272	221,7	181	127,6	58,2	47,4
KSM		443		232	176,4	138	61	50,86
Laprol 202		44,1	25,8	19,8	16,5	10,7	4,3	3,9
Laprol 602		63,6	43,7	35,3	27,7	19,6	8,4	7,77
Laprol 2002		298	198	163	135	93,1	40,5	38,9
Laprol 503		209	110	76,6	59,6	36,6	12,3	10
Laprol 3003		295	176	143	119	86,2	41,8	35,1
Laprol 2502		417	269	230	182	137	60	53,96
Laprol 3503-2-70		574,6	338	275	228	162	76,7	64,47
Laprol 3503-2-Б5		374	230,5	190	159	115	58,9	49,29
PVBE+Risella, %								
100 -		12227	5799	4239	3021	1970	720	
50 50		970	483	360,5	304	197	68,7	
- 100		126	68,5	49	42,4	27	10,4	8,8

and b_1, b_2, b_3, $\bar{b}$, $\bar{b}_{п}$, S_{n-1} for naphtene, polyglycol and polybutene oils and glycerin are adduced in Tabl.2. Coefficients C_1, TCV_2, ΔT are conditional and are used for estimation and comparison of viscous-and-thermal properties of one level viscosity oils, for coefficients b_1, b_2, b_3, $\bar{b}$, $\bar{b}_{п}$, S_{n-1} this estimations can be used for more wide diapason of viscosity.

Results of calculations of coefficients C_1, TCV_2, ΔT and b_1. b_2. b_3. $\bar{b}$, $\bar{b}_ц$. S_{n-1} for naphtene. polyglycol and polybutene oils and glycerin are adduced in Tabl.2. Coefficients C_1, TCV_2, ΔT are conditional and are used for estimation and comparison of viscous-and-thermal properties of one level viscosity oils, for coefficients b_1. b_2. b_3. $\bar{b}$, $\bar{b}_ц$. S_{n-1} this estimations can be used for more wide diapason of viscosity.

II. Result and discussion

1. Analysis of results, which are adduced in Tabl. 1 and Tabl. 2 shows, that for naphtene oils Vitorex-334, Esso-Christo, 5350, Risella-33, NKM-40 with similar viscosity kinematic viscosity equals at 90°C 10,4-11,3 cs and at 45°C 47,8-53,8 cs coefficient C_1 varies from 4,4 to 5,08; TCV_2 – from 2,6 to 4,57; ΔT – from 1,16 to 2,0 cs/°C; b_1 – from 1,838 to 2,245; b_2 – from 1,581 to 2,322; b_3 – from 1.997 to 2.903; $\bar{b}$ – from 1.899 to 2.243; $\bar{b}_ц$ from 1.921 to 2.247; S_{n-1} from 0.1219 to 0.5270. **Decreasing of viscosity of oil Risella** (comp. Risella-33 and Risella-17) from 10,4 to 4,2 cs (at ~60%) at 90°C and from 49,1 to 12,3 cs (at ~75%) at 45°C leads to decreasing of coefficients: C_1 from 4,72 to 2,93 (at~62%); TCV_2 – from 3,32 to 1,89 (at~43%); ΔT – from 1,86 to 0,25 cs/°C (at~87%); b_1 – from 2,245 to 1,379 (at~35%); b_2 – from 1,861 to 1,274 (at~32%); b_3 – from 2.903 to 1.555 (at~46%); $\bar{b}$ - from 2.336 to 1.403 (at~40%); $\bar{b}_ц$- from 2.376 to 1.407 (at~41%); S_{n-1} from 0.5270 to 0.1420 (at~70%).

Decreasing of viscosity of oil NKM (comp. NKM-70 and NKM-40) at ~33% at 90°C and at ~43% at 45°C leads to decreasing of coefficients: C_1 at ~15%; TCV_2 at ~31%; ΔT at ~62%; b_1 at~20%; b_2 at ~22%; b_3 at ~18%; $\bar{b}$– from 2.369 to 1.899 (at~20%); $\bar{b}_ц$- from 2,3899 to 1,9210 (at~20%); S_{n-1} from 0,3848 to 0,3520 (at~8,5%).

For the statistic copolymer of propylene and ethylene oxides of oils KSM, Orites-210 DS and Laprol-2502-2-70 with similar viscosity these coefficients change little.

For polybutene and mineral oils coefficients C_1, TCV_2, ΔT vary in wide bounds, coefficients b_1, b_2, b_3 are comparable with naphtene and polyglycol oils.

Thus we can introduce mean sum of each coefficient for generalized assessment of viscous-and-thermal characteristic of oils (Tabl. 2).

By this estimation we have a row of oils by viscous-and-thermal properties

a) by C_1 polybutene > glycerin > mineral > naphtene > polyglycol;
b) by TCV_2 glycerin > polybutene> naphtene > mineral > polyglycol;

c) by ΔT polybutene > polyglycol> glycerin > mineral > naphtene;

d) by b_1 glycerin > polybutene > mineral > naphtene > polyglycol;

e) by b_2 glycerin > polybutene > naphtene > mineral > polyglycol;

f) by b_3 glycerin > polybutene > mineral > naphtene > polyglycol;
g) by average of sum of C_1, TCV_2, ΔT

polybutene > glycerin > mineral > polyglycol > naphtene.

Assessment of viscous-and-thermal properties of oils by mean sum of coefficients b_1, b_2, b_3 (that is by $\bar{b}$ and $\bar{b}_ц$), which takes account of declivity of dependence ***v = f(T)*** at different temperature sections (parts) gives another row of oils by viscous-and-thermal properties (in order of high estimation):

a) by $\bar{b}$ glycerin > polybutene > mineral> naphtene > polyglycol;

b) by $\bar{b}_ц$ glycerin > polybutene > mineral > naphtene > polyglycol;

c) by S_{n-1} polybutene > mineral > polyglycol> naphtene > glycerin;

d) by mean sum of coefficients $\bar{b}$, $\bar{b}_ц$. S_{n-1}

glycerin > polybutene > mineral > naphtene > polyglycol.

Dependences of viscosity from temperature and pressure which are represented in Fig. 1- Fig. 3 [4; 7], confirm preferences of polyglycol oils. In Fig. 1 dependence of dynamic viscosity η (cp) for initial naphtene (1) and glycol (3) oils and these oils in saturation state (2) i 4 accordingly) from temperature is represente.

Table 2

Viscous-and-thermal characteristics of naphtene and polyglycol oils [7] and polibutene [8] for lubrication of ethylene high-pressure compressors

Oils	Viscous-and-thermal coefficients					
	C_1	TCV_2	ΔT	b_1	b_2	b_3
Naphtene:						
Risella-33	4,72	3,32	1,86	2,245	1,861	2,903
Risella-17	2,93	1,89	0,25	1,279	1,274	1,555
NKM-70	5,23	3,74	3,07	2,303	2,022	1,783
NKM-40	4,47	2,60	1,16	1,838	1,581	2,278
Esso-Christo	5,08	3,19	1,83	2,215	2,099	2,414
Vitorex-334	4,40	4,57	2,00	2,233	2,322	2,081
5350	4,41	4,11	1,99	2,187	2,176	1,997
Polybutene:						
Polybutene for succynimide additives (M=860)	20,27*	8,18	265,8	3,443	3,065	4,070
Polybutene Tredkat-99(M=460)	20,0*	3,56	27,55	2,283	1,956	2,844
Risella-33+50% of polybutene (M=860)	7,02	5,64	13,05	2,693	2,572	2,900
Risella-33+30% of polybutene (M=860)	4,87	5,05	1,99	2,214	2,468	1,781
Polyglycol:						
KSM	3,80	2,77	6,37	1,804	1,681	2,014
Orites-210 DS	4,02	2,60	3,72	1,873	1,574	2,384
Laprol-2502-2-70	3,83	2,61	5,95	1,765	1,610	2,030
Glicerin	8,27	6,61	6,25	2,931	2,783	3,190
Mineral:						
Compresorna 12(M)	5,67	3,68	3,55	2,255	2,004	2,702
Vaseline	4,47	2,86	1,13	1,872	1,715	2,140
Indusrtrial-20	3,53	2,57	0,83	1,686	1,607	1,821
Aviacijna MS-20	6,44	3,75	14,9	2,448	2,009	3,197

Oils	Viscous-and-thermal coefficients		
	$\bar{b}$	$\bar{b}_g$	S_{n-1}
Naphtene:			
Risella-33	2.336	2,376	0,5270
Risella-17	1.403	1,407	0,1420
NKM-70	2.369	2,3899	0,3848
NKM-40	1,899	1,921	0,352
Esso-Christo	2,243	2,247	0,1593
Vitorex-334	2.212	2,214	0,1219
5350	2,12	2,122	0,1067
Polybutene:			
Polybutene for succynimide additives (M=860)	3,526	3,549	0,5076
Polybutene Tredkat-99(M=460)	2,361	2,389	0,5447
Risella-33+50% of polybutene (M=860)	2,722	2,725	0,1659
Risella-33+30% of polybutene (M=860)	2,154	2,1729	0,3474
Polyglycol:			
KSM	1,833	1,838	0,1684
Orites-210 DS	1,944	1,972	0,4096
Laprol-2502-2-70	1,802	1,809	0,2124
Glicerin	2,968	2,973	0,2060
Mineral:			
Compresorna 12(M)	2,320	2,338	0,3536
Vaseline	1,909	1,917	0,2149
Indusrtrial-20	1,705	1,707	0,1082
Aviacijna MS-20	2,551	2,598	0,6007

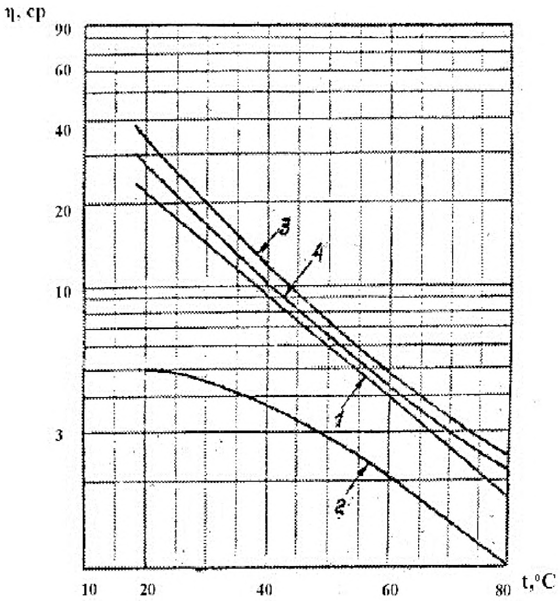

Fig. 1. Dependence of dynamic viscosity of initial oil (1,3) and of oil in saturation state by ethylene (2,4) on the temperature:

1,2-naphtene oil SAE-40 (Risella-33);

3,4-polyglycol oil Orites 125 DS (Orites 88 DS) [4; 7]

In fig. 2 and fig.3 relation of dynamic viscosity from pressure of naphtene oil Codex H23, polyglycol Orites 88DS (modern Orites 125 DS), Ucon 75H 1400, Orites 210 DS (modern Orites 270DS) and polybutene Orites L66 (modern Orites 125 MS) and Orites L100 (modern Orites 270 MS) oils (t= 50° 80°C) are shown.

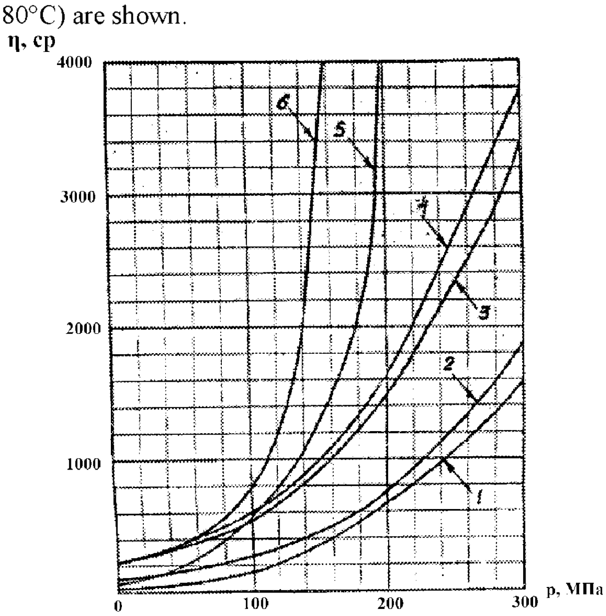

Fig. 2. Relation of viscosity of oils from pressure (at t=50°C):

1 – naphtene oil Codex H23; 2 – polyglycol oil Orites 125 DS (Orites 88DS); 3 – polyglycol oil Ucon 75H 1400; 4 – polyglycol oil Orites 270 DS (Orites 210 DS); 5 – polybutene oil Orites 125MS (Orites L 66); 6 – polybutene Orites 270 MS (Orites L 100) [4; 7]

Polybutenes have enough high temperatures of flashing ($t_{fl.}$)[8], which increase when molecular mass increases (M):

M	660	700	780	940	1410	1520
$t_{fl.}$,°C	280	325	360	>500	>500	>500

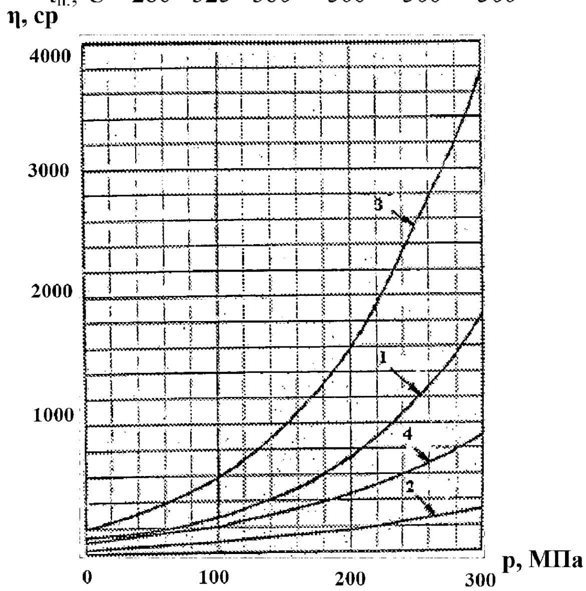

Fig. 3. Relation of dynamic viscosity of polyglycol oil with pressure at 50°C (1,3) and 80°C (2,4):

1,2 – Orites 125 DS (Orites 88 DS); 3, 4 – Orites 270 DS (Orites 210 DS) [4; 7]

In Fig. 3 dependences of dynamic viscosity on pressure for polyglycol oils Orites 125 DS (Orites 88 DS) and Orites 270 DS (Orites 210 DS) at t=50 i 80 °C are represented.

Comparing of naphtene oils by viscosity shows that oils with low viscosity have more acute viscous-and-thermal characteristic than oils with high viscosity. (Fig.4).

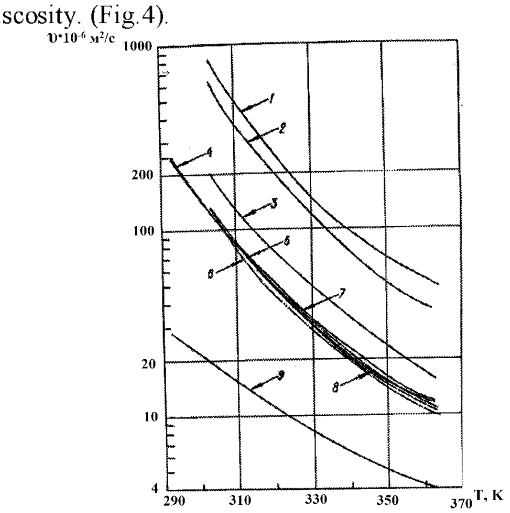

Fig.4. Viscous-and-thermal characteristic of naphtene oil:

1 – Risella -33 + 50% of polybutene "Tredkat-99"; 2 – Risella 33 +30% of polybutene for succynimide additives; 3 – NKM-70; 4 – Risella 33; 5 – X (Japan); 6 – Vitorex-334; 7 – NKM-40; 8 – 5350; 9 – Risella-17.

Viscous-and-thermal characteristic of

polyglycols: Laprol-202; Laprol-602; Laprol-1002; Laprol-2002; Laprol-503; Laprol-3003; Polyol LG-56; Laprol-5003; Laprol-1503; Laprol-2502; Syntheso-D 201; Orites-270 DS (regenerative); Syntheso-D 201 N; Laprol-3503-2-70; Laprol-3503-2-65 are represented in the Fig. 5.

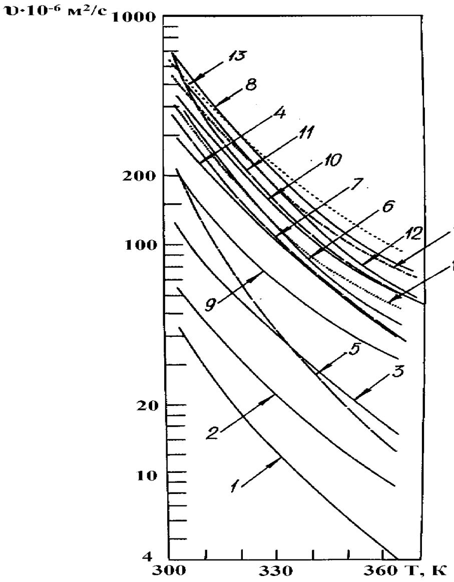

Fig. 5. Viscous-and-thermal characteristic of polyglycols:

1 – Laprol-202; 2 – Laprol-602; 3 – Laprol-1002;
4 – Laprol-2002; 5 – Laprol-503; 6 – Laprol-3003;
7 – Polyol LG-56; 8 –Laprol-5003; 9 – Laprol-1503;
10 – Laprol-2502; 11 – Syntheso-D 201; 12 – Orites-270 DS (regenerative);
13 – Syntheso-D 201 N; 14 – Laprol-3503-2-70; 15 – Laprol-3503-2-B5.

This information is adduced in Tabl. 1 and coefficients of viscous-and- thermal characteristic are calculated.

Viscous-and-thermal characteristic of statistic copolymer of propylene and ethylene oxides of oils KSM, Orites-210 DS and Laprol-2502-2-70 with similar viscosity is represented in Fig.6.

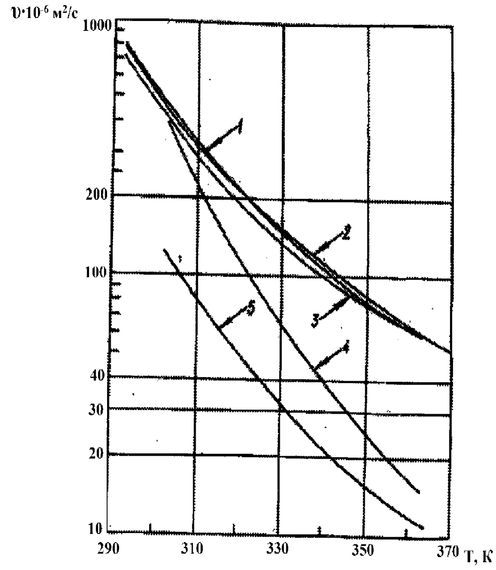

Fig. 6. Viscous-and-thermal characteristic of synthetic oils:
1 – Orites -210 DS; 2 – KSM; 3 – Laprol 2502-2-70; 4 – Glycerin; 5 – Esso-Christo

Conclusions

1. Studying of viscous-and-thermal properties of naphtene and polyglycol oils and choosing characteristics that the most complete characterize these properties.

2. For the first time, an estimation of the viscous-and-thermal properties of lubricating oils and compositions on their basis was made for the lubrication of surfaces of solids of dynamic contact of friction units designed for high and high-pressure ethylene compressors, according to a complex criterion:

- the ratio of viscosity of oils for two temperatures;
- relative temperature coefficient of viscosity;
- interval temperature coefficient of viscosity;
- three coefficients of an adequate equation of approximation of the logarithm of viscosity dependence on the logarithm of temperature for three temperature intervals: on 30° to 90°C, on 30° to 60°C, on 60° to 90°C.

3. The comprehensive assessment of the viscosity and temperature properties of these lubricating oils and compositions of lubricating oils behind the root-mean-square and arithmetic mean of these coefficients and the root-mean-square deviations from the arithmetic mean of these coefficients was represented. which made it possible to compile 11 rows of the efficiency of the lubricating oils.

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4. Investigation of antifriction properties of naphtene and polyglycol oils during little and high loading of solid lubricant pair

Introduction

Analysis of literature shows that 3 types of lubricants: naphtene, polybutene and polyglycol oils are used for lubrication of ethylene compressors.

Naphtene oil which ingresses into polyethylene do not lower quality indexes of polyethylene but have shortcomings:

- substantial solubility of ethylene in oil and as a result substantial lowering of viscosity and others hydrodynamic properties forces to feed for lubrication substantial quantity of oil:
- substantial solubility of oil in ethylene which leads to substantial dl ingress into ethylene and as a result increasing of extracting substances and «smoking» of mass during processing of polyethylene into products and to scale formation on piston's surfaces;
- low loading ability which forces to limit by ethylene plants of little and medium productivity.

For large technological lines was required equipment, which guarantee high coefficient of using working times. One of the essential factors directed to this was using synthetic lubricants with high antiwear and antiseizure properties.

Use of naphtene and polybutene oils for lubrication of friction pair of the ethylene high-pressure compressors substantially decreases using coefficient of compressors equipment, but use of polyglycol oils decreases properties of polyethylene – dielectrical and sanitarian-hygienical indexes and resistance to atmospheric and electromagnetic influences.

Alloying of compressors lubricants with viscous, antiseizure or others additives substantially decreases temperature of flashing and decreases dielectrical properties of polyethylene.

The ways of finding effective compressors oils are alloying of oils with high- temperature or viscous additives, which are similar to accordingly naphtene and polyglycol oils and also synthesis of new polyglycols.

Practical significance of turned out results consists of exposed appropriateness, which let substantially choose oil for lubrication of ethylene high-pressure compressors and define ways for subsequent investigations. New criterions of assessment of viscous-and-thermal and antiwear properties which are brought in let use them for assessments of others lubrication materials.

I. Experimental

Wearing of bronze (firm «Kranz»), Beryllium bronze Бр ВНТ-2,5-1-68, Tina- Stannum bronze Бр ОС 12,2, Tina-phosphorous bronze Бр 00-10-land composition material on the base of aromatic polyamide phenilon C-2+20% of graphite fiber from hydrocellulose, (viscose) graphelon-20 was investigated on three-pin-disk friction machine. Specimens pins were made in shape of three fingers with diameter 6 mm and height 15 mm (last sphere 6,35 mm). Counterfaces were made by method of pressing and annealing of metal-ceramic bronze (wolfram group BK-6 and BK-11) as inserts with d_e=45,0 mm, d_i=25,0 mm and thickness 15 mm (HB 8200-8400 MPa; Ra_o=0,04-0,06 mkm). Normal loading on one specimen Ni=67 N, velocity of sliding 1,3 m/s, time of investigation 4 hours (friction track 16,14 km), temperature 318±2°C. Lubricant – polyglycols Laprol 2502-2-70, Laprol 2002 and naphtene oil Risella-33.

Intensiveness of wearing was calculated by diameter of wear spot (wear capacity):

$$J = \frac{V_i}{N_i S}\left[\frac{mm^3}{N \cdot m}\right], \quad (1)$$

where V_i – average volume of wear capacity on one sample [mm^3];

N_i – normal loading on one sample [N];

S – wear track [m].

Results of investigation are represented in Tabl. 1. The result of wear intensity J = (0.21-2.4)·10^{-8} $mm^3/(H{\cdot}m)$ are calculated by diameter wear spots d_3 = 0,754-1,461 mm, according to which it is possible to estimate approximately the limits of lubricating film specific loads.

As we can see from the Tabl. 1, during little loadings (N_i=67N) and relatively high sliding velocity (ϑ = 1,3m/s) for pair «bronze – BK-11» and «bronze – VK-6» preferences of polyglycol (statistic polymer of propylene and ethylene oxides Laprol-2502-2-70 and linear polypropyleneglycol Laprol 2002) oils to naphtene oil Risella-33 are not seen and on the contrary, for pair «graphelon-20-BK-1 1» and «graphelon-20-BK-6» polyglycols are more effective than naphtene oil.

Except specimens of bronze (firm «Kranz») and Бр ОФ 10-1, for which intensiveness of wearing in friction on BK-11 during lubrication with polyglycols 1,09-1,55 time larger than on BK-6, for the rest of specimens from bronze (Бр OC 12-2 and Бр БНТ 2,5-1-68) wearing on BK-6 1,02-1,48 time bigger than on BK-11.

In general: wearing of specimens from bronze during lubrication with polyglycol oils 1,31-5,86 time in friction on BK-11 and 1,11-4,84 time in friction on BK-6 bigger than with naphtene oil.

It is necessary to give an estimation of the antiwearing and antiscratching properties on the results of tests on a four-ball friction machine. The specific loads of 1850-7500 MPa can be achieved in contact of working bodies of a four-ball friction machine.

4.2. Four-ball friction machine

Comparable characteristic of loading capacity and antiwear properties of lubricants on four-ball friction

Table 1

Antifriction properties of naphtene an polyglycol oils during investigation of pair specimens (bronze, graphelon-20) – counterface (metalceramic material) during low loading

Lubricant	Specimen	Wear intensiveness of specimen J, (x 10^{-8}) $mm^3/(N{\cdot}m)$ counterface	
		BK-11	BK-6
Risella-33	Bronze (firm «Kranz»)	1,48	1,17
Laprol 2502-2-70	-//-	2,40	2,05
Laprol 2002	-//-	2,02	1,30
Risella-33	Bronze Бр OO 10-1	0,33	0,53
Laprol 2502-2-70	-//-	0,83	0,76
Laprol 2002	-//-	0,76	0,70
Risella-33	Bronze Бр OC 12-2	0,32	0,53
Laprol 2502-2-70	-//-	0,47	0,68
Laprol 2002	-//-	0,42	0,62
Risella-33	›ronze Бр BHT 2,5-1-68	0,21	0,32
Laprol 2502-2-70	-//-	1,05	1,55
Laprol 2002	-//-	1,23	1,26
Risella-33	Graphelon-20	1,50	1,56
Laprol 2502-2-70	-//-	1,24	1,17
Laprol 2002	-//-	0,95	0,77

machine in high-load contact conditions lets choose the most effective one.

Tests were carried out on four-ball friction machine [15-18], Machine parameters and wear indexes were found:

1) relative sliding velocity^

$$\upsilon = \frac{d_b \omega \sin\alpha}{2} = 0{,}576\pi d_b n, \quad (2)$$

where d_b – ball's diameter (d_b=12.7mm);

ω – angular rotation velocity of upper ball;

α – angle in the base of pyramid from the balls (between tetrahedron height and edge -rib of tetrahedron), which (when diameter of balls d_b=12,7 mm) equals 35°20';

n – rotation velocity of upper ball; n=1470 rot./min., (f=24,5 s^{-1}) during wear testing; n=1140 rot./min. (f=19 c^{-1}) during testing of loading capacity; linear velocity 0,09 i 0,07 m/c accordingly;

f – rotation frequency.

2) loading on one ball in theoretical point of contact:

$$N_i = \frac{N}{3\cos\alpha} = \frac{N}{3\cdot 0{,}8158} = 0{,}4086N \approx 0{,}41N, \quad (3)$$

where N – axial loading on three balls.

3) friction coefficient:

$$f = \frac{F_{fr}}{N_i} = \frac{f_{fr} l}{3aN_i} = \frac{f_{fr} l}{3a\dfrac{N}{\cos\alpha}} = \frac{f_{fr} l}{\dfrac{d_b}{2}\dfrac{\sin\alpha}{\dfrac{\cos\alpha}{3}}N} = \frac{2lf_{fr}}{d_b N tg\alpha}, \quad (4)$$

where F_{fr} – friction force;

l – distance from the rotation axis to the contact point of lever with tensiometer (*l* =83 mm);

f_{fr} – force, that bends tensilebeam:

$$f = \frac{2\cdot 83\cdot f_{fr}}{12{,}7\cdot 0{,}7089N} = 18{,}4382\frac{f_{fr}}{N}; \quad (5)$$

4) static initial specific loading P_N, which stands lubrication layer at the end of friction:

$$P_L = \frac{N_i}{\dfrac{\pi d_H^2}{4}} = \frac{4\cdot 0{,}41N}{\pi d_H^2} = \frac{0{,}5223N}{d_H^2}, \quad (6)$$

where d_H – diameter of elastic deformation area by Hertz, which is calculated by Hertz's formula:

$$\frac{d_H}{2} = 0{,}872\sqrt[3]{\frac{0{,}41Nd_b/2}{E}}$$

$$d_H = 1{,}744\sqrt[3]{\frac{0{,}205d_bN}{E}} = 1{,}744\sqrt[3]{\frac{0{,}205\cdot 12{,}7N}{210000}} = 0{,}040364\sqrt[3]{N} \text{ [mm]}, \quad (7)$$

where E – modulus of ball's elasticity (for steel ШХ-15 E=2,1·10^5 N/mm^2);

N – normal loading on 3 balls [N];

5) specific loading, which is at the end of friction:

$$P_E = \frac{N_i}{\frac{\pi d_w^2}{4}} = \frac{4\cdot 0{,}41N}{3{,}14d_w^2} = \frac{0{,}5223N}{d_w^2}, \quad (8)$$

where d_w – wear spot diameter.

6) overfall of specific loading, which stands lubrication layer at the beginning of sliding:

$$\Delta p = P_I - P_E = 0{,}5223N\left(\frac{1}{d_H^2} - \frac{1}{d_w^2}\right), \quad (9)$$

7) load capacity coefficient of oil:

$$k_1 = \frac{P_H}{P_E} = \frac{d_з^2}{d_H^2}; \qquad k_2 = \sqrt{\left(\frac{d_w - d_H}{d_H}\right)^2} \quad (10)$$

8) hydrodynamic effects, which characterize conditions of boundary friction were calculated by formulas:

- at the beginning of testing

$$S_{hH} = S_{h(N)} = \frac{\eta \upsilon d_H^2}{N_i} = \frac{\nu\rho\upsilon d_N^3}{N_i} \text{ [m}^2\text{]}; \quad (11)$$

- at the end of testing

$$S_{hw} = S_{h(k)} = \frac{\eta \upsilon d_w^2}{N_i} = \frac{\nu\rho\upsilon d_w^3}{N_i} \text{ [m}^2\text{]}, \quad (12)$$

where ρ – density of oil [kg/m^3]

η – dynamic viscosity of oil [N·s/m^2];

ν – kinematic viscosity of oil [m^2/s]

υ – sliding velocity [m/c];

d_H, d_w – diameter by Hertz and diameter of wear spot;

N_i – normal loading on one ball Ha [N],

9) generalized wear index (by testing results on seizure loading or long-duration wearing:

$$J_1 = \frac{\sum_{i=1}^{n} d_{wi}}{n} \text{ [mm]}; \quad (13)$$

$$J_2 = \frac{\sum (d_{wi} - d_{Hi})}{n} \text{ [mm]}; \quad (14)$$

$$J_3 = \sqrt{\frac{\sum_{i=1}^{n} (d_{wi} - d_{Hi})^2}{n}} \text{ [mm]}; \quad (15)$$

$$J_4 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{d_{wi} - d_{Hi}}{d_{Hi}}\right)^2} \text{ [dimensionless]}, \quad (16)$$

where d_{Wi}, d_{Hi} were chosen from N=200 N to N≈N_{cr}. (seizure) by 100 N + d_w at N_{cr} (seizure).

Dimension generalized wear index is known as well [33]:

$$\text{GWI} = I_W = \frac{SS_1 + SS_2}{n} \text{ [N]}, \quad (17)$$

$$SS_1 = \sum_{j=1}^{n_1} N_j d_{Hj} / d_{зj} \qquad SS_2 = \sum_{v=1}^{n_2} N_v d_{Гv} / d_{зv}$$

(up to N<3100 N), (N≥3100N); n=20

Artificial approach of this index structure is present.

10) during analysis of antiwear properties of oils conditional antiwear index was used [3]:

$$I_1 = \frac{N_{cr}}{d_w}\left[\frac{N}{mm}\right], \quad (18)$$

where N_{cr} – critical seizure loading [N];

d_w – average diameter of wear during long-duration testing;

then we can calculate generalized index of antiwear properties of oils:

$$I_2 = \frac{N_{cr}}{d_w}\cdot K_w\left[\frac{N}{mm}\right], \quad (19)$$

(higher value of I_2, higher assessment of antiwear

$$K_w = \frac{N_{cr}}{N_w}$$

properties of oils), where (dimensionless) – index of wear loading;

N_w – loading, in which testing of long-duration wearing was done.

Conditional character of this index is seen.

Statistic information of three series of wear testing for these lubricants was accumulated for the assessment of the experiment error: naphtene oils Risella-33 (3 series), Risella-17, NKM-40, NKM-70, 5350, Vitorex-334, Esso-Christo; polyglycol oils Orites-370 DS (3 series), Laprol-2002, Syntheso- D 201 and compositions of oils Risella+5% of Orites-270 DS, EBPE, Laprol-2502-2-70+20% of EBPE, Laprol 2502-2-70 +20% of EBF, Laprol 2002+20% of EBF, Laprol -2002+20% of EBPE (Tabl. 2). In first and third series number of recurring tests was 5, and in second series-3. 20 lubricants were tested (individual and compositions). For each series average diameter of wear spot, dispersions, mean-square deviations, coefficients of variation and Cochran's criterion were calculated. For three series coefficient of variation varied from 2,58 to 12,46. Table values of Cohran's and Student's criterions were taken by [32].

For the first series of tests calculated Cochran's criterion was Gc=0,3880, which is less than from the table $G_T\{N=5; n=5; a=0,01\}=0,5875$ and $G_T\{N=5; n=5; a=0,05\}=0,5065$ for significance level α=0,01 and α=0,05 accordingly. This confirms the zero hypothesis about row homogeneity (5) of dispersions. Error of experiment for the first series:

$$S_{er}=\sqrt{\frac{\sum_{i=1}^{N=5}S_i^2}{N}}=\sqrt{\frac{0,0027962}{5}}=0,02365\ \text{mm}.$$

Proxy interval for average value:

$$\Delta d=\pm\frac{t_T\{\alpha=0,05; f=(N\cdot n)-1\}\cdot S_{er}}{\sqrt{N\cdot n}}=\pm\frac{2,06\cdot 0,02365}{\sqrt{25}}=\pm 0,0097\ \text{mm}.$$

For the second series:

$G_{calc}=0,3773$, which is less than from the table $G_T\{N=6; n=3; \alpha=0,01\}=0,6321$ and $G_T\{N=6; n=3; \alpha=0,05\}=0,5391$. This confirms homogeneity of dispersions row (6). Error of experiment for the second series:

$$S_{er}=\sqrt{\frac{\sum_{i=1}^{N=6}S_i^2}{N}}=\sqrt{\frac{0,00706815}{6}}=0,03432\ \text{mm}.$$

Proxy interval for average value:

$$\Delta d=\pm\frac{t_T\{\alpha=0,05; f=(Nn)-1=14\}\cdot S_{er}}{\sqrt{N\cdot n}}=\pm\frac{2,11\cdot 0,03432}{\sqrt{18}}=\pm 0,0171\ \text{mm}.$$

For the third series:

$G_{calc}=0,2356$, which is less than from the table $G_T\{N=9; n=5; \alpha=0,01\}=0,3934$ and $G_T\{N=9; n=5; \alpha=0,05\}=0,3344$. This confirms homogeneity of dispersions row (9). Error of experiment for the third series:

$$S_{er}=\sqrt{\frac{\sum_{i=1}^{N=10}S_i^2}{N}}=\sqrt{\frac{0,033207}{9}}=0,0608\ \text{mm}.$$

Proxy interval for average value:

$$\Delta d=\pm\frac{t_T\{\alpha=0,05; f=(Nn)-1=44\}\cdot S_{er}}{\sqrt{N\cdot n}}=\pm\frac{2,01\cdot 0,0608}{\sqrt{44}}=\pm 0,0182\ \text{mm}.$$

Joining up of first and third series of tests has lead to such statistic assessments:

$G_{calc}=0,2173$, which is less than from the table $G_T\{N=14; n=5; \alpha=0,01\}=0,29624$ and $G_T\{N=14; n=5; \alpha=0,05\}=0,25114$. This confirms homogeneity of dispersions row (14). Error of experiment:

$$S_{er}=\sqrt{\frac{\sum_{i=1}^{N=15}S_i^2}{N}}=\sqrt{\frac{0,0360032}{14}}=0,0507\,mm.$$

Proxy interval for average value:

$$\Delta d=\pm\frac{t_T\{\alpha=0,05; f=(Nn)-1=69\}\cdot S_{er}}{\sqrt{N\cdot n}}=\pm\frac{2\cdot 0,0507}{\sqrt{70}}=\pm 0,0121\ \text{mm}.$$

Results of recurring tests of oils Risella-33, Risella-33, Orites-270 DS, Laprol-2002, Syntheso-D 201, Risella-17, NKM-40, NKM-70, 5350, Vitorex-334, Orites-270 DS (n=5) and oils EBPE, Risella-33+5% of Orites-270 DS, Laprol-2502 +20% of EBPE, Laprol-2502 +20% of EBF, Laprol-2002+20% of EBF, Laprol-2002 +20% of EBPE are represented in tabl. 2.

Results of calculation show that dispersion of this row is homogeneous (α=0,05). Proxy intervals for average value: ±0.0097; ±0,0177; ±0,0164; ±0,0113.

Results of calculation are recalled. Error of experiment does not have big value.

4.3. Antifriction properties

Loading capacity and antiwear properties were tested on four-ball friction machine (FBFM) [15; 16; 17; 18; 19]: balls from the steel ШХ-15(HRC 52-54) with diameter 12,7 mm, loading time 1 min., rotation number of upper ball 1140 (during testings of polyethyleneglycols rotation number of upper ball 1470 per minute) and 4 hours and rotation number 1470 per minute during tests on loading capacity and antiwear properties accordingly (in last test axial loading N=200 N; N_i=82 N).

Results of tests on FBFM on loading capacity (seizure loading on one ball N_i) and antiwear properties (average diameter of wear spot d_i) are adduced in Tabl. 3-5 and shown in Fig. 1-11.

As we can see from the Tabl. 3-5, by loading capacity oils are placed in a row (by seizure loading on one ball): polyglycols (N_i=333 N) > mineral (N_i =245,9 N) > polybutene (N_i =225,4 N) > naphtene (N_i =206,1 N), and by antiwear properties by diameter of wear spot during long- duration tests:

polybutene (d_i=0,549 mm) > polyglycols(0,651 mm) > naphtene (d_i=0,695 mm)^ mineral (d_i=0,740 mm).

This row is similar to the rows of hydrodynamic effects at the beginning (S_{hH}) and at the end (S_{hw}) of tests:

by S_{hH}: polybutene ≥ polyglycol ≥ mineral ≥ naphtene;

by S_{hw}: polybutene ≥ polyglycol ≥ mineral ≥ naphtene.

That is, more «soft» conditions of boundary friction leas to smaller values of wear when loading conditions of tests are relatively small. That is why index d_w when N_i→min in 4 hours is not enough informative relatively with assessment of antiwear properties of oils.

More information give results when Ni→rnin in 30 hours of tests (fig. 1), or realization of long-duration tests (4 hours) in boundary of loadings from N_i=80 N to N_i=362 N (tabl. 6).

In this case we have a row by antiwear properties: polyglycols > polybutene compositions > naphtene.

It is known, that increasing of moisture in polyglycol oils decreases antiwear properties of oils and quality indexes of polyethylene.

Addition to naphtene (compare Risella-33 and Risella-33+50% of PVBE) [5], poly-α-olefin (compare this oil and it with addition of 4% of SKEP) and polyglycol (compare Syntheso D-201 and Syntheso D-201 N) oils antiseizure, antiwear and viscous additives leads to substantial decreasing of flashing temperature.

Testing of mixtures of polyglycol oil and glycerin shows, that antiwear properties of such mixtures substantially become worse when content of glycerin is more than 3% in polyglycol oil (tabl. 7). Input of viscous polybutene additives to naphtene oils up to 5% decreases wear of steel, and input of more than 5% – not substantially influences on wear.

Testing of wear from loading during long-duration tests (Tabl. 6), which determine temporary resistance of lubricant to thermomechanical influences shows the advantages of Risella-33 over naphtene oil NKM-40 and advantages of polyglycol oil Laprol over Orites. Input of viscous additives into naphtene oil also decreases wear during long-duration testing, but critical loadings do not change much (Tabl.6 і 7).

From, the synthetic oils Orites 210 DS has the highest antiwear properties (Fig. 6).

As it seen from the Fig.9, ramified polypropyleneglycols on the base of glycerin give substantial increasing of loading capacity when molecular mass of oligomer increases.

Table 2

Statistic findings of wear tests on FBFM

Lubricant	Diameter of wear spot, mm (recurring tests)				
	1	2	3	4	5
First series (Ni=82 N; t=4 hours; n=l 140 rot. /min.)					
Risella-33	0,475	0,499	0,449	0,474	0,477
Risella-33	0,463	0,486	0,472	0,489	0,492
Orites-270 DS	0,624	0,700	0,640	0,648	0,690
Laprol-2002	0,439	0,453	0,477	0,458	0,454
Syntheso-D 201	0,540	0,534	0,571	0,616	0,568
Sum					
Second series (N_i=82 N; 1=4 hours; n=l140 rot. /min.)					
EBPE	0,544	0,515	0,551	-	_
Risella-33+5%					
of Orites- 270ds	0,486	0,499	0,426	-	_
Laprol-2502 +					
20% of EBPE	0,480	0,440	0,460	_	_
Laprol-2502					
+20% of EBF	0,418	0,377	0,421	_	_
Laprol-2002					
+20% of EBF	0,495	0,576	0,480	_	_
Laprol-2002					
+20% of EBPE	0,480	0,464	0,538	-	_
Sum					
Third series (Ni=82 N; x=4 hours; n=1470 rot. /min.)					
Risella-17	0,992	0,784	1,010	0,930	0,926
Risella-33	0,652	0,780	0,788	0,750	0,754
NKM-40	0,710	0, 580	0,683	0,656	0,662
NKM-70	0,445	0,457	0,477	0,428	0,488
5350	0,491	0,643	0,585	0,474	0,548
Vitorex-334	0,568	0,505	0,601	0,560	0,520
Esso-Christo Orites-270 DS	0,738	0,728	0,637	0,694	0,686
1 series	0,662	0,734	0,513	0,636	0,644
2 series	0,544	0,760	0,640	0,646	0,650
Sum					

Continuation of tabl.2

Lubricant	Average diameter of wear spot, mm	Dispersion, ($\cdot 10^{-4}$) mm^2	Mean-square deviation, ($\cdot 10^{-2}$) mm	Vary coefficient, %
	First series (Ni=82 N; t=4 hours; n=1140 rot. /min.)			
Risella-33	0,4748	3,142	1,773	3,73
Risella-33	0,4804	1,533	1,238	2,58
Orites-270 DS	0,6604	10,848	3,294	4,99
Laprol-2002	0,4562	1,867	1,366	3,00
Syntheso-D 201	0,5658	10,572	3,251	5,75
Sum		27,962		
	Second series (N_i=82 N; 1=4 hours; n=1140 rot. /min.)			
EBPE	0,5367	3,645	1,909	3,56
Risella-33+5%				
of Orites- 270ds	0,4703	15,163	3,894	8,28
Laprol-2502 +				
20% of EBPE	0,4600	4,000	2,000	4,35
Laprol-2502				
+20% of EBF	0,4053	6,044	2,458	6,07
Laprol-2002				
+20% of EBF	0,5170	26,67	5,164	9,99
Laprol-2002				
+20% of EBPE	0,4940	15,16	3,894	7,88
Sum		70,682		
	Third series (Ni=82 N; x=4 hours; n=1470 rot. /min.)			
Risella-17	0,9284	78,25	8,846	9,53
Risella-33	0,7448	29,57	5,440	7,30
NKM-40	0,6582	21,00	4,580	6,96
NKM-70	0,4590	5,80	2,410	5,24
5350	0,5482	46,00	6,780	12,37
Vitorex-334	0,5508	14,25	3,770	6,84
Esso-Christo Orites-270 DS	0,6966	15,50	3,940	5,65
1 series	0,6378	63,25	7,950	12,46
2 series	0,6480	58,45	7,650	11,79
Sum		332,07		

Table 3

Antifriction and viscous-and-thermal properties of mineral oils

Oil	Temperature of flashing, °C		Loading capacity		Antiwear properties during tests τ=4 hours, N_i=82 N	
	closed crucible	opened crucible	ν, мм2/s (90°C)	Ni, N	ν, $мм^2$/s (45°C)	S_{hH}, ($\cdot 10^{-16}$)m^2 (45^{0}C)
Vitorex-334	206	-	11,3	238	49,7	6,04
Esso-Christo	212	-	10,6	213	53,8	6,74
5350	202	-	11,9	205	52,5	6,58
Risella-33	202	221	10,4	199	49,1	6,17
Risella-17	-	-	4,15	164	12,3	1,51
NKM-40	195	-	10,7	201	47,8	5,92
NKM-70	205	-	15,9	203	83,2	10,45
NKM-200	-	-	10,6	226	80,0	10,03
Compressorna 12(M)	-	-	11,5*	278	109,8	13,99

Continuation of tabl. 3

Industrial 20	-	-	9,2	242	32,6	-
Industrial 45	-	-	12,1 ,	269	60,2	-
Aviacijna MC-20	-	-	28,2	281	198	25,00
MGD-14M on the base of diesel oil F-14	210	-	13,6*	349	-	-
N-50	-	-	-	213	-	-
ChR-200	-	-	-	205	45,1**	-
BMT-15	-	-	-	175	-	-
Vaseline medical	-	-	10,0	201	44,6	5,55

Oil	Antiwear properties during tests τ=4 hours, N_i=82 N		Density, kg/m^3	
	d_3, mm	S_{hw}, ($\cdot 10^{-14}$) m^2 (45°C)	45°C	90°C
Vitorex-334	0,60	0,99	842	819
Esso-Christo	0,69	1,69	869	845
5350	0,55	0,83	869	845
Risella-33	0,85	2,88	871	848
Risella-17	0,93	0,93	852	826
NKM-40	0,66	1,30	859	833
NKM-70	0,46	0,77	871	848
NKm-200	0,82	4,21	869	835
Compressorna 12(M)	0,92	8,29	883	861
Industrial 20	1,07	-	-	-
Industrial 45	0,85	-	-	-852
Aviacijna MC-20	0,57	3,52	875	-
MGD-14M on the base of diesel oil F-14	0,54	-	-	-
N-50	0,60	-	-	-
ChR-200	0,50	-	-	-
BMT-15	0,96	-	-	-
Vaseline medical	0,65	1,16	863	838

In Fig. 12 dependence of seizure loading on one ball on molecular mass of polyglycols is represented:

- linear polypropyleneglycols (1);
- ramified polypropyleneglycols on the base of glycerin (2);
- statistics copolymers of propylene and ethylene oxides (70%) Laprol (3);
- statistics copolymers of propylene and ethylene oxides (%) Orites (4);
- blockcopolymers of ethylene oxide (6-18%) and propylene oxide on the base of glycerin (5);
- statistics copolymers of propylene oxides and ethylene oxides (70%) on the base of glycerin (6);
- polyethyleneglycol PEG-400 (7);
- copolymer of propylene oxides (30%), ethylene oxides (67%) i glycerin residua (3%) (molecule with star jointing of bonds; number of opened oxygen groups is minimum (8);
- Syntheso D202 (9);
- Syntheso D201 N (10);
- Hydropol-200 (11);
- Proxanol CL-3 (12).

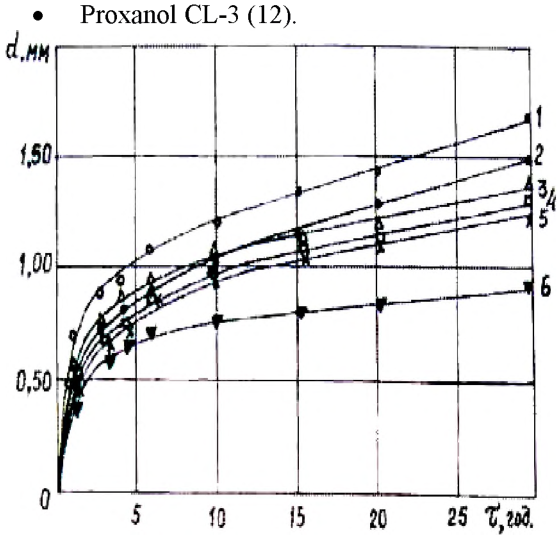

Fig. 1. Dependence of mean diameter of wear spot for steel balls (steel ШХ-15) on the time of testing on FBFM in oils :

1 – kompressorna 12(M); 2 – vaseline oil; 3 – naphtene Risella-33; 4 – mixture of Risella-33+PVBE (30:70); 5 – the same (50:50); 6 – PVBE.

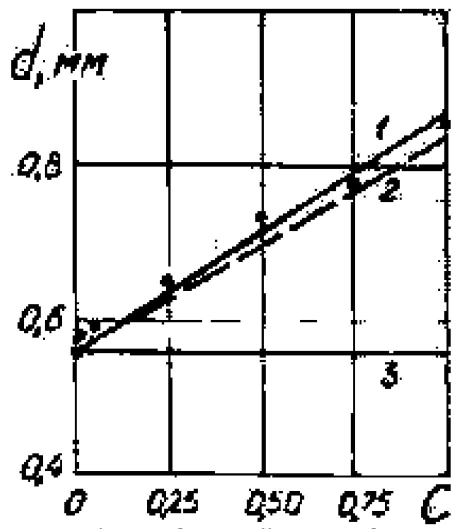

Fig.2. Dependence of mean diameter of wear spot of steel balls (steel ШХ-15) during tests on FBFM on concentration (c_v) of mineral oil in PVBE:
1 – Risella-33; 2 – industrial 45; 3 – vaseline medical.Testing conditions: n=1470 rot./min., N=200 (N_i=82 N), f=24,5 s^{-1}, τ=4hours., d_e=12,7 mm.

As we can see from the Fig.12, when molecular mass increases loading capacity of polyglycols increases linearly, more over for each class of polyglycols there is different inclination of straight line to the abscissa axis. By increasing of the inclination angle there is a row of polyglycols: (1) <(6) <(2) <(3,4) <(5).

By the prognosis of N_i when M=10000 there is a row of polyglycols:

(1) <(6) <(2) <(5) <(3);N_i, N: 345 <418 <542 <675 <695. With information of testing (fig.1-11) on seizure loading (τ=60 s) by relations d_H=f(N) and d_w=ψ(N) we can estimate antiwear properties with formulas (4.12), (4.13), (4.14), (4.15). Calculations are represented in Tabl. 8. As we can see from the tabl. 8, values of criterions of antiwear properties of oils (τ=60 s; step-by-step loading) are different from the ones when τ=4 hours and N=const=200 N, that is why J_1-J_4 can be reliable assessments of antiwear properties.

This is confirmed by correlations of criterions of such pairs of oils: Risella-33/5350, Syntheso D201 N / Syntheso D 201, Laprol 2502/ Laprol 1502, Risella-33+50% PVBE / Risella-33 (100%), Risella-33+50% PVBE / PVBE (100%) (tabl.9), that is why new criterions show another side of antiwear properties of oils in comparing to known ones which are obtained at low loadings and long-duration tests.

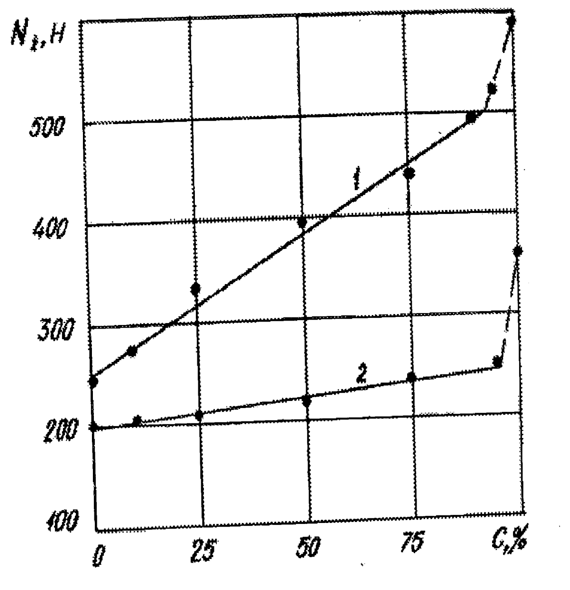

Fig. 3. Dependence of boundary loading on one ball from steel ШХ-15 during tests on FBFM on concentration of PVBE in naphtene oil Risella-33 (number of upper ball rotations: 1-835; 2-1470). Testing conditions: τ=l min., d_e=12,7 mm

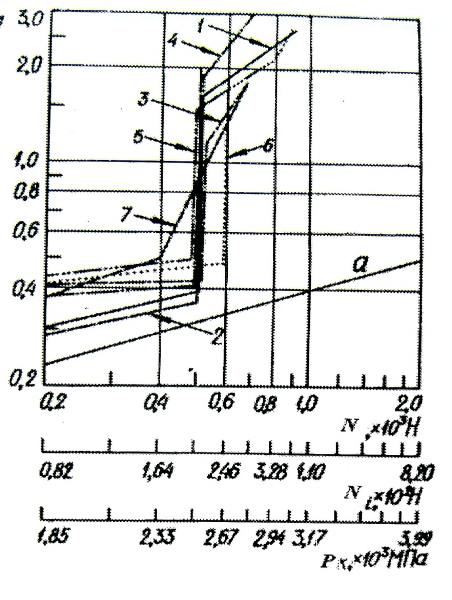

Fig. 4. Relations of wear spot (d) with the axial loading (N), loading on one ball in the theoretical point of contact (N_i) and average initial pressure in the contact point (P_c) for fluids:1 – NKM-40; 2 – 5350; 3 – Esso-Christo;4 – NKM-70; 5 – Risella-33; 6 – Vitorex-334;7 – Risella-1.

Table 4

Antifriction and viscous-and-thermal properties of naphtene and polybutene and others oils and compositions on their base

Oil	Temperature of flashing, °C		Loading capacity		Antiwear properties during tests τ=4 hours., N_i=82 N	
	closed crucible	opened crucible	ν, mm^2/s at 45°C .	N_i, N	ν, mm^2/s at 45°C .	S_{hH}, ($\cdot 10^{-16}$) m^2 (45°C)
Risella-33+50% of PVBE	85	166	68,7	217	304	-
Risella-33+of peroxide FGK	-	-	-	262	-	-
KPL-201	220	-	15,4	185	89,0	-
Witco CL-1000	230	≥240	23,0	190	143	-
Witco CL-1200	250	≥250	26,0	195	184	-
Witco CL-15 00	250	≥250	29,5	220	215	-
Polybutene-200	-	-	-	267	-	-
Polybutene for succynimide additives	-	-	374	320	5839	735,41
Polybutene Tredkat-99	-	-	146	201	1074	131,24
Lowmolecular polyethylene	-	-	172,3	320	13842	1837,2
PVBE	-	170	720,6	385	3850	516,56
Glycerin	-	-	15,6	275	129	-
Poly-α-olefin	306	-	35,8**	287	234,5***	28 45***
Poly-α-olefin + 4% of polymer SKEP	240	-	39,1**	277	257,5***	31 39***
KPL (additive)	-		-	220	-	-
SKTN-A(additive)	180	-	-	267	-	-
Peroxide ФЖК	-	-	-	287	-	-

Continuation of tabl. 4

Oil	Antiwear properties during tests τ=4 hours, N_i=82 N		Density, kg/m^3	
	d_3, mm	S_{hw}, ($\cdot 10^{-14}$) m^2 (45°C)	45°C	90°C
Risella- 33+50% of PVBE	0,63	-	-	-
Risella-33+of peroxide FGK	0,93	-	-	-
KPL-201	0,87	-	-	-
Witco CL-1000	0,45	-	-	-
Witco CL-1200	0,46	-	-	-
Witco CL-1500	0,46		-	-
Polybutene-200	0,70	-	-	-
Polybutene for succynimide additives	0,45	50,98	873	850
Polybutene Tredkat-99	0,45	9,10	847	821
Lowmolecular polyethylene	0,47	145,11	920	-
PVBE	0,56	69,01	930	-
Glycerin	0,64	-	-	-
Poly-α-olefin	0,61	4,91***	869,6*	-
Poly-α-olefin + 4% of polymer SKEP	0,61	5 42***	871,8*	-
KPL (additive)	0,71	-	-	-
SKTN-A(additive)	0,88	-	-	-
Peroxide ФЖК	1,04	-	-	-

Table 5

Antifriction and viscous-and-thermal properties of polyglycol oils

Oil	Temperature of flashing, °C		Loading capacity		Antiwear properties during tests t=4 hours, Ni-82 N			
	closed crucible	opened crucible	ν, mm^2/s (45°C)	N_i, N	ν, mm^2/s (45°C)	S_{hH}, $(\cdot 10^{-16})$ m^2 (45°C)	d_w, mm	S_{hw}, $(\cdot 10^{-14})$ (45 °C)
PEG-200	-	-	-	246	-	-	1,0	-
PEG-400	-	-	-	328	-	-	0,81	-
Laprol 202	-	-	4,3	238	20,0	2,88	0,62	0,52
Laprol 602	-	-	8,4	242	34,5	4,98	0,53	0,56
Laprol 1002	-	-	15,3	246	61,0	8,81	0,51	0,89
Laprol 2002	234	-	40,5	262	157,0	22,67	0,47	1,79
Laprol 1502- 2-70	-	-	31,0	361	105,0	9,93	0,76	3,32
Laprol 2502- 2-70	216	250	60,0	402	230	33,19	0,66	7,26
KSM	218	250	61,0	398	232	-	0,77	
Orites – 125 DS	-	-	-	395	-	-	0,72	-
Orites-270 DS	220	250	59,0	447	237	34,2	0,64	6,82
Breox CL 660	-	-	-	287	-	-	0,80	-
Breox CL 1300	214	285	63,2	328	205,4	31,44	0,63	5,98
Breox CL 1400	247		58,2	369	221,7	34,06	0,66	7,45
Laprol 503	-	-	12,3	226	75,0	10,83	0,58	1,61
Laprol 3003	-	-	45,8	308	195	28,15.	0,52	3,01
Polyol LG-56	-	-	41,8	320	168	24,24	0,41	1,27
Laprol 3503- 2-Б6	-	-	58,9	254	190	27,42,4-	0,44	1,78
Laprol 5003- 2-Б10	-	-	101,2	373	325	46,90	m49	4,20
Proxanol CL-3	-	-	-	340	-	-	0,83	-
Laprol 3503- 2-70	-	-	76,7	287 :	275		0,71	10,81
Laprol 10003- 2-70	-	-	82,0	418	~800**	123,78**	0,74	38,16**
Shyntheso D 201	242	≥250	62,0	287	245	35,38	0,57	5,30
Shyntheso D 201N	106	120	95,5	369	334,7	45,70	0,56	6,45
Shyntheso D 202	238	270	57,9	451	264,7	48,30	0,67 |	9,32
Hydropol-200	-	-	-	440	-	-	0,78	-
Laprol 2503-2-70*	-	-	-	369	-	-	0,67	-

* star structure; ** at 40°C

Table 6

Influence of axial loading (N) on wear during long-duration tests (n=l140 rot./min., τ=4 hours, f=19 s^{-1})

Oil	Diameter of wear spot, mm							
	198 N	294 N	392N	491N	589 H	687 N	785 N	883 N
Orites-210 DS	0,64	0,76	0,72	0,67	0,71	0,72	1,55	2,8
Laprol-2502-2-70	0,68	0,76	0,76	0,67	0,78	1,26 |	1,37	1,6
NKM-70	0;52	0.57	0,61	2,8				
NKM-40	0,65	0,61	1,28	1,36				
Risella-33	0,63	0,50	0,53; 0,53*	0,65	0,9**			
Risella-33+polybutene for succynimide additives: 5% 15% 30%	0,45 0,51 0,61	0,52 0,53 0,6	0,56; 0,61* 1,6; 0,83* 0,60;0,57*	0,91 0,94	1,7**			
Risella-33+50% of polybutene	0,49	0,65	0,82	0.88	0,83; 2,1			

* 436 N (N_i=180 N); ** 540 N (N_i=220 N)

Table 7

Antiwear properties of mixtures (f=19 s^{-1}, τ=4hours, N=200 N, n=1470 rot./min.)

Basic oil	Additive		Diameter of wear spot, mm
	name	%	
Risella-33	Polybutene for succynimide additives	0	0,85
		5	0,48
		15	0,48
		30	0,48
		100	0,45
Risella-33	Lowmolecular polyethylene	5	0,46
		15	0,48
		30	0,46
		100	0,47,
Risella-33	Polybutene for succynimide additives + lowmolecular polyethylene	5	0,49
Risella-33	Polybutene	50	0,59
NKM-70	Polybutene for succynimide additives	0	0,46
		5	0,50
		15	0,50
		30	0,47
Orites-210 DS	Glycerin	0	0,64
		1	0,60
		5	0,74
		10	0,79
		100	0,64

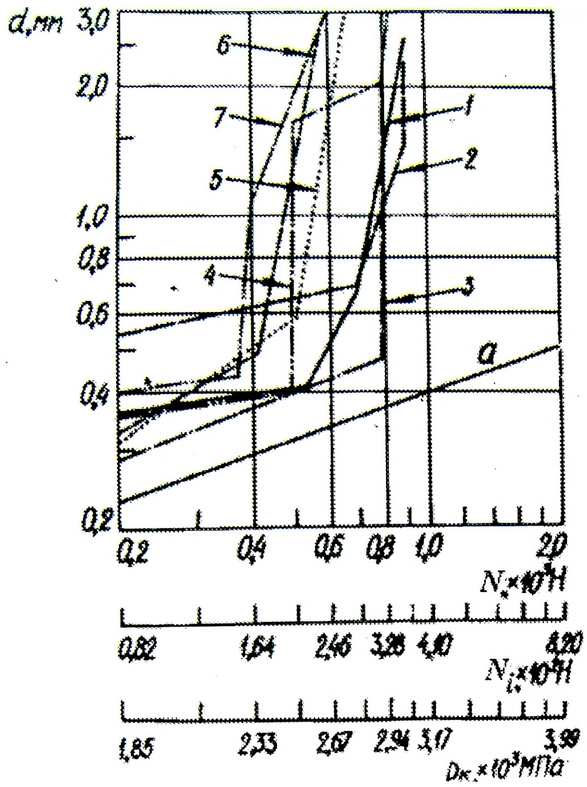

Fig. 7. Relation of wear spot (d) with the axial loading (N), loading on one ball in the theoretical point of contact (N_i) and average initial pressure in the contact point (P_c) for fluids: 1 – lowmolecular polyethylene (fluid); 2 – polyphenilether Ф4Е; 3 – polybutene for succynimide additives; 4 – polybutene "Tredcat-99"; 5 – Risella-33+ 50% of polybutene; 6 – Risella-33+30% of lowmolecular polyethylene; 7 – Risella-33+30% of polybutene for succyimide additives

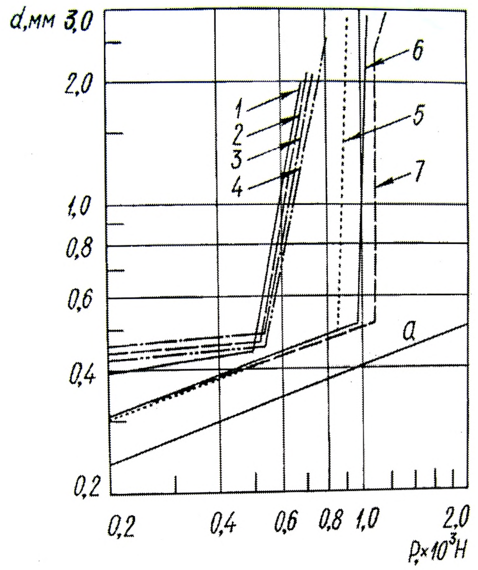

Fig. 8. Relation of wear spot (d) with the axial loading (N) for linear polypropyleneglycols and statistic copolymers of ethylene and propylene oxides:1 – Laprol 202; 2 – Laprol 602; 3 – Laprol 1002; 4 – Laprol 2002; 5 – Laprol 1502-2-70; 6 – Laprol 2502-2-70; 7 – Orites 210 DS.

Table 8

Criterions of assessment of oils antiwear properties

Oil	τ=60s; step-by-step loading				τ=4 hours; N=200=const	
	J_1, mm	J_2, mm	J_3, mm	J_4	d_3, mm	J_4^*
Laprol 2002	0,4425	0,1407	0,1429	0,5122	0,47	0,9915
Laprol 1500	0,4076	0,0848	0,0853	0,2646	0,76	2,2203
Laprol 2500	0,4306	0,0987	0,0997	0,2981	0,66	1,7966
Orites 270 DS	0,4302	0,0897	0,0901	0,2675	0,64	0,7119
Syntheso D 201	0,3870	0,0835	0,0840	0,2768	0,61	0,5847
Syntheso D 201 N	0,4281	0,1049	0,1053	0,3284	0,56	0,3729
Hydropol-200	0,6990	0,3587	0,3629	1,0492	0,78	2,3051
Proxanol CL-3	0,3769	0,0550	0,0563	0,1943	0,83	2,5169
Risella-33	0,4680	0,1820	0,1882	0,6907	0,85	2,6017
5350	0,3278	0,0470	0,0471	0,1730	0,55	1,3305
PVBE (100%)	0,4816	0,1503	0,1728	0,4674	0,56	1,373
Risella-33+ 50% of PVBE	0,4910	0,2010	0,2230	0,7147	0,63	1,669

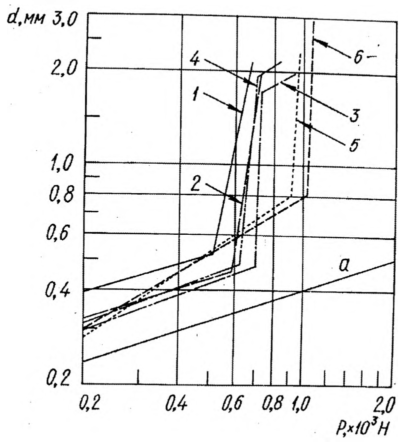

Fig. 9. Relation of wear spot (d) with the axial loading (N) for ramified polypropylene on the base of glycerin:1 – Laprol 503; 2 – Laprol 3003; 3 – Laprol 3503-2-70; 4 – Laprol 3503-2-65; 5 – Laprol 5003; 6 – Laprol 10003-2-70.

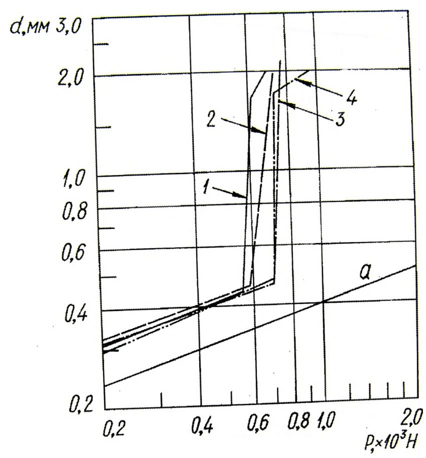

Fig. 10. Relation of wear spot (d) with the axial loading (N) for ramified polypropyleneglycols: 1 – Polyol LG-56; 2 – Laprol 3003; 3 – Syntheso D 201 N; 4 – Laprol 3503-2-70.

Conclusions

1. The properties of high-pressure PE (trademark 10803-020) when lubricating with naphtene and polyglypol oils were tested.

3. Use of naphtene and polybutene oils for lubrication of friction pair of the ethylene high-pressure compressors substantially deteriorates using coefficient of compressors equipment, but use of polyglycol oils deteriorates properties of polyethylene - dielectrical and sanitarian- hygienical indexes and resistance to atmospheric and electromagnetic influences.

4. Alloying of compressors lubricants with viscous, antiseizure or others additives substantially decreases temperature of flashing and deteriorates dielectrical properties of polyethylene.

5.For the first time dependence of seizure loading during testing on FBFM on the molecular mass of different polyglycols and bounding conditions for high viscous fluids (by extrapolation) are found

6.Into procedure of generalization assessment of antiwear properties of lubrication oils of the base of results of investigations antiseizure indexes dimensionless index of wear- mean-square relative deviation of diameter of spot of wear from the spot by Hertz has been brought in.

Table 9

Comparable characteristic of antiwear properties of oils based on the criterions d_w, J_1-J_4

Oil	τ=60s; step-by-step loading				τ=4 hours; N=200=const	
	J_1/J_1'	J_2/J_2'	J_3/J_3'	J_4/J_4'	d_3/d_3'	$J_4^*/J_4^{*'}$
Risella-33/5350	1,428	3,872	3,996	3,992	1,545	1,955
Syntheso D201 N/ Syntheso D 201	1,106	1,256	1,254	1,1867	0,918	0,866
Laprol 2502 /Laprol 1502	1,056	1,164	1,169	1,127	0,868	0,809
Risella-33+50% PVBE / Risella-33 (100%)	1,049	1,104	1,185	1,035	0,741	0,642
Risella-33+50% PVBE/PVBE(100%)	1,020	1,337	1,291	1,529	1,125	1,216

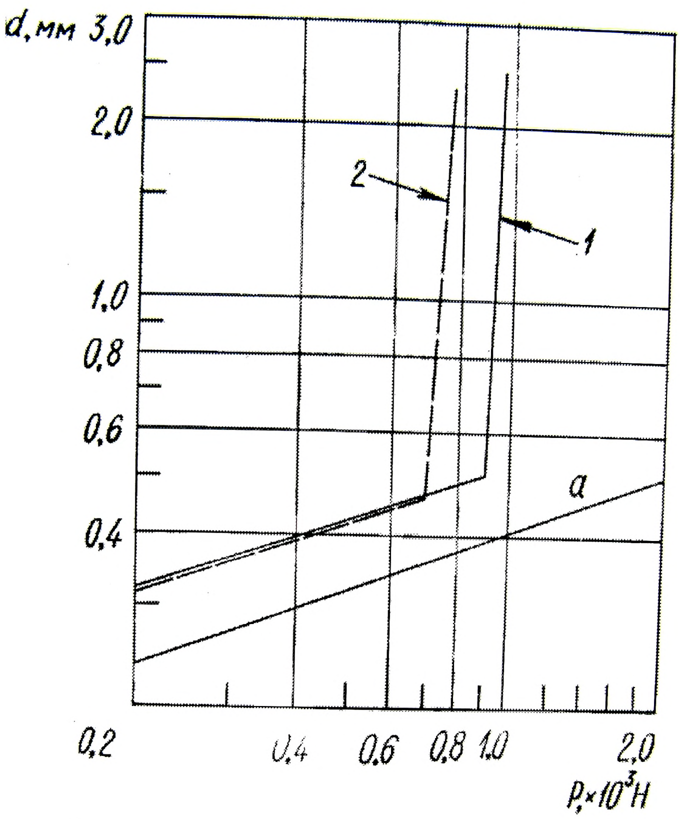

Fig. 11. Relations of wear spot (d) with loading (N) on one ball in theoretical point of contact of polyglycol oils:1 – Syntheso D-201 N; 2 – Syntheso D 201

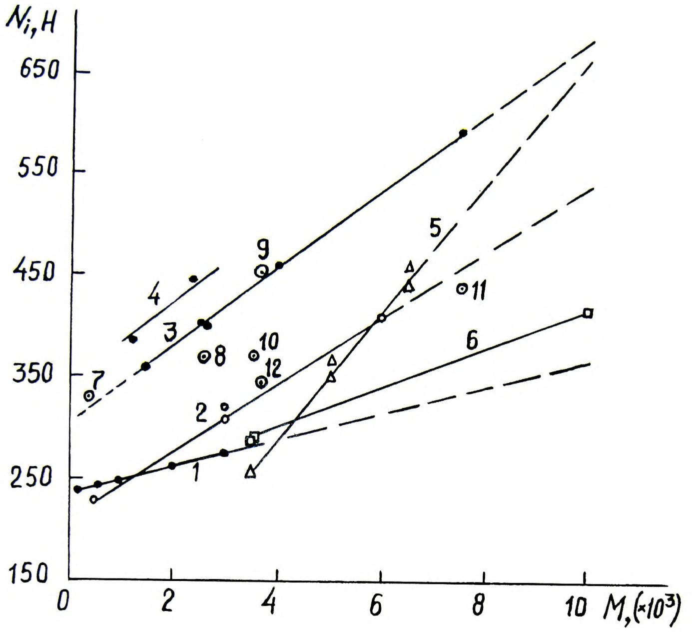

Fig. 12. Relation of loading capacity with molecular mass of polyglycols during testing on four-ball friction machine:1 – linear polypropylene; 2 – ramified polypropyleneglycols on the base of glycerin ; 3- statistic copolymer of propylene oxide and ethylene oxide (70%) Laprol; 4 – statistic copolymer of propylene oxide and ethylene oxide (%) Orites; 5 – blockcopolymer of propylene oxide and ethylene oxide (6-8%) on the base of glycerin; 6 – statistic copolymer of propylene oxide and ethylene oxide (70%) on the base of glycerin; 7 – polyethyleneglycol PEG-400; 8 – copolymer of propylene oxide (30%), ethylene oxide (67%) and glycerin residua with the star structure of molecule; 9 – Syntheso-202;Syntheso-201 N; 11 – Hydropol- 200; 12 – Proxanol CL-3.

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5. Compatibility of oils with polyethylene

Introduction

About 60% of high-pressure polyethylene is useв for makingproducts by method of moulding and pressurization-containers for food industry, products of domestic chemistry and children's toys, 20%- for making special films, which are stable to thermo- and photooxidation, films of capacitors and cableisolation with the heightened demands to the thermal aging and dielectricproperties [14].

One of the most important problems of the making is choosing the highlubrication gaskets of the cylinders or shafts of ethylene compressor. Delivering fluid lubricant to the friction pair is realized either by injection it intothe gas (phase of the suction- when use gaskets with the pistons rings) or byfeeding it through the openings of drilling of gasket's element (when use gladgaskets) [1; 3].

According to [1], in compressors at the compression up to 22-40 MPaspecific loadings of the gasket's elements reaches 7-10 MPa. In ethylenecompressors gas compresses from 25 up to 110-120 MPa (on the first degree) and from 110-120 MPa up to 180-250 (and even to 350) MPa (on the second degree). There fore, gasket elements of compressors experience during lubrication influence of the limit specific loadings from the hydrodynamic to limit regime and even to seizure [2;14].

In ethylene compressors friction pair are used:

- piunger made from the nitrided steel 38 ХМЮА or with coating of Wolfram carbide ; gasket elements from the bronze Бр ОСН 7-13-1;
- bush of the cylinder from the carbide of Wolfram (type БК-6), gasket rings fromthe special alloyed cast iron or from the bronze Бр ОФ> 10-1.

And also indexes of flow of plastics (g for 10 mm.), changes of bound of strength and flow during tension, relative extension during breakage ought to be found.

Demands to physic-and-chemical properties of polyethylene are determined by STATE STANDARD 16337-77 (for polyethylene) and STATE STANDARD 16336-77 (for compositions of polyethylene). Dielectrical properties of polyethylene and its composition are determined by [11-14]:

- tangent of angle of dielectrical loss – STATE STANDARD 22372-77;
- electrical strength at variable voltage (frequency 50 hertz) – STATE STANDARD 64333-71;
- dielectrical penetrability (frequency 10^6 hertz) – STATE STANDARD 22372-71;
- resistance to thermal aging – STATE STANDARD 16336-77.

Block-effect (sticking together of films) and content of extraction substances which are in initial polyethylene and which educe from it during secondary processing relate to quality indicators of polyethylene too. Content of these substances is estimated by excess of organic substance during lubrication of ethylene compressors with mineral oil and by using light mineral oils as solvents during peroxidative initiation of polymerization of ethylene [12-14].

Feasibility study of supplying of lubrication of seal elements relates not only to quality of polyethylene but to time wasted of compressor's equipment for repair (up to 2-7 days for a year), which for high productivity producers (synthesis of polyethylene) turns as substantial economical losses. More over it is necessary to add that after every seal replacement necessity (100-300 hours) of feeding through lubricators excess of oil (for running-in of friction pair) comes into existence. Polyethylene made in this period contents of substantial quantity of oil that is not up to the requirements (for cable isolation) [6-7].

Table 1

Characteristic of properties of naphtene and polyglicol oils (information of producers)

Index	Rieslla-33	NK M-40	NKM-70	Laprol 2502-2-70	Orites-270 DS
Density, kg/m^3 at 293 K at 303 K	 884 878	 873 867	 884 878	 1078	 1080
Coefficient of refraction of light (293 K)	1,4820	1,4794	1,4800	-	-
Viscosity kinematic, cs at 293 K at 303 K at 373 K	 126 42,4 8,8	 80,2 39,3 9,8	 180 70,4 12,8	 417 182 54	 462 186 46,8
Acid number, mg KOH/g	0,007	0,006	0,006	0,019	0,016
Temperature of solidifica-tion, K	255	255	260	-	≤270
Tempera-ture, K in closer crucible in open crucible	475 494	470 488	478 498	489 523	493 523
Content of water, %	0	0	0	0,1	0,1
Content of mechanic impurities, %	0	0	0	0	0

Materials

The demands to wear resistance of surfaces are: intensity of wearing counterface from alloy BK-6 is

ought to be not higher than 0,02 mkm/hour or 0,05 mm for 2500 hours of compressor's work.

Pressure of pumping is 200-300 MPa, temperature of gas at the end of process reaches 373 K, average velocity of piston – up to 2,5 m/s. Consumption of the oil for 1 t final product – polyethylene for different compressors is from 0,7-0,9 to 4,7-6,5 kg.

Properties and nature of oils determine quality indicators of polyethylene and reliability of work of seal pistons and plungers of ethylene's compressors. For lubrication of friction pair of these compressors mineral (naphthene - «white» oils), polybutene and polyglycol oils are used [3; 4],

Specifications to oils are: transparence, colourlessness, absence of sediment and mechanic impurities, viscosity (not less than) approximately 450 cs at 303 K, 200 cs at 323 K, 50 cs at 373 K; temperature of flash must be higher than 293 R from the maximal allowable (373-383 K), but better not lower than 473 K; temperature of solidification – not higher than 273 K; acid number -not more than 0,4 mg KOH/g; alkali number 0 mg KOH/g; content of moisture not more than 0,1%; ashes -0%; point of turbidity of 1% solution -not more than 353K [9].

According to manufacturers naphtene and polyglycol oils for the most quantity indicators satisfy these requirements (Table1).

Physic-and-ehemical properties and quantity of oil which ingresses in polyethylene determine its properties and use for cable isolation, products, which contact with food etc [8].

Methods of testing

Content of oil appreciably has an influence on such quality indicators as resistance (durability) to thermal aging and cracking and photooxidation processes,tangent of angle of dielectrical loss, dielectrical penetrability, breakdown electrical stress, sanitarian-hygienical properties. Content of oil in polyethylene is estimated by IR-spectroscopy (graduate by solution in CCl_4), tangent of angle of dielectric loss (frequency 10^3, 10^4, 10^6 hertz), dielectric penetrability (frequency 10^6 hertz) [5-7]. Were tested properties of high-pressure polyethylene (trademarkl0803-020), which was made in autoclave reactor with lubrication of compressors by naphtene oil Risella-33, and its artificial mixtures with 0,10 and 0,15% of oils: polyglycol Orites-210 DS and Syntheso-201 N, polyvynilbutylether (PVBE) and mixture 70% PVBE+30% Risella-33 without or with addition of thermostabilizer and 0,1-0,5% inhibitors of chain oxidation process – ionol, monox, diafen.

Artificial mixtures were got on laboratory mixer «Venbery» with mixing during 5-7 min. (t=393-403 K). After were made tablets, which were rolled (T=433±5 K) and fiictioned 1:1,2 during 2-16 hours.

Were found indexes [6-9]:

- tangent of angle of dielectric losses tg δ (frequency 10^6 Hz) by STATE STANDARD 22372-77;
- electrical strength $U_{cr.}$ during variable voltage with frequency 50 Hz by STATE STANDARD 6433.3-71;
- dielectric penetrability ε(frequency 10^6 Hz) by STATE STANDARD 22372-77;
- density ρ, boundary flow σ_T, limit strength σ_B and relative elongationduring breakage γ by STATE

STANDARD 16337-77;

- index of solution flow (ISF).

More over were taken into account methods of finding sanitarian-hygienical, dielectric, physics-and-mechanics properties and resistance to thermooxidative aging [10; 13; 14], Polyethylene for cable isolation by STATE STANDARD 16336-79 has to have such indexes:

- tangent of angle of dielectric losses tg δ (frequency 10^6 Hz) not more than $tg\delta \leq 3\cdot 10^4$;
- dielectric penetrability ε(frequency 10^6 Hz) not more than $\varepsilon \leq 2,3$;
- electrical strength when thickness of specimens is 1 and i variable voltage with

frequency 50 Hz not less than $U_{cr.} \geq 40$ кВ/мм [6-10].

Table 2

Physics-mechanics and dielectric properties of polyethylene (trademark 10803-020), synthesized during ingress of naphtene oil Risella-33, with addition of 0,15% of different oils and thermooxidants (recipe 01 and 02)

Recipe	Oils additives	Time of thermal aging, hours	ρ, kg/m^3	IFS, g/10 min.	tgδ,10^{-4}	σ_B, MPa	σ_T, MPa	γ,%
-	-	0	918,5	2,05	1,0	12,65	9,91	630
-	Syntheso - D201 N	0	919,2	2,16	2,11	12,75	10,30	613
0,2	Syntheso - D201 N	0	919,5	2,07	1,95	13,54	10,89	595
0,2	Syntheso - D201 N	6	-	11,6	10,95	9,32	10,89	555
0,2	Syntheso - D201 N	8	-	-	16,8	8,50	9,90	430
0,1	Syntheso - D201 N	0	920	2,15	1,95	12,96	10,3	598
0,1	Syntheso - D201 N	6	-	2,21	1,99	12,85	10,2	574
0,1	Syntheso - D201 N	8	-	2,26	4,28	11,67	10,0	563
-	PVBE	0	918,3	2,15	1,68	12,56	10,4	583
0,2	PVBE	0	918,5	2,22	1,65	13,54	11,09	608
0,2	PVBE	6	-	2,41	1,71	13,44	10,79	561
0,2	PVBE	8	-	2,51	2,5	13,34	10,59	560
0,1	PVBE	0	918,5	2,20	1,15	12,75	10,79	593
0,1	PVBE	6	-	2,22	1,52	12,16	10,20	565
0,1	PVBE	8	-	2,30	1,85	11,28	9,42	577
-	PVBE+30% Risella-33	0	918,3	2,06	1,98	12,56	9,71	600
0,2	PVBE+30% Risella-33	0	918,3	2,37	2,10	13,63	11,09	612
0,2	PVBE+30% Risella-33	6	-	2,39	2,19	12,26	10,04	555
0,2	PVBE+30% Risella-33	8	-	2,44	2,72	11,48	9,91	550
0,1	PVBE+30% Risella-33	0	918,3	2,22	1,05	13,54	10,40	603
0,1	PVBE+30% Risella-33	6	-	2,32	1,36	12,85	10,20	600
0,1	PVBE+30% Risella-33	8	-	2,35	1,44	12,36	9,91	593

Table 3

Viscous-mechanical properties of polyethylene (trademark 10803-020) during addition of different quantity of lubricants

Polyethylene trademark	Oil	Concentration of oil	ISF g/10 min	tg δ, 10^{-4}	Resistance to cracking, hours
M 10803-020	-	-	2,05	1,0	2,5
M 10803-020	Syntheso D-201 N	0,15	2,16	2,11	2,5
M 10803-020	Syntheso D-201 N	0,10	2,11	1,82	2,5
M 10803-020	PVBE	0,15	2,15	1,68	2,5
M 10803-020	PVBE	0,10	2,23	1,04	2,5
M 10803-020	PVBE (70%)+ Risella-33 (30%)	0,15	2,06	1,98	2,5
M 10803-020	PVBE (70%)+ Risella-33 (30%)	0,10	2,35	1,09	2,5

Polyethylene trademark	Oil	Mechanical properties			Density, km/m^3
		σ_1, MPa	σ_2, MPa	γ,%	
M 10803-020	-	12,65	9,91	630	918,5
M 10803-020	Syntheso D-201 N	12,75	10,3	613	919,2
M 10803-020	Syntheso D-201 N	13,04	10,69	608	919,3
M 10803-020	PVBE	12,56	10,4	583	918,3
M 10803-020	PVBE	12,94	10,49	600	918,7
M 10803-020	PVBE (70%)+ Risella-33 (30%)	12,56	99,971	600	918,3
M 10803-020	PVBE (70%)+ Risella-33 (30%)	12,26	10,11	555	918,1

Table 4

Properties of ethylene compositions (recipe 0,1 and 0,2) with different content of oils inside

Recipe	Oil	Concentration of oil	Thermal aging, hours	IFS, g/10 min.	Tg δ, 10^{-4}	Resistance to cracking, hours
0,2	Syntheso D-201 N	0,15	init. 5,5	2,07 11,6	1,95 10,95	2,5
0,2	Syntheso D-201 N	0,10	init. 6 8	2,19 do not sust. do not sust.	2,59 9,32 16,9	2,5
0,1	Syntheso D-201 N	0,15	init. 6 8	2,15 2,21 2,26	1,95 1,99 4,28	2,5
0,1	Syntheso D-201 N	0,10	init. 6 8	2,21 2,18 2,22	1,88 1,79 1,96	2,5
0,2	PVBE	0,10	init. 6 8	2,18 2,22 2,30	1,15 2,19 2,30	2,5
0,2	PVBE	0,15	init. 6 8	2,22 2,41 2,51	1,65 1,71 2,5	2,5
0,1	PVBE	0,10	init. 6 8	2,20 2,17 2,09	1,48 1,54 2,19	2,5
0,1	PVBE	0,15	init. 6 8	2,20 2,22 2,30	1,15 1,52 1,85	2,5

Continuation Table 4

0,2	PVBE (30%)+ Risella-33 (70%)	0,15	init. 6 8	2,37 2,30 2,44	2,10 2,19 2,72	2,5
0,2	PVBE (30%)+ Risella-33 (70%)	0,10	init. 6 8	2,31 2,35 2,38	1,50 1,53 1,54	2,5
0,1	PVBE (70%)+ Risella-33 (30%)	0,10	init. 6 8	2,15 2,25 2,25	1,09 1,11 1,35	2,5
0,1	PVBE (70%)+ Risella-33 (30%)	0,15	init. 6 8	2,22 2,32 2,35	1,05 1,36 1,44	2,5

Continuation Table 4

Recipe	Oil	Concentration of oil	Mechanical properties			Density, km/m^3
			σ_1, MPa	σ_1, MPa	σ_1, MPa	
0,2	Syntheso D-201	0,15	13,54 9,32	10,89 10,89	595 555	919,5
0,2	Syntheso D-201	0,10	12,76 12,36 10,40	10,39 11,18 11,48	595 594 436	920,0
0,1	Syntheso D-201	0,15	12,96 12,85 11,67	10,30 10,20 10,00	598 574 563	920,0
0,1	Syntheso D-201	0,10	12,46 12,07 11,38	10,69 10,69 10,59	610 449 448	919,5
0,2	PVBE	0,10	13,74 12,46 12,26	11,08 9,32 9,52	597 555 560	918,7
0,2	PVBE	0,15	13,54 13,44 13,34	11,09 10,79 10,59	608 561 560	918,5
0,1	PVBE	0,10	12,85 12,95 13,54	10,89 10,40 10,49	525 585 588	918,7
0,1	PVBE	0,15	12,75 12,16 11,28	10,79 10,20 9,42	593 565 577	918,5
0,2	PVBE (30%)+ Risella-33 (70%)	0,15	13,63 12,26 11,48	11,09 10,40 9,91	612 555 550	918,3
0,2	PVBE (30%)+ Risella-33 (70%)	0,10	12,36 12,46 12,75	10,11 9,91 9,91	570 563 580	918,3
0,1	PVBE (70%)+ Risella-33 (30%)	0,10	13,34 12,95 12,26	10,69 9,91 9,91	585 577 595	918,5
0,1	PVBE (70%)+ Risella-33 (30%)	0,15	13,54 12,85 12,36	10,40 10,20 9,91	603 600 593	918,3

Results and discussion

Results of laboratory tests are adduced in Table 2. As we can see from Table 2, resistance to thermal aging for ethylene composition determines by oil's nature, its content in polymer and activity and content of thermostabilizer – antioxidants. For recipe with content 0,05% of oil Orites-210DS and 0,1-0,2% stabilizer nonox WSP resistance to thermal aging is 8 hours, that is up to the requirements of STATE STANDARD 16336-77, for ethylene composition with content 0,05% of polyvynilbutylether oil is more than 14 hours.

As is seen from the tabl. 2, addition of 0,15% of poly glycol Syntheso – D201 N with additive to initial and with thermoadditives (by recipe 01 and 02) of polyethylene leads to substantial changes of physics-and-chemical and dielectric properties. For recipe 02 of thermal aging during 8 hours leads to decreasing: tgδ from 1,95 to $16 \cdot 10^{-4}$, σ_B from 13,54 to 8,5 MPa, σ_T from 10,89 to 9,9 MPa, γ from 595 to 437%, and for recipe 01 these changes smaller: tgδ from 1,95 to $4{,}28 \cdot 10^{-4}$, σ_B from 12,96 to 11,67 MPa, σ_T from 10,3 to 10,0 MPa, γ from 598 to 563%.

Addition of 0,15% of initial polyvynilbutylether or with mixtures of Risella-33 to initial and with thermoadditions polyethylene leads to small changers its properties (these changes are smaller for recipe 01 than for recipe 02) for indexes: tgδ from $1{,}05\text{-}2{,}1 \cdot 10^{-4}$ to $1{,}44\text{-}2{,}72 \cdot 10^{-4}$, σ_B from 12,75-13,63 MPa to 11,28-13,34 MPa, σ_T from 10,4-11,09 MPa to 9,42-10,59 MPa, γ from 593-612% to 550-593%. In table 3 are adduced properties of polyethylene (trademark 10803-020) during in put to it of 0,1 and 0,15% (weight) of tested oils. As is seen from the Table 3, physics-and-mechanical properties of polyethylene stay up to requirements of STATE STANDARD 16337-77.

Analysis of results in Table 4, shows that physics-and-mechanical properties of compositions are up to requirements of STATE STANDARD 16337-77. Oil PVBE and its mixtures with oil Risella-33 provide quality of compositions of recipe 0,1 and 0,2 up to requirements of STATE STANDARD 16337-77, (and to index "resistance to thermal aging". Oil Syntheso D-201 makes worse properties of polyethylene compositions of recipe 0,1 and 0,2, especially its resistance to thermooxidative aging [14].

Conclusions

Were tested properties of high-pressure polyethylene (trademarkl 0803-020), which was made in autoclave reactor with lubrication of compressors by naphtene oil Risella-33, and its artificial mixtures with.

It is shown resistance to thermal aging for ethylene composition determines by oil's nature, its content in polymer and activity and content of thermostabilizer – antioxidants. As is seen, addition of 0,15% of poly glycol Syntheso – D201 N with additive to initial and with thermoadditives (by recipe 01 and 02) of polyethylene leads to substantial changes of physics-and-chemical and dielectric properties.

Analysis of results shows that physics-and-mechanical properties of polyethylene (trademark 10803-020) during in put to it of 0,1 and 0,15% (weight) of tested oils and of compositions are up to requirements of STATE STANDARD 16337-77. Oil PVBE and its mixtures with oil Risella-33 provide quality of compositions of recipe 0,1 and 0,2 up to requirements of to index "resistance to thermal aging". Oil Syntheso D-201 makes worse properties of polyethylene compositions of recipe 0,1 and 0,2, especially its resistance to thermooxidative aging.

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