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IONIC LIQUIDS VS. CONVENTIONAL HYDRAULIC OILS A COMPARISON OF PROPERTIES AND CHALENGES

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ABSTRACT
Ionic liquids (ILs), a combination of cations and anions in a "liquid form", have been recognized as a very promising high-performance lubricant and have attracted considerable attention within the field of tribology. Due to its remarkable lubrication and anti-wear capabilities, as compared with classical mineral based oils, they represent very promising candidate for the use as a hydraulic fluid.
The paper presents the most important properties of the ILs in comparison to mineral based hydraulic oil. In the foreground are properties important for use as a hydraulic fluid: corrosion protection, good lubricating properties, low viscosity dependence on temperature, low compressibility, non-flammability, environmental friendliness, low vapor pressure and compatibility with materials.
Keywords: hydraulic mineral oil, ionic liquids, properties comparison

1. IONIC LIQUIDS AS A POTENTIAL HYDRAULIC FLUID
Ionic liquids (ILs) are molten organic salts with very low melting points. They are a new class of liquid, high tech materials with extraordinary properties e. g. excellent lubricating properties, high viscosity index, low compressibility… Based on their unconventional properties ILs allows new approaches to technical challenges [1]. Accordingly, they are suitable for use as hydraulic fluids.
Some of the most important ILs properties can be mentioned: virtually no vapour pressure, non-flammable, melting until -60 °C, excellent thermo-oxidative stability up to 300 °C, low friction coefficients, good lubrication properties, good wettability of metal surfaces, "adjustable" viscosity, good viscosity index and high tribological shear stability, very low compressibility…
In spite of some mentioned excellent individual IL's properties, it is relatively difficult to find in amongst numerous tested ionic liquids such an ionic liquid that would feature the majority of good properties derived from a top hydraulic liquid [2]. The continuation of this point shows the comparison of some measured results of the tested ionic liquids with the mineral hydraulic oil Hydrolubric VG 46, an oil of HLP quality level, according to standard DIN 51524-2.

2. COMPARISION OF BASIC FLUID PROPERTIES
When selecting an "ideal alternative candidate" for use as a hydraulic fluid, especially in the case of new type of hydraulic fluid, the testing the fluid, is not as uniquely defined, as in case of classical lubricants. It is because of same unique properties that fluids frequently impose the use of special laboratory equipment. Therefore some special, additional measurements need to be also performed for the selecting and comparing alternative fluids with mineral based hydraulic oils.

2.1 Corrosion testing
As ILs are salts, it was to be expected that the corrosion protection ability would be one of the parameters, more difficult to approach regarding the properties of the mineral-based hydraulic oils. That was confirmed in by the laboratory test, particularly during the corrosion test in a humid chamber, where most the tested ILs proved to be considerably worse than the mineral hydraulic oil. Test was carried out in accordance to standard DIN EN ISO 6270-2. This, a very rigorous test is more

rarely used for the testing of hydraulic fluid but is very useful for quick estimates, as because of tightened-up conditions the time until occurrence of corrosion is distinctively shortened [3].
The measurements were performed at constant atmosphere up to the appearances of the first signs of corrosion and sometimes also after that in order to gain additional information. From Figure 1 is apparent, that some ILs are real stimulator of rust (e.g. IL-TEA…), on the contrary, the other one (e.g. IL-17PI…) offers much better protection than classical mineral hydraulic oil.

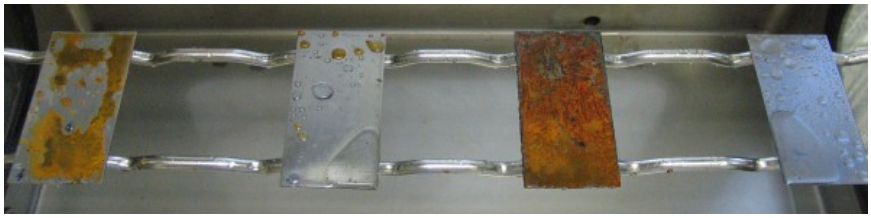

Figure 1. Corrosion testing in a humid chamber

Beside the humid chamber test two additionally test were carried out. The test of corrosiveness to copper was carried out because of the presence of non-ferrous metals based on copper in the hydraulic components. This test was carried out in accordance to standard ASTM D 130. After completion copper test on the testing copper strips there were no visible changes, meaning that the result of that test 1a - no influence to copper. Consequently, the (most of) ILs are compatible with materials containing copper.
Corrosion testing of components exposed to ambient air is also interesting, s. c. open-air test. For this non-standardised test, the same steel plates were used, as used for the determination of corrosion in the humid chamber. Also the plate preparation was done according to humid chamber test standard. Within open air-test, plates were coated with the fluid tested sample and in the continuation of the test possible changes of the surface appearance were observed at room conditions. In the case of mineral hydraulic oil, the corrosion in the open air did not appear even after a long time period (>60 days), whilst in the cases of some ionic liquids it had already appeared after 20 to 30 minutes. In the case of ionic liquid EMIM-EtSO4 the corrosion already occurred also after 2 to 3 days. In practice, this corrosion is not problematic because all of hydraulic components are already factory protected.

2.2 Testing of lubricating properties

Another very important feature for use of ILs as a hydraulic fluid is its lubricating properties. Lubricating properties can be measured by the welding-point determination and wear test according to standardised procedure (e.g. IP 239-85), as well as the friction coefficient. Figure 2 shows the comparison between the welding point and wear diameter for tested ILs.

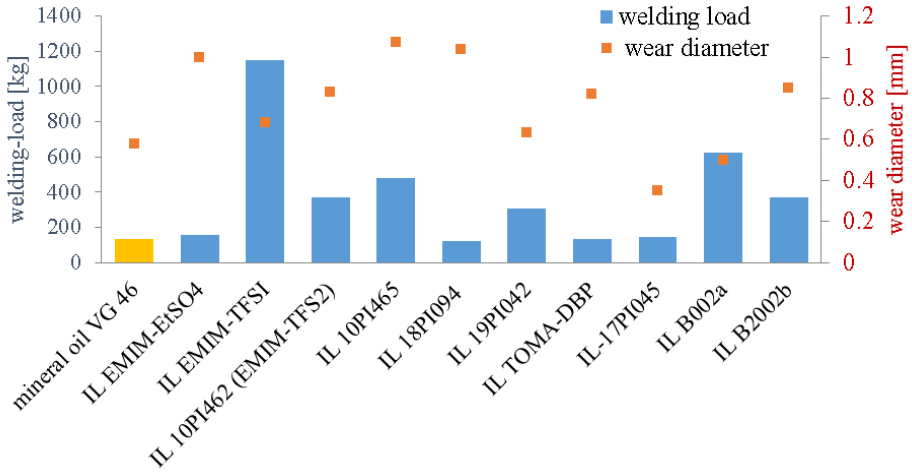

Figure 2. Ionic liquid lubrication properties in comparison with mineral oil

Some samples have an exceptionally high welding point, for example IL-EMIM-TFSI has as much as 1150 kg, which points out exceptional properties at extreme pressures but, interestingly, the wear

diameter is bigger than that of the mineral oil, implying that the anti-wear properties are worse. As in the case of hydraulic oils the anti-wear properties are more important.
Additional information in regard the lubricating ability and heat generation, is given by the friction coefficient - Figure 3. Measured Stribeck's curves show, that the friction coefficient of the mineral hydraulic oil within the entire range is considerably higher than that of showed ILs.

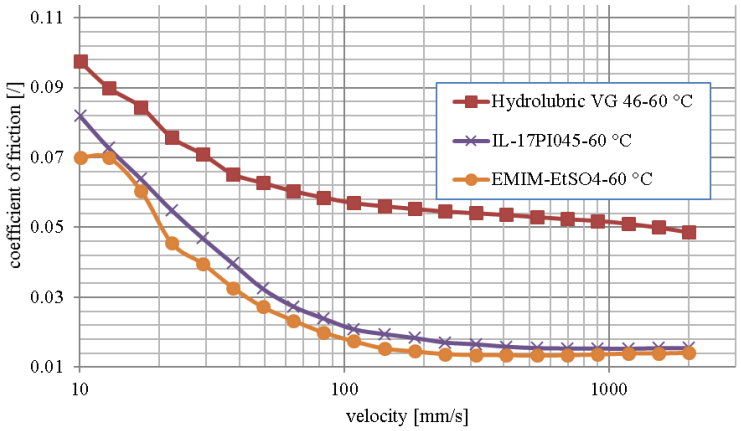

Figure 3. Measured Stribeck's curves

In general, the ILs have a very similar friction coefficient within the entire range. The results prove excellent lubricating properties of both shown ionic liquids.

2.3 Compressibility of hydraulic fluid

The fluid compressibility as a material property of hydraulic fluid is of key importance, particularly in the sphere of high-pressure hydraulic systems. Despite the widely used assumption that hydraulic fluids are incompressible, the fact remains that all fluids are compressible. Compressibility is important in systems desired high dynamic and precise actuator control, without delayed signal and actuator response [4].

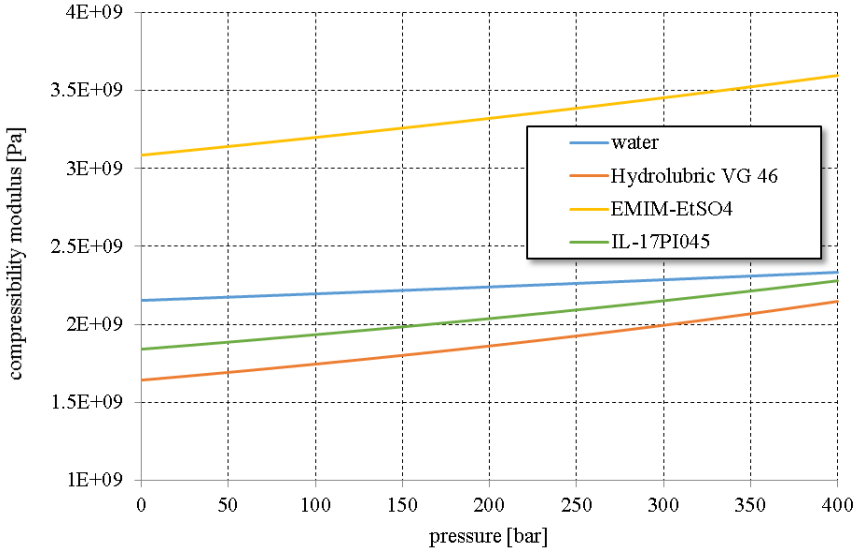

Figure 4. *Measured compressibility versus pressure for different considered fluids*

The fluid compressibility was measured in two ways: through the pressure and volume change with known initial liquid volume, and through velocity of sound propagating in the liquid. In both cases the special designed measuring device was used [4]. The results from measurement methods are shown in the Figure 4.
Based on measurements it can be seen, that in case of EMIM-EtSO4, its compressibility is even lower than that of water. For that IL it can be claimed from the point of view of compressibility that because of its rigidity it is more proper for use in hydraulic systems than the mineral hydraulic oil.

3. COMPARISION OF MOST IMPORTAN FLUID PROPERTIES

The measurement results of most important and other physical-chemical properties of mineral based hydraulic oil and some ILs, for use within modern, hydraulic system with the possibility to monitor all important physical and chemical parameters of the fluid at a distance (on-line condition monitoring [5]), are collected in Table 1.

Table 1. Comparison of same fluid properties

Property	Mineral oil VG 46	EMIM-$EtSO_4$ (and other ILs)
Flash point [°C]	224	230 (or higher)
Density/15 °C [g/cm^3]	0.871	1.241 (or lower)
Viscosity/40 °C [mm^2/s]	47.07	39.44 (“adjustable”)
Viscosity/100 °C [mm^2/s]	7.36	7.66
Viscosity index	119	168 (until 200 and even higher)
Welding point [kg] Wear diameter [mm] Friction coeff. @ 100 mm/s	130/140 0.58 0.07	140/180 (until 1000) 1.0 (less than 0.6) 0,015
Humid chamber Cu (3 h, 100 °C) Open air	3 h 1a several days	30 min (several days) 1a several days
Compressibility [MPa]	1.6	until 3.1(always higher than of oil)
Compatibility with material	no problem	not compatible with some paints cote and cellulose filter

4. CONCLUSION

Fluids used in modern, energy-efficient, highly dynamic and high-performance hydraulic systems must have extremely good lubricating properties and be a little compressible. Additionally, there are many other properties here, such as thermal stability, low viscosity dependence on temperature, fire resistance, environmental acceptability… Conventional mineral based hydraulic oils are not able to meet all these requirements at the same time. The solution in this regard offers ionic liquids, as novel, high-tech lubricants of the future.

The purpose of the paper is to highlight the some excellent properties of certain ionic liquids, appropriate for use within hydraulic systems. Without any doubt ionic liquids show very attractive properties for the application as engineering liquids, which were not covered by other fluids so far.

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