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Compatibility of ionic liquids with hydraulic system components

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A B S T R A C T

The aim of this work was to identify, which of the known ionic liquids used within the technical area, primarily as a lubricant, would also be appropriate for use as a hydraulic fluid. In this context, their suitability has been proved based on experimental research with respect to the appropriate physical and chemical properties as required for mineral based hydraulic fluid. Primary aim of the research was to determine the ability of ILs to protect against corrosion, which is one of the important factors in choosing an ionic liquid. The results show that, despite excellent lubricating properties, certain ILs fail on this corrosion test. Except the corrosion protection performance of the basic hydraulic components parts, e.g. hydraulic pumps and valves, in the foreground was their compatibility with other materials used within other parts of hydraulic system, e.g. coating of the hydraulic tank and the filter material. For this purpose standard tests methods for mineral based hydraulic oils have been used, supplemented with non-standard tests, carried out at the same conditions as they occur during the operation of the hydraulic system.

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A R T I C L E   I N F O

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1. Introduction

Mineral based hydraulic oil is nowadays still the most widely used type of hydraulic fluid, with all its advantages and disadvantages in regard to its specific field of application. There is no ideal solution, so we are tending to attain them as closely as possible, always searching for new options resp. alternatives. One of the alternative hydraulic fluids is water (pure water), which is in fact environmentally acceptable, low-cost, non-flammable fluid with low isothermal compressibility. But due to the other major disadvantages, such as poor lubrication properties, low viscosity, tendency to corrosion, the consequent problems need to be solved by using specific (more expensive) materials and manufacturing processes or including special coatings. And at the end, it can only be used under limited operating conditions [1-3]. All these drawbacks limit the overall use of water as a hydraulic fluid, preventing a direct replacement of mineral hydraulic oil with water.

The newer, very promising option to a future alternative to today's commonly used hydraulic fluids represents ionic liquids (ILs). Based on their unconventional properties, ionic liquids allow fundamentally new approaches to technical challenges. They have the potential to open doors to radical innovations [4].

Ionic liquids were first reported as very promising high-performance lubricants in 2001 and have attracted considerable attention within the field of tribology since then because of their remarkable lubrication and anti-wear capabilities as compared with lubrication oils in general use. Ionic liquids have many of good features as described in different literature. Therefore they should be the ideal candidates for new lubricants, suitable for use under harsh conditions, where conventional oils and greases or solid lubricants fail [5-8].

A large number of studies have already been carried out in this area so far but only a few with ionic liquids suitable for use within hydraulic systems. Despite their excellent individual properties, it is very difficult to find an ionic liquid that would combine the majority of good characteristics, essential for use as a hydraulic fluid [9-11].

Besides the low isothermal compressibility, as an excellent property of the most ionic liquids [12], its good lubricating property is among the next more important conditions for the use of ionic liquids as a hydraulic fluid. Their lubricating properties need to be better or at least the same as of conventional hydraulic mineral based oil. This problematic has so far been quite well studied by a number of authors (e.g. [13-19]) and is not in the forefront of this paper. However, good lubricating properties serve for the pre-selection of appropriate ionic liquids for further testing [19].

In addition to good lubricating properties, the ionic liquids as an appropriate medium for the use in the high-pressure hydraulic system must also have other good properties. For wide commercial use they need to meet numerous special requirements, e.g. harmlessness to human health, good thermal and chemical stability, low corrosion impact on the metallic parts of hydraulic components, and be compatible with various materials used within hydraulic components and system, such as seals, coating protection, and the filter material. The latter properties we will focus on in the next sections.

2. Materials and methods

Good corrosion protection is in addition to the good lubrication properties the next very important feature of a hydraulic fluid. Due to the fact that the ionic liquids are actually salts, can be expected that the corrosion protection capacity would be one of the parameters, the most difficult to approach the properties of the conventional hydraulic liquids, particularly, the mineral-based oils. That was confirmed in laboratory test, particularly, in corrosion test in a humid chamber, where most of tested ionic liquids proved to be considerably worse than the mineral hydraulic oil.

Compared to the other corrosion test, e.g. by using the rotating cage (e.g. [20]), the test in humid chamber is very rigorous and very useful test for a rapid assessment the corrosion protection of a different hydraulic fluids. Because of very tightened-up conditions, the time until occurrence of corrosion it is very short. Besides humid chamber test, the corrosion protection capacity was determined by the standard method of determination of corrosiveness to copper and practical method of determination of corrosion in the open air. Corrosion tests were so performed in three different ways:

- Testing of corrosion-preventing in a condensation water alternating atmosphere according DIN 51386-1 [21]. Corrosion test in humid chamber (DIN EN ISO 6270-2) [22] was conducted at constant conditions. The chamber was closed throughout the test, with temperature of 40 °C and relative humidity of 100 %).
- Standard test method for corrosiveness to copper from petroleum products by copper strip test according ASTM D 130-04 (copper is a commonly used material for sliding surfaces inside hydraulic pumps and motors).
- Corrosion in open air (practically method, in accordance with the real operating atmosphere conditions).

2.1 Corrosion test in humid chamber

The corrosion test in a humid chamber is very suitable for comparing different protection materials with known corrosion resistance and those in the course of testing. The corrosion protection capacity in humid chamber is determined in detail by the standard DIN EN ISO 6270-2. Testing is carried out at constant atmosphere in duration until the occurrence the first signs of corrosion and sometimes also after that in order to gain additional information.

The humid chamber is a closed container the bottom of which is covered with heated distilled water. In that way, the relative humidity in the chamber is always 100 %. The tests are often performed with interruptions. Table 1 shows the individual testing circumstances as defined by that standard.

For the test in the humid chamber the apparatus type HK 400 and accessories have been used, and as a testing material steel metal plates (according to standard) made from steel type ST 1405 (according to DIN 1623, part 1), with thickness of 0.7 mm to 0.8 mm, roughness of R_a = 0.6 µm to R_a = 1.9, and the standard plate size 150 × 210 mm. The test plates were prior the testing sanded with the 120-grit sandpaper, and cleaned with acetone and ethanol.

The humid chamber must be placed in a space without aggressive atmosphere, with room temperature and relative air humidity of not more than 75 %. It must be so positioned that it is protected against air draught and direct sun rays. The bottom of chamber has to be filled with distilled water between 10 and 12 mm level. The water level must be checked each time prior to heating. The test plates have to be placed within the test space at the same level as shown in the Fig. 1.

The polished, degreased and dry sheet steel plate should be thinly coated with protective agent or lubricant (in our case with mineral based hydraulic oil or ionic fluid) having to completely cover the cleaned surface, and then introduced into the humid chamber. The required temperature in the chamber in amount of 40 °C ± 3 °C must be reached within 90 minutes, condensed water having to form on the samples.

During the test in constant atmosphere (K), the constant temperature (40 °C ± 3 °C) must be maintained throughout the testing. Testing has to be effected in so many cycles that the first visible signs of corrosion – brown stains (1 cycle = 24 hours) appear. When testing in an alternating condensation atmosphere (A1), heating must be interrupted after 8 hours, reckoning from the heating activation, the humid chamber door opened and left open for 16 hours. In this way, the first cycle is at an end. Then, the distilled water level has to be checked, water added if necessary, and the device closed. Other details regarding the test procedure and testing samples are given in the standards DIN EN ISO 6270-2.

Table 1 Atmospheric types in corrosion tests in a humid chamber [21]

Test atmosphere	Code	Cycle duration (h)	Test period (min, h)	Air temperature (°C)	Relative humidity (%)
Constant	K	-	-	40 ± 3	100
Alternating condensation atmosphere	A1	24	8 h (including warm-up)	40 ± 3	100
			16 h (including cooling down, chamber open)	18 to 28	< 100
	A2	24	8 h (including warm-up)	40 ± 3	100
			16 h (including cooling down)	18 to 28	100

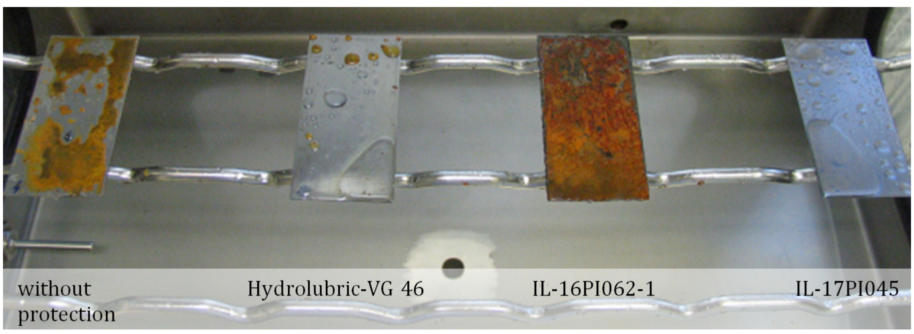

Fig. 1 Test plates coated with different lubricants in humid chamber after 24 h

2.2 Corrosiveness to copper

Because of the presence of non-ferrous metals based on copper in hydraulic components the test of corrosiveness to copper also was carried out. The corrosiveness to copper is carried out in accordance to standard ASTM D 130 [23].

The polished copper plate has to be dipped into the sample (50 ml) at a prescribed temperature and time. The test tube has to be placed into the bath at the specified temperature 50 °C or 100 °C and specified time of heating (usually for 3 h). After three hours, heating must be stopped, the plate taken out of the test tube and corrosiveness assessed with the standard copper plates (etalons), as shown in Fig. 7. Corrosiveness is expressed by values 1 to 4 obtained by comparing corroded copper plate with freshly polished standard plate by assessing the appearance of the test plate (ASTM Copper Strip Corrosion Standards).

2.3 Corrosion in the open air at the ambient condition

In this case a non-standardized, practically test was performed. Identical steel plates as for the humid chamber corrosion test were used. Also the plate preparation was the same. Each plate was coated with the ionic liquid sample, whereby possible changes of the surface appearance were observed at the ambient conditions (room temperature approximately about 20 °C and the humidity about 60 %).

2.4 Compatibility with hydraulic components materials

Presented standard tests of the corrosion protection in a humid chamber, corrosiveness to copper and practically test of corrosion in the open air, were performed with the standardised test materials, as described in the previous chapter. In addition to these test it is reasonable to check compatibility the ILs with the materials that are used for the manufacturing of hydraulic components – pumps and especially valves. Valve housing, valve control piston, springs, washers, etc. are the most exposed vital part of a hydraulic component and thus the entire hydraulic system.

For practically testing the compatibility with these materials the more interesting ionic liquids IL-17PI045 (as very promising IL) and EMIM-$EtSO_4$ (as often mentioned and researched IL) were used (these ILs have been chosen on the basis of extensive IL pre-selection research [24, 25], as explained in chapter 2; see also chapter 3). Our target was to test the effect of both ionic liquids on the component parts the real hydraulic systems.

For the purpose of this test the original components of the renowned hydraulic equipment producer have been procured. They are shown in Fig. 2. The following components were used:

- directional control valve piston made of steel 10715, case hardened 0.4 mm and hardened to 58-62 HRC (Fig. 2, item 1),
- spring made of steel spring wire according to DIN 17223-1 (Fig. 2, item 2),
- washer made of steel DC01 (Fig. 2, item 3),
- bolt made of steel 10715 without subsequent thermal treatment (Fig. 2, item 4),
- valve housing made of grey cast iron GG30, DIN 1691, stress-relief annealed (Fig. 2, item 5),
- valve housing made of steel 10718, drilled from blank (Fig. 2, item 6),
- valve housing made of steel Hyt 60R (Fig. 2, item 7),
- piston RTB 15 made of steel 16MnCr5 (Fig. 2, item 8),
- piston housing RTB 15 made of steel 42CrMo4 without subsequent thermal treatment (Fig. 2, item 9),
- piston VE 60 made of steel 16MnCr5, case hardened (Fig. 2, item 10).

Prior to the test start, the component parts were not specially prepared, but were used such as supplied by the producer. After completion of manufacture, they were protected by him with low-viscosity corrosion protection oil. They were used in such a condition as they are usually, used in practice. Exceptions are all three valve housings from which small samples were cut off by saw.

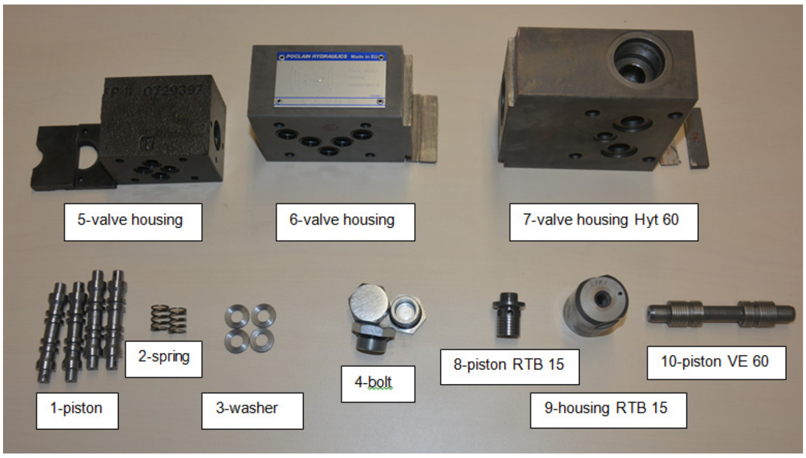

Fig. 2 Samples of hydraulic valve parts

The compatibility test was so performed in this way that different components were first fully wetted and then permanently dipped in the samples of ionic liquids EMIM-$EtSO_4$ and IL-17PI045. Some of the component parts, which are also installed in the same valve, were dipped in the same glass cup. In that way, items 1, 2 and 3 shown in Fig. 2, were united and so were the items 5, 6 and 7 and items 9 and 10. In the liquid IL-EMIM-$EtSO_4$ items 1, 2, 3, 4, 5, 6 and 7, but not the items 8, 9 and 10 were dipped. In the liquid IL-17PI045 all items from 1 to 10 were dipped. Glass cups with test components prior to the test start are shown in Fig. 3.

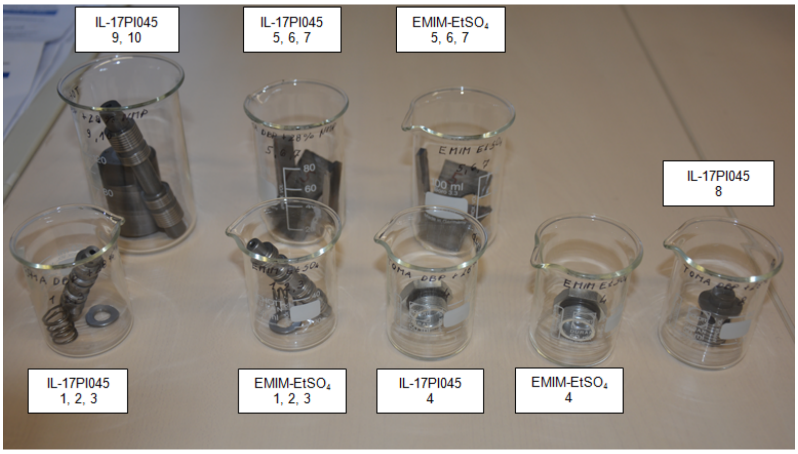

Fig. 3 Hydraulic valve samples prior to soaking

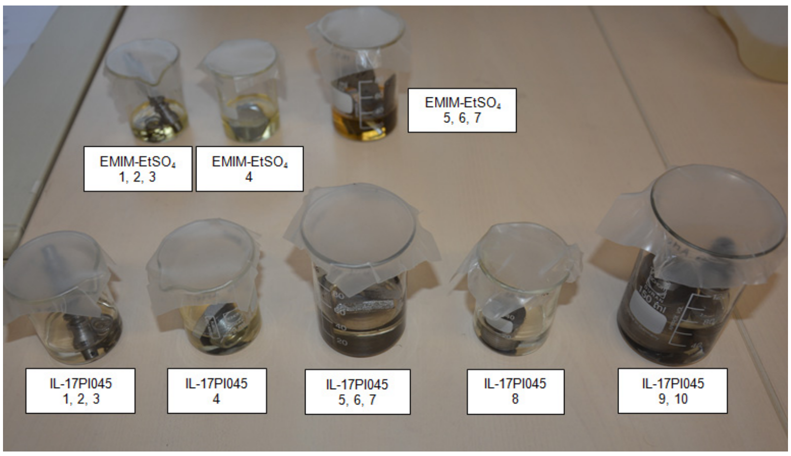

Fig. 4 Hydraulic valve samples during test of compatibility with ionic liquids

After the insertion the components parts into each cup, they were poured with 10 to 30 ml of ionic liquid. The components parts were so firstly wetted with the ionic liquid, and then placed into upright position, so that the bottom part was completely immersed, while the remaining part above the surface level, during testing, was exposed to the influence of room temperature and humidity (with the exception of washer, which was completely immersed). This corresponds to the actual situation in the hydraulic component when the hydraulic system is not under pressure (standby mode) or when the components are temporarily stored. Fig. 4 shows the condition during execution of compatibility test.

2.5 Compatibility with paint coats

Most hydraulic tanks are painted inside and outside, with different types of paint coats. Therefore, it is very important that the ionic liquid used for purposes as a hydraulic liquid should be compatible with the used paint coat. As known, the compatibility the paint coats with mineral based hydraulic oils is not a problem.

Concerning protective coatings for hydraulic reservoirs, in particular the compatibility of the protective paint in regard to the type of hydraulic fluid, there is not a specific standard which would be related to this issue in detail. There are more or less recommendations or recommended practices (RP), mostly linked to related areas, providing guidance on achieving effective corrosion control in storage tanks. They contain information pertinent to the selection of lining materials, surface preparation, lining application, cure, and inspection of tank bottom linings for existing and new storage tanks, e.g. API RP 652 Standard - Linings of Aboveground Petroleum Storage Tank Bottoms. Thus, manufacturers of lubricants are using simple, practical experiments, e.g. testing by continuous contact through immersing of painted metal samples in the liquid under test, at constant room temperature: 20 to 25 °C.

The test of paint coat compatibility was performed with both selected ionic liquids. The metal plate samples were painted with two paints typically used for the tank interior and exterior. The interior is painted with epoxy type priming coat, while the exterior is additionally coated with epoxy type thick-layer finishing coat. Some metal plate samples were painted only with the interior paint and some were additionally coated still with the paint for the tank exterior.

The test was performed so that about 40 ml of each of the ionic liquid were poured into glass cups; then single metal plate samples coated with the paint coat for the tank interior and a metal plate sample coated with the paint coat for the tank exterior were introduced into them. At the beginning of testing the entire metal plates were wetted with the test liquid; during testing the bottom part of the metal plate was permanently dipped into the liquid, while the top part was above the surface level as shown in Fig. 5.

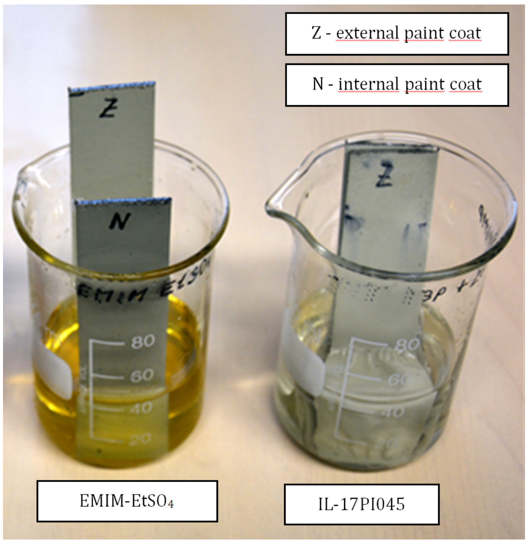

Fig. 5 Test of compatibility with paint coats

2.6 Compatibility with filter material

As the liquid in the hydraulic system acts as a lubricant reducing wear of hydraulic elements, reduction of solid particles in the circulation is important. This is particularly applicable, when clearances in the hydraulic system are small, as, then, a high degree of liquid cleanliness is required for trouble-free operation and reaching the expected useful life time of components. Contaminants are removed by filters. Therefore, the next relevant issue is the hydraulic fluid compatibility with the filter cartridge material.

The ability of the hydraulic liquid to flow through fine filter elements without their clogging is called the filterability or filtration capacity. The filtration capacity of mineral oils is assessed by the laboratory test method according to standard ISO 13357 [26]. With respect to mentioned the compatibility with the filter material, can be carried out in the very close connection with the filterability test.

The first part of standard ISO 13357 covers the testing in the presence of water in oil and the second part the testing without it. For other liquids, in principle, the test is not applicable because the testing filters membranes may be are not compatible with them. According to that standard the membrane filter from mixed cellulose esters, of 47 mm diameter and pore size 0.8 µm is to be placed in a Petri dish which, in turn, is to be put into the oven with 70 °C ± 2 °C temperature for 10 minutes.

We wanted to determine in the described manner also the filterability of both samples of ionic liquids EMIM-$EtSO_4$ and IL-17PI045 as well the mineral oil Hydrolubric VG 46 and at the same time the compatibility with the cellulose as a filter material.

As has already been indicated in the Standard ISO 13357, that in addition to mineral oils the standardised test method can be used also for other liquids, but the latter are maybe not compatible with membrane filters, in our case that proved to be true. As both ionic liquids deformed the cellulose filter membrane and the filterability determination by that method was not possible. The filter element covered with IL-17PI045 started to decompose immediately after the contact with liquid and was dissolved. The sample of EMIM-$EtSO_4$ ionic liquid deformed the filter element into a glassy circle.

Taking into account the negative effect of ionic liquids IL-17PI045 and EMIM-$EtSO_4$ on the cellulose filter paper when trying to determine the filterability according to standard ISO 13357, an additional analysis was performed by us, too. The 0.45 µm filter paper of type ME 25 (Schleicher & Schuel) and 0.8 µm filter paper of type ME 27 (Whatman) were used for the test of compatibility of the mentioned liquids with the cellulose filter paper.

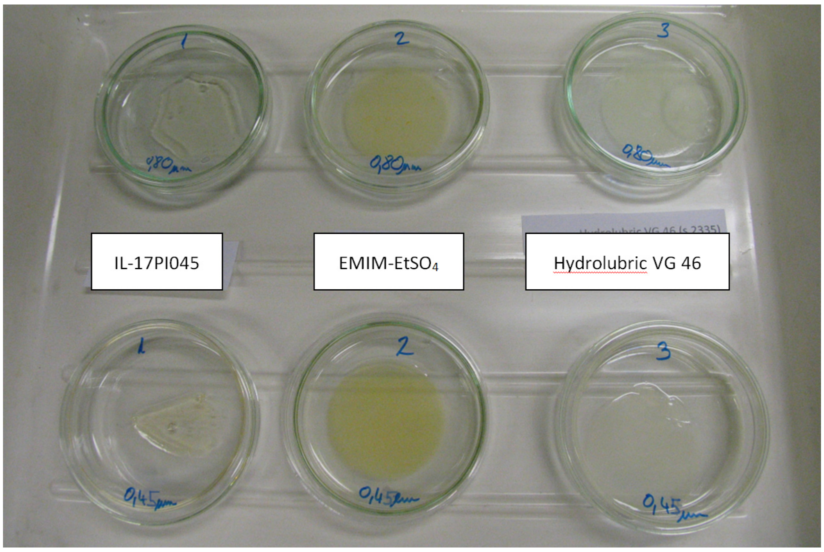

Fig. 6 Compatibility of ionic liquids of mineral oil with cellulose filter paper

3. Results and discussion

3.1 Corrosion test in humid chamber

According to the described method, a larger number of ILs has been tested. Types of testing ILs were carefully selected on the basis of practical experiences from related fields [4] and according to their tribological properties identified by the previous tribological tests – welding point and wear diameter test [19, 24]. The pre-selection procedure can be carried out also in the reverse order - firstly the corrosiveness test and then the lubrication properties test.

Table 2 shows time to first occurrence of corrosion for only some of ILs, in comparison to mineral hydraulic oil Hydrolubric VG 46. It can be seen that corrosion protection in most cases does not amount to 1 cycle (24 hours). In that case, the time in minutes or hours up to the occurrence of the first signs of corrosion is stated in parentheses. In most cases, the corrosion protection in comparison with the mineral hydraulic oil is worse – shaded in gray.

In other cases, the corrosion protection capacity is comparable to that of the mineral hydraulic oil or even much better, as it can be seen on the last three samples in the Table 2 respectively from Fig. 1. According to the viscosity suitable for use in most hydraulic systems, particularly, the last two samples (IL-10 and IL-11) are very interesting. Beside the appropriate viscosity they have higher welding load point, smaller wear diameter (which corresponds to the lower sliding friction between component parts and lower wear of the component parts), and much higher viscosity index (the smaller change of viscosity with temperature). Otherwise the best results of the corrosion test in humid chamber out of all ionic liquids were measured on the sample IL-17PI064 (quaternary ammonium dialkylphosphate + 7 % H_2O) which was the only one to offer protection against corrosion for 1 cycle (24 hours) and/or even slightly longer. However, the viscosity of that sample is too high for most hydraulic systems.

Table 2 Comparison of some physical-chemical properties

Property/Method	Welding point IP 239-85 [kg]	Wear diameter IP 239-85 [mm]	Viscosity 40 °C ASTM D 445 [mm²/s]	Viscosity index ASTM D 2270 [/]	Corrosion in Humid chamber DIN EN ISO 6270-2
Sample					
Hydrolubric VG 46,	140	0.58	47.07	119	0 (3 h)
IL EMIM-EtSO$_4$	180	1.00	39.44	168	0 (15 min)
IL-EMIM-TFSI	1120	0.65	71.89	132	0 (1.5 h)
IL-10PI462 (EMIM-TFSI)	-	-	-	-	0 (30 min)
IL-16PI028-5 (quaternary ammonium dialkylphosphate)	-	-	-	-	0 (30 min)
IL-10PI028-3 (quaternary ammonium perfluorocarboxylate)	-	-	-	-	0 (45 min)
IL-16PI062-2 (quaternary ammonium dialkylphosphate)	135	0.82	59.14	-	0 (4 h)
IL-16PI062-1 (quaternary ammonium perfluorocarboxylate)	-	-	61.46	-	0 (5 min)
IL-18PI094 (quaternary ammonium perfluorocarboxylate + 30 % EG)	125	1.04	49.28	109	0 (15 min)
IL-17PI064 (quaternary ammonium dialkylphosphate +7 % H_2O)	190	0.49	102.90	105	1
IL-18PI163 (quaternary ammonium dialkylphosphate + 40 % NMP)	160	0.38	47.36	155	0 (3.5 h)
IL-17PI045	145	0.35	46.59	155	0-1 (> 7.5 h)

3.2 Corrosiveness to copper

The results are given as the corrosiveness to Cu with the designation of the corrosion degree determined from the table or by comparison with the etalon, as shown in Fig. 7, by stating the temperature and duration of the test.

The test was carried out (according to ASTM D 130) with two ionic liquid samples, IL-17PI045, as the most promising for the use as hydraulic fluid and EMIM-EtSO$_4$ as often referred and used within different technical application.

After completion of testing, the appearance of the copper strip was compared with the etalon as shown in Fig. 7. For both tested ILs there were no visible changes, meaning that the result of that test is 1a: both ionic liquids are compatible with materials containing copper. To the same conclusion we have come with other tested ILs – corrosiveness to copper is much lower than that of steel and does not represent any problems.

Fig. 7 Determination of corrosiveness to copper for IL-11 17PI045

3.3 Corrosion in the open air at the ambient condition

In case of mineral hydraulic oil the corrosion in the open air did not appear even after a long time period (more than 60 days), while in case of some ionic liquids it appeared already after 20 to 30 minutes. In case of ionic liquid EMIM-EtSO$_4$ the corrosion occurred too, already after 2 to 3 days. Fig. 8 shows the condition after 4 days since the test start. It can be observed that the condition is worse on the plate bottom part, where the ionic liquid layer was slightly thicker due to uneven base.

In case, when the steel plate, after coating with ionic liquid IL-17PI045, was left in the open air at room temperature, corrosion did not appear even after 3 months since the test start. Therefore the testing in the open air was interrupted after this period.

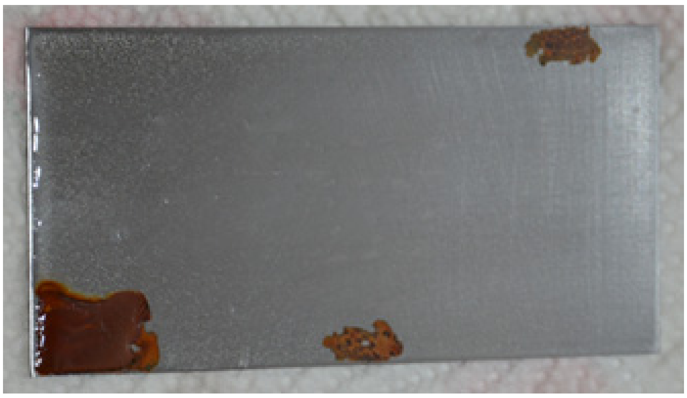

Fig. 8 Test of corrosion in the open air for EMIM-EtSO$_4$ after 4 days

3.4 Compatibility with hydraulic components materials

The test showed compatibility of hydraulic valve components with both interesting ionic liquids. During several-month test period the changes of component part surface were not observed. This was surprising, particularly, when using the ionic liquid EMIM-EtSO$_4$ which did not witness good corrosion protection either in the corrosion test in humid chamber or in the test of corrosion in the open air. A possible reason could be that in this case the component parts were previously protected by a purpose anticorrosion agent. On item 5 sawn from the valve housing and not protected on the sawn surface, the first signs of corrosion did appear after about 90 days in case of EMIM-EtSO$_4$, as shown in Fig. 9.

According to the results of the compatibility test corrosion problems are not to be expected in the practical use of both ionic liquids in the hydraulic system, unless water is present in the system.

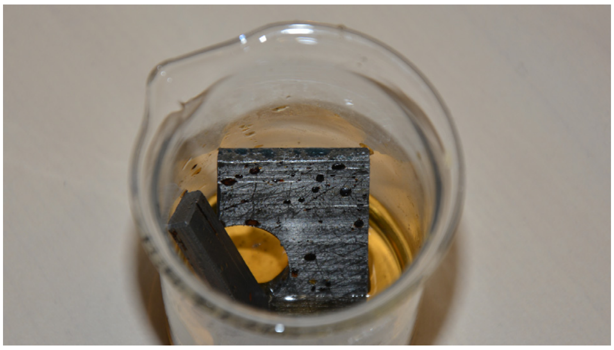

Fig. 9 Test of soaking in EMIM-EtSO$_4$ after 90 days; item 5

3.5 Compatibility with paint coats

Already after a few days of testing, it was proved that the ionic liquid IL-17PI045, which in all previous tests it proved to be an excellent substitute to mineral oil was not compatible either with the paint coat for the tank interior or with the coat for the tank exterior. The paint coat starts to wrinkle and peeled off on the part of the metal plate permanently dipped in the test liquid. The condition after 4 days of the test of this IL is shown in Fig. 10.

The ionic liquid EMIM-EtSO$_4$ is compatible with the usual paint coats of the tank metal plates and does not present any problem in this regard. After more than 7 months of testing, no changes of the condition of painted metal plate occurred either on the permanently dipped part of the metal plate or on the wetted part above the surface level.

The results of this test confirm the generally fact that (nowadays) there is no an ideal hydraulic fluid, which also applies for the ionic liquid. In the case of certain superior properties for a particular IL may be other properties conversely poor. Thus, in the case of IL-17PI045 as an excellent candidate for the future hydraulic fluid, the latter problem can be solved by another kind of protection or other materials for the hydraulic tank.

Fig. 10 Ionic liquid IL-11 (17PI045) and painted metal plate

3.6 Compatibility with filter material

The filter paper was covered with a thin layer of mentioned liquids and their effect was observed (Fig. 6). After 5 minutes, the filter paper covered with ionic liquid IL-17PI045 shrivelled and after 15 minutes it became gelatinous. The ionic liquid IL-1 (EMIM-$EtSO_4$) and the mineral hydraulic oil did not have such an effect on the filter paper. The filter paper covered with EMIM-$EtSO_4$ became only a little brittle.

According to the results of testing of the filterability in conformity with and compatibility with cellulose filter paper discussed in this point, it can be concluded that the ionic liquids IL-17PI045 and EMIM-$EtSO_4$ are not compatible with the cellulose filter paper. Therefore, the use of cellulose filter elements within hydraulic systems with those two liquids is not recommendable. But this incompatibility with the cellulose does not represent a major practical problem for the filtering of ionic liquids within the hydraulic system, as they are for the filter cartridges different materials available, e.g. micro-fiberglass or polyester.

The problem represents the filterability test according the ISO 13357 standard, that dictates the cellulose. The performing the filterability test need the reconsider the use of other filter membrane materials, for example glass fibres. This would, however, still have to be established.

4. Conclusion

The presented results of the research work allow the suggestions for the use of ionic liquids within hydraulic systems and some limitations. Most ionic liquids tested were corrosive in the presence of moisture. Consequently, even greater attention must be paid to moisture prevention in the hydraulic system. Alternatively, stainless hydraulic components can be used, which, however, results in undesirable structural and price changes.

Some ionic liquids, such as, e.g. IL-17PI045, shows the best proposition for use as a hydraulic fluid, since it has much better properties than mineral oil. But on the other hand is not compatible with conventional paint coats of hydraulic tanks. Therefore, the latter must not be painted, when that liquid is used. Another limitation in the use of this liquid is incompatibility with the cellulose filter elements. As a result, absorption filter elements, usually based on cellulose, could not be utilized, when this liquid is used in the hydraulic system.

At present, one of the greatest limitations for wider technical use of ionic liquids, also in hydraulic systems, is at the moment (due to the production of small quantities) considerably higher price than that of conventional hydraulic mineral oil. The target areas of use of ionic liquids in hydraulic equipment are currently the small-volume hydraulic systems, such as wind turbines, mobile hydraulic equipment etc.

The performed researches are only a modest beginning of researches of this extensive area of new lubricants with promising properties. In particular, in the continuation of the research work it would be reasonable to test the selected ionic liquids still in the real hydraulic system. All the obtained results of the presented researches and the mentioned limitations can be of assistance in selecting proper system components and represent guidelines for further work in this sphere.

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