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New microemulsion hydraulic fluid for mechanised mine supports

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Abstract

A new oil-in-water microemulsion composition has been proposed, incorporating a suite of multifunctional chemical additives (surfactants, improver additives) produced and marketed in Russia. The composition is intended for use as a hydraulic fluid for mechanised mine supports. The physicochemical properties of the developed concentrate and the well-known SOLCENIC GM 20 microemulsion concentrate (Fuchs, Germany) are close to each other. The developed microemulsion concentrate is recommended as a replacement for the foreign-made product.

Keywords: microemulsion, corrosion inhibitor, hydraulic fluid, mine support

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INTRODUCTION

Water-based functional fluids are used as injection fluids in the hydraulic systems of mine longwall supports, as cutting coolants, etc.

One of the main requirements to hydraulic fluids for mechanised mine supports is non-inflammability during operation. This requirement is caused by numerous cases of mine fire events, especially after the catastrophe in Marcinelle (Belgium) in 1956 at the Bois du Cazier mine. Fires were caused by possible damage of mine supports, electrical wirelines or oil pipelines for hydraulic machines. Combustion of hydraulic oil occurred.

After the catastrophe in Marcinelle, the mine technical inspection started developing new incombustible hydraulic fluids. The major requirements to hydraulic fluids were listed in the Luxembourg Report (the 1st edition of 20.12.1960). At present, the 7th Luxembourg Report of 01.04.1995 is in effect, and its requirements are compulsory for the underground application of hydraulic fluids. The Committee on industrial safety and health protection at the coal mining enterprises of the European Community has established the main requirement to hydraulic working fluids: fire safety. In addition, hydraulic fluids should protect mine support equipment from corrosion, be stable against microbiological affection, provide high lubricating characteristics, be stable to the action of chemical elements, exhibit stability of viscous characteristics within a broad temperature range, be stable against decomposition and layering.

Hydraulic working fluids are to transmit a force in the closed hydraulic systems and can be divided into three main groups [1]:

1) fluids with high mineral oil content (40–60 %) – common emulsions or macroemulsions;

2) fluids with low mineral oil content (up to 20 %) – semi-synthetic media or microemulsions;

3) fluids without mineral oil – synthetic media.

Fluids with the high oil content (macroemulsions) exhibit rather low physical stability, that is, these systems are prone to layering into two phases, especially under the dynamics conditions of highly loaded mechanised mine supports. Instability of hydraulic fluid under performance conditions causes the necessity of its frequent replacement in the hydraulic drive system, which is uneconomical. In addition, emulsions with high mineral oil content can get inflamed if spilled or in other emergency situations.

At present, microemulsions are most frequently used as hydraulic fluids for mine supports because they contain substantial amounts of water, which provides their non-inflammability and fire safety. These fireproof fluids based on water are designated as HFA. Microemulsions are distinguished by their high physical stability under static and dynamic conditions under high load in the hydraulic drives of mine supports. Large amounts of water in the microemulsion concentrate do not produce readily inflammable vapours, so these concentrates are safe.

It is reasonable to use water-oil microemulsions with small proportions of the oil component (15–25 %) and high content of surfactants as the working fluids for mine supports. The properties of these microemulsions have been described in [2]. The concentrate of microemulsion should necessarily contain, in addition to a large amount of surfactant, also corrosion inhibitors, bactericides and fungicides. The working hydraulic fluids for use in mine supports are prepared by mixing microemulsion concentrate in the proportion of 2–5 vol% with water.

Various trademarks of the concentrates are present on the hydraulic fluid market for mechanised mine supports.

One of the known microemulsion concentrates is SOLCENIC GM 20 (Fuchs, Germany). This is a concentrate of fireproof fluid of HFA class, intended for application in the hydraulic system of mechanised supports, developed in agreement with the requirements of the manufacturers of modern mining equipment. The SOLCENIC GM 20 concentrate has been developed using the advanced technologies applied by Fuchs company (Germany) for hydraulic fluid concentrates. SOLCENIC GM 20 contains mineral oil (20 %), as well as specially chosen corrosion inhibitors and additives improving their greasiness, so this concentrate exhibits high stability when mixed with technical water in the concentration of 2–3 %. SOLCENIC GM 20 preparation possesses high stability against biological damage of the working fluid under the coal mine conditions. The microemulsion concentrate SOLCENIC GM 20 has been used for a long time at a number of coal mines in Donbass (Krasnoarmeyskaya Zapadnaya mine, Zasyadko mine, etc.).

In spite of the good quality of the product, the high price of hydraulic fluid SOLCENIC GM 20 for large-tonnage supply to coal mining enterprises has caused the necessity to develop a cheaper composition in which the surfactants and other additives manufactured at the chemical plants in Russia within the available cost range would be used.

In addition, it was necessary to achieve compatibility of the developed microemulsion composition with the microemulsion preparation SOLCENIC GM 20. This is important because conversion of mine support operation to the hydraulic fluid of different nature can lead to layering of the final product in the case of incompatibility of microemulsion concentrates. In these cases, it would be necessary to pour a fluid off and to wash the mine support system before replacing the fluid for a new one. These operations require time and material expenditures.

The goal of the present work is to investigate the possibility to obtain a microemulsion concentrate for use as hydraulic fluid in mechanised mine supports, on the basis of raw materials (surfactants, additives) manufactured in our country, and to compare the physicochemical characteristics and compatibility of the developed microemulsion composition with the known microemulsion preparation SOLCENIC GM 20.

EXPERIMENTAL

Materials

The materials used in the work were: industrial oil I-20 (GOST 20799-88); 2-mercaptobenzothiazole (captax) (GOST 739-41, Russia); fatty alcohol $C_{15}–C_{18}$ (GOST 13937-86, Russia); a mixture of monoethyl ethers of polyethylene glycol, OP-10 grade (GOST 8433-81, Russia); sodium lauryl ether sulphate (Russia); monoethanolamine (GOST 19234-87, Russia); triethanolamine (GOST 9966-88, Russia); ethylene glycol (GOST 19710-2019, Russia); neonol (GOST 12.1.007, Russia); polyethylene glycol PEG-6000 (GOST 12.1.007-76:4, Russia); sodium ethylenediamine tetraacetate (GOST 10652-73, Russia); alkylbenzene sulphonic acid (TU 2481-036-04689375, Russia); oleic acid (GOST 758091, Russia); sodium naphthenate (GOST 13302-77, Russia); calcium hydroxide (GOST 9262-77, Russia).

Investigation procedures

The microemulsion composition was obtained under laboratory conditions by mixing the components in a mechanical agitator at the rotation frequency of 3000–3500 r.p.m. with heating.

RESULTS AND DISCUSSION

A new composition of the oil-in-water microemulsion composition incorporating a set of multifunctional chemical additives has been proposed in the work. These chemical additives are emulsifiers (decreasing the surface tension between oil and water phases); microemulsion stabilisers (provide system stability under static and dynamic conditions); metal corrosion inhibitors; bactericides; fungicides; the substances that enhance system performance in waters with increased hardness and acidity; the substances with lubricating effect; the substances providing a broad temperature range for hydraulic fluid performance, etc. The following goals have been put forward:

1) The composition of surfactant mixture should provide the possibility of complete stabilisation of mineral oil in water.

2) The amount of each ingredient in surfactant mixture should be determined by optimising the composition of microemulsion by varying the concentrations of components.

3) The preparation under development should be compatible with SOLCENIC GM 20, that is, the physicochemical and consumer characteristics should not be changed after mixing these two microemulsions.

Colloidal stability of the microemulsion composition

An essential property of hydraulic fluids based on microemulsions is their colloidal stability, which means the stability of microemulsions against layering into two phases (oil and water) due to aggregation (adherence) of mineral oil particles in water [2, 3].

Microemulsions are fine dispersed systems formed by two mutually insoluble liquids. A critical parameter determining the ability of oil phase particles to form a stable colloidal system is the particle size.

The characteristics of mineral oil particles in the oil-in-water emulsions are presented in Table 1 [4]. It follows from these data that micro- and submicron emulsions have preferable colloidal stability characteristics. The characteristic that differentiates a microemulsion from macroemulsion is a low oil content in the system and a higher ratio of emulsifiers and stabilisers to the dispersed (oil) phase. According to the literature data, the main issue for successful preparation of a microemulsion system is the choice of emulsifying agent [2, 3].

A mixture of surfactants with different chemical structures was used to form microemulsion in the oil-water system. This is associated with the fact that the composition of mineral oil in nonhomogeneous and includes the hydrocarbons of different classes: paraffinic (aliphatic), naphthenic, aromatic, and unsaturated hydrocarbons (olefins) [5]. Industrial mineral oil (I-20) used in the work to prepare microemulsion belongs to the group of alkyl naphthenic hydrocarbon oils with low viscosity (5–20 mm^2/s at 50 °C). So, to stabilise mineral oil, we used a mixture of surfactants containing aliphatic, naphthenic, aromatic and olefinic fragments in the structure of molecules.

The high concentrations of surfactants (emulsifiers and stabilising agents) are a positive issue in the mechanism of microemulsion preparation. However, when optimising the composition, we

TABLE 1

Characteristics of mineral oil particles in oil-in-water emulsions [4]

Particle size	Description	Characteristics
300–1000 nm (0.3–1.0 μm)	Macroemulsion	White-blue, milk-like liquid. Satisfactory physical stability.
100–300 nm (0.1–0.3 μm)	Submicron emulsion	Semi-transparent liquid. Increased physical stability.
10–100 nm (0.01–0.1 μm)	Microemulsion	Semi-transparent to transparent liquid. High physical stability.

also took into account the economical factor for obtaining the concentrate in the form of microemulsion, because the cost of hydraulic fluid is determined first of all by the prices of surfactants and other additives.

The proposed chemical additives perform several functions at a time in the composition. The main surfactants in the preparation of microemulsions were the salts of fatty acids and the salts of fatty sulphonic acids. Sulphonol, superalkaline calcium sulphonate and the salts of ethanol amines and fatty acids are the derivatives of aliphatic hydrocarbons, while sodium naphthenate is a derivative of naphthenic hydrocarbons.

Multifunctional auxiliary surfactants performing additional functions (wetting, emulsifying, and stabilising) were also applied. This was a mixture of monoalkyl ethers of polyethylene glycol of OP-10 grade, polyethylene glycol (PEG-6000), neonol and fatty alcohols. These substances are necessary when preparing microemulsion for achieving a maximal decrease of the surface tension between the oil and water phases, for the formation of micelles of complex composition and for providing additional stabilisation of the oil–water surface layer.

In addition to surfactants, functional additives were also used for obtaining microemulsion to provide the necessary consumer properties of the hydraulic fluid: captax (2-mercaptobenzothiazole) – as metal corrosion inhibitor, Sodium ethylenediamine tetraacetate (EDTA) – to ensure the possibility to prepare the working solution of the concentrate using water with increased hardness, ethylene glycol – as a non-freezing agent to conserve the properties of microemulsion within a broad temperature range, calcium hydroxide – to provide the necessary level of acidity (pH > 10).

The microemulsion composition was tested for colloidal stability within a broad temperature range (Table 2). Microemulsion composition remains stable (without any signs of layering) for more than 30 days at a temperature of 20–30 °C, for 10 h at a temperature of 60–80 °C and for 48 h at a temperature from −10 to −30 °C under static conditions. It has been determined that microemulsion composition after melting and after being affected by high temperatures does not change its initial physicochemical properties.

The features of working-fluid performance in the hydraulic drives of mechanised supports imply its use under pressure, with high flow rates and substantial deformations of the flows in velocity, section, and direction. So, it was necessary to meet the conditions of the colloidal stability of the water emulsion system under dynamic conditions. The behaviour of emulsion systems under dynamic conditions should exhibit colloidal stability under the action of a high load on the system. The colloidal stability of the water emulsion system was tested under dynamic conditions. This parameter was assessed for centrifuging in a laboratory ultracentrifuge for 30 min at the rotor frequency of 15000 r.p.m. and in the rotary viscosity meter “Reotest-2”(Mettingen, Germany) for 30 min at the maximal shear velocity (deformation velocity) $\acute{\varepsilon} = 1312\ s^{-1}$. It has been determined that the microemulsion composition remains stable (without any signs of layering) under the chosen dynamic conditions, which are close to the load occurring during operation in mine supports (see Table 2).

The working hydraulic fluids contain water up to 95–97 %. For this reason, when diluting the concentrate with water, it is necessary to take into account the possible effect of different water

TABLE 2

Colloidal stability of the microemulsion composition under static and dynamic conditions

Composition	Static conditions		Dynamic conditions	
	30 days at 25–30 °C	10 h at 60–80 °C	Centrifuging for 30 min at 15000 r.p.m. at 25–30 °C	Exposure for 60 min with the shear velocity of $\acute{\varepsilon} = 1312\ s^{-1}$ at 25–30 °C
Concentrate of microemulsion	Colloidal stability	Colloidal stability	Colloidal stability	Colloidal stability
3 % solution of microemulsion concentrate	Colloidal stability	Colloidal stability	Colloidal stability	Colloidal stability
Concentrate SOLCENIC GM 20 (Fuchs, Germany)	Colloidal stability	Colloidal stability	Colloidal stability	Colloidal stability
3 % solution of concentrate SOLCENIC GM 20	Colloidal stability	Colloidal stability	Colloidal stability	Colloidal stability

TABLE 3

Stability of 3 % solution of microemulsion concentrates to iron(III) chloride

3 % solution of concentrate	0.5 % $FeCl_3$	0.25 % $FeCl_3$	0.1 % $FeCl_3$	0.01 % $FeCl_3$
Microemulsion	Becomes cloudy, homogeneity is disturbed	Becomes cloudy, homogeneity is disturbed	Colloidal stability	Colloidal stability
SOLCENIC GM 20 (Fuchs, Germany)	Becomes cloudy, homogeneity is disturbed	Becomes cloudy, homogeneity is disturbed	Colloidal stability	Colloidal stability

TABLE 4

Stability of 3 % solutions of microemulsion concentrate against the action of acid (HCl) at different pH

3 % solution of the concentrate	0.1 M HCl, pH 1.0	0.085 M HCl, pH 1.07	0.05 M HCl, pH 1.3	0.01 M HCl, pH 2.0
Microemulsions	Disturbance of colloidal stability	Disturbance of colloidal stability	Colloidal stability	Colloidal stability
SOLCENIC GM 20 (Fuchs, Germany)	Disturbance of colloidal stability	Disturbance of colloidal stability	Colloidal stability	Colloidal stability

TABLE 5

Colloidal stability of 3 % solutions of microemulsion composition concentrates depending on water hardness*

3 % solution of the concentrate	Tap water	Mine water	
	H = 9.0 mg-eq/L or 12.62°H	H = 44.0 mg-eq/L or 61.7°H	H = 103.0 mg-eq/L or 144.4°H
Microemulsion	Colloidal stability	Colloidal stability	Becomes cloudy, disturbance of colloidal stability
Microemulsion without EDTA	Colloidal stability	Becomes cloudy, disturbance of colloidal stability	Precipitate is formed, colloidal instability
SOLCENIC GM 20 (Fuchs, Germany)	Colloidal stability	Becomes cloudy, disturbance of colloidal stability	Precipitate is formed, colloidal instability

* Measurement units: H, mg-eq/L – in Russia; °H, water hardness degree – in Germany.

sources, in particular different levels of hardness and acidity (for example, mine waters) under emergency conditions. Mine waters are polluted mainly with the suspended rock and coal particles, and strongly mineralised. In addition to the major hardness ions (calcium and magnesium salts), mine waters also contain iron and aluminium salts. Mine waters are acidic (pH 2.0–4.5, sometimes below 2.0) [6].

In the present work, we tested the stability of water-base emulsion against the action of iron salts (iron(III) chloride) and the acid-base medium within the acid pH range. The emulsion concentrate was diluted with water, and the calculated amounts of $FeCl_3$ or HCl were added; then the mixture was kept for 24 h at 25–30 °C. One can see in the data presented in Table 3 that the working 3 % solution of microemulsion is stable to the action of iron salts until their concentration in the composition reaches 0.1 %. Under pH variations, it has been shown that the working solution of microemulsion retains its colloidal stability in the acid medium up to the acid concentration of 0.5 M (pH 1.3) (Table 4).

The colloidal stability of the working fluid, prepared by diluting microemulsion concentrate, to water hardness was assessed. The concentrate of microemulsion was diluted with tap water and mine waters with different hardness (H, mg-eq/L) in the presence of additives. According to the data obtained (Table 5), the developed composition of microemulsion hydraulic fluid allows preparing working solutions by diluting with water characterised by large hardness values.

The main components overcoming water hardness in water-based emulsion fluid are complexone additives (for example, EDTA).

Corrosion stability of the microemulsion concentrate

Hydraulic fluids are intended for operation in the hydraulic systems of mine supports, which implies their direct washing action on metal structures that form mine supports, so it is necessary to assess the anticorrosion effect of the concentrate of water0emulsion composition. Water-based functional fluids should provide protection from corrosion to prevent its development on the surface of the material in contact with working fluids. Corrosion activity can be the reason of local corrosion, corrosion softness, the formation of craters, and the deposition of corrosion products on the surfaces of materials. The reasons for corrosion activity of working fluids are associated with the accumulation of aggressive chemical compounds in the fluids. Among these compounds, the main effect on metal corrosion is caused by peroxides.

To prevent corrosion, anticorrosive agents and other auxiliary substances are introduced into water-based functional fluids: animal, vegetable, mineral or synthetic oils, fats, oil or fat components, fatty alcohols.

It is also necessary to assess the anticorrosion action of hydraulic fluid on steel and on the alloys containing copper and zinc (for instance, brass). Hydraulic fluids should be well compatible with zinc and copper because zinc-coated pipes are used to transport hydraulic fluids from the pump station to the mining face, and mine supports contain zinc- and copper-containing elements connected to steel structural elements.

An anti-corrosive agent (corrosion inhibitor) that has been developed for steel and nonferrous metals contains a mixture of components with different mechanisms of inhibiting action. The mixture contains captax, derivatives of ethanolamines (the salts of fatty acids with ethanolamines), and superalkaline component. The corrosion inhibitor also contains sodium naphthenate, a mixture of monoalkyl ethers of polyethylene glycol of OP-10 grade.

Captax (2-mercaptobenzothiazol) is a known sulphur- and nitrogen-containing corrosion inhibitor for steel and nonferrous metals, soluble in oils and in alkaline aqueous solutions. Captax is an inhibitor suppressing the corrosion of steel and nonferrous metals by destroying hydroperoxides that are formed in the working fluid as a result of metal oxidation [7, 8].

It is known that compositions containing ethanolamine derivatives are used as corrosion inhibitors. Ethanolamine derivatives belong to the group of nitrogen-containing corrosion inhibitors that are able to hamper oxidation processes due to participation in the oxidation of hydrogen atoms in amino groups [8]. The samples of ethanolamines with fatty acids were used in the microemulsion composition.

The inhibiting effect of superalkaline calcium sulphonates is because these compounds do not form dissociating ion solutions in water. These compounds protect iron and nonferrous metals from corrosion due to the features of sulphonate adsorption on the metal surface [9, 10]. The excess of calcium hydroxide in superalkaline calcium sulphonate provides the alkaline reaction of the working fluid.

The salts of humic acids (HA) were investigated as a possible additive into the microemulsion composition. It is known that sodium humates exhibit surfactant properties [11, 12] and can be used as surfactants in microemulsions. These substances were also studied as oxidation inhibitors (antioxidants) in the model reactions of hydrocarbon oxidation because HA are natural polyphenolic compounds.

Initiated oxidation of cumene and ethylbenzene was chosen as a model system because the mechanism and all elementary stages are well known for these compounds [13]. Liquid-phase oxidation of cumene and ethylbenzene, initiated by azodiisobutyronitrile (AIBN, reaction initiator), in dimethylsulphoxide (DMSO) in the presence of humic acids was studied within a broad concentration range. The process kinetics was followed using the volumetric gas analysis by measuring the amount of oxygen absorbed at a constant temperature of 75 °C and constant partial pressure of oxygen 760 mm Hg. The process was carried out in the kinetic region, where the reaction rate is independent of mixing rate.

It follows from the data shown in Fig. 1 that the addition of HA to the model reaction mixture

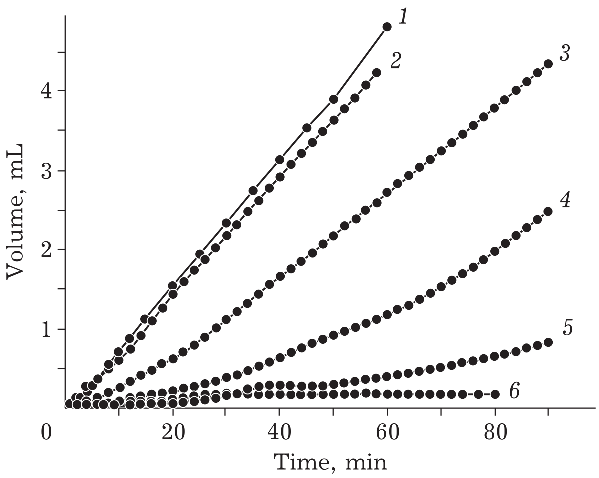


Fig. 1. Volume of absorbed oxygen depending on time of cumene oxidation (kinetic curves) in the presence of humic acid (HA) solutions with varied concentrations of humic acids [HA], g/L: 0 (*1*), 0.1 (*2*), 1.0 (*3*), 2.0 (*4*), 5.0 (*5*), 10.0 (*6*) [14].

TABLE 6

Oxygen absorption rate ($W_{[O]}$) in the system hydrocarbon – AIBN (initiator) – HA for varied humic acid concentration [14]

[HA], g/L	$W_{[O]}$, 10^{-6} mol/(L · s)	
	Cumene	Ethylbenzene
0	2.76	1.17
1.0	1.72	0.81
2.0	0.93	0.76
5.0	0.31	0.37
7.0	0.24	0.27
10.0	0.08	0.21

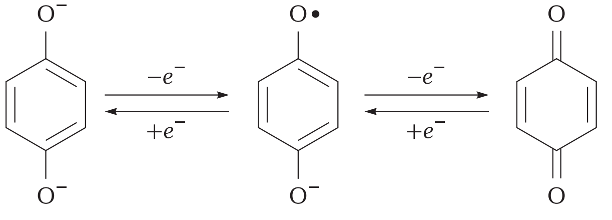
Note. HA – humic acids, AIBN – azodiisobutyronitrile (initiator).

of the hydrocarbon with initiator causes suppression of the oxidation of hydrocarbon substrate, and the effect increases with an increase in HA concentration. The rate of oxygen absorption ($W_{[O]}$) for the oxidation of hydrocarbons (cumene, ethylbenzene) decreases substantially with an increase in the concentration of HA in the systems under oxidation (Table 6).

The groups responsible for electron transfer with the participation of HA macromolecules and other hydroxyl-containing components are phenolic hydroxyls and quinoid fragments (Scheme 1) [15].

According to the results obtained, HA from brown coal exhibit pronounced antioxidant properties and serve as efficient inhibitors of oxidation processes. These compounds can hamper oxidation due to hydrogen atoms of their phenol hydroxyl groups (–OH) participating in oxidation [10, 14]. As corrosion inhibitors, the derivatives of humic acids can be related to the substances with prolonged inhibiting action due to the large amount of hydroxyl groups (–OH) in the structure of their macromolecules, which provides an increase in the duration and efficiency of this action.

The high antioxidant activity of HA allows recommending them for use as a component of the complex corrosion inhibitor for steel and non-ferrous metals in microemulsion hydraulic fluids.



Scheme 1.

Similarly to HA, the salts of naphthenic acids (naphthenates) are a complex mixture rather than a single component, structure or formula. Nevertheless, they find diverse applications in technical directions. Naphthenates are used in industry, in particular for the production of surfactants (synthetic detergents for technical applications), lubricating compounds, metal corrosion inhibitors, additives to fuels and lubricant oils, bactericides, insecticides, fungicides, acaricides, etc. [16]. Thus, sodium naphthenates are multifunctional additives and are used as inhibitors of the listed processes, emulsifiers and stabilising agents in the microemulsion composition. The mechanism of inhibiting action of sodium naphthenates involves adsorption of its macroanions on the metal surface, which leads to screening and causes diffusion limitations for oxidising reagents. Adsorbed sodium naphthenate particles prevent oxygen adsorption on the metal surface and thus cause a decrease in corrosion rate.

Captax, the derivatives of ethanolamines, superalkaline components and the salts of naphthenic acids are known metal corrosion inhibitors. However, the anticorrosion composition (complex inhibitor) developed by us, containing a mixture of these components, has not been described previously.

The corrosion inhibitor in water-emulsion hydraulic fluid is a mixture of components containing ingredients with different mechanisms of inhibiting action, namely nitrogen-, sulphur-, hydroxyl-containing components, a superalkaline component, and sodium naphthenate. So, the performance of the microemulsion composition will involve blocking of the main mechanisms of corrosion for the metal structures of mine supports.

The procedure used to determine anticorrosion activity was as follows. The samples of metal plates were kept in microemulsions at a temperature of 60±1 °C for 4 h with permanent mixing with a mechanical stirrer rotating at a frequency of 1000±50 r.p.m., and then in the microemulsion medium at room temperature (20–25 °C) for 30 days.

We have shown (Table 7) that the concentrate of microemulsion and its 3 % solution exhibit high anticorrosion effect with respect to steel and non-ferrous metals. Corrosion degree was determined in agreement with [17].

Bacteriological analysis of microemulsion fluids

There always exists a danger of various microorganisms, first of all bacteria and fungi, emerging in water-based hydraulic fluids [18]. The growth of microorganisms in the hydraulic system can be causes by a number of reasons, including corrosion of the equipment, an increase in temperature, worsening of the efficiency of filtering elements, penetration of bacterial cells and the products of bacterial metabolism into the system. When the spent working fluid is poured off the hydraulic system, it gets on the soil and in water, thus causing a hazardous action on living organisms and the environment. For this reason, to prevent the propagation of microorganisms, flame-resistive and environmentally safe antimicrobial additives are always included into the concentrate of hydraulic fluid [19].

Bacteriological analysis of microemulsion fluids was carried out using the dish method according to [20]. The material under investigation (sample) was inoculated on the dense culture medium (agar-agar) in Petri dishes. Incubated microemulsion samples were kept at 37 °C for 1 day on the culture medium. After incubation, the colonies were counted, keeping in mind that each colony is a result of propagation of a single cell.

Results of bacteriological analysis are presented in Table 8. According to the Decree of the Ministry of Health of the Russian Federation of September 26, 2001, No. 24 “On implementation of sanitary rules”, the norm for drinking water is less than 50 grown colonies of microorganisms [21]. So, all the studied microemulsion samples prepared using tap water are bacteriologically safe. This result is due to the presence of a number of multifunctional additives in the composition, such as the salts of naphthenic acids, and the salts of ethanolamines of fatty acids.

The tests for compatibility of the developed concentrate and SOLCENIC GM 20 concentrate were also carried out. It has been shown that when these two preparations are poured together in one vessel, the colloidal stability of the resulting product does not worsen. Consumer properties (anticorrosive, bactericidal, viscous, stability under static and dynamic conditions, fire safety) do not worsen because each of these preparations possesses these properties.

TABLE 7

Corrosion degree of steel and nonferrous metals, determined according to [17]

Composition	Corrosion degree		
	Steel	Brass	Copper
Microemulsion concentrate	Absence	Absence	Absence
3 % solution of microemulsion concentrate	Absence	Absence	Absence
SOLCENIC GM 20 (Fuchs, Germany)	Absence	Absence	Absence
3 % solution of SOLCENIC GM 20 cconcentrate	Absence	Absence	Absence

The comparative physicochemical characteristics of two microemulsion concentrates are listed in Table 9. The main parameters of the developed microemulsion concentrate and SOLCENIC GM 20 preparation are close to each other.

CONCLUSION

A new composition of microemulsion hydraulic fluid for mechanised mine supports has been developed. Comparative analysis of the physicochemical properties of the developed concentrate and the known microemulsion concentrate SOLCENIC GM 20 (Fuchs, Germany) was carried out.

It is shown that the developed concentrate is compatible with SOLCENIC GM 20 preparation, that is, the colloidal chemical and consumer characteristics of the product obtained by mixing these two microemulsions remain unchanged.

The close values of the main physicochemical parameters of two microemulsion compositions allow us to recommend the developed composition as a replacement for expensive foreign preparation on the market of hydraulic fluids for mechanised mine supports.

TABLE 8

Bacteriological analysis of microemulsion samples

Bacteriological parameter	SOLCENIC GM 20 (Fuchs, Germany)		Microemulsion	
	Concentrate	3 % solution of concentrate	Concentrate	3 % solution of concentrate
Number of colonies of microorganisms, pcs.	5	3	1	10

TABLE 9

Physicochemical characteristics of SOLCENIC GM 20 concentrate and the developed microemulsion concentrate

Parameter	SOLCENIC GM 20 concentrate (Fuchs, Germany)	Developed microemulsion concentrate
Appearance	Homogeneous oily light-yellow liquid	Homogeneous oily yellowish-brown liquid
Water proportion, vol%	50–55	50–55
Boiling point, °C	102–103	101–102
Density, g/cm^3	1.01–1.03	1.01–1.02
Acidity (pH)	10.4	10.7
Kinematic viscosity at 50 °C, mm^2/s	28	24
Freezing point, °C	<0	<0
Flash point, °C	>100	>100
Stability at 50 °C after 25 days	Stable, without layering	Stable, without layering
Liability to foaming at 20±5 °C, cm^3	<50	<50
Effect on sealing material:		
Rubber	No changes	No changes
Polymer	No changes	No changes

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