Hydraulic fluids with new, modern base oils – structure and composition, difference to conventional hydraulic fluids; experience in the field

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Abstract

The paper describes the comparison and the difference of modern hydraulic fluids compared to conventional hydraulic fluids. A comparison of different base oil groups, solvent neutrals, group I and comparison with hydrotreated/hydroprocessed group II and/or group III base oils is presented. The influence on oxidation stability, elastomer compatibility, carbon distribution and physical properties is outlined.

KEYWORDS: API base oil classification, group I, group II, group III, hydrotreated base oils, modern hydraulic fluids, temperature stability, hydraulic fluid market.

1. Introduction

Hydraulic fluids count for about 14% (e.g. 130,000 tons/year in Germany [1]) of total lubricant consumption in industrial countries. The main fluid group are mineral oil-based hydraulic fluids. These fluid groups can be monograde fluids which are normally used in stationary industrial application (machine tools, hydraulic presses, plastic injection machines etc.) or multigrade, so-called HVI fluids in mobile hydraulic systems (e.g. excavators). Minimum viscosity index of multigrade hydraulic fluids has to be VI ≥ 140.

Nowadays there is a clear trend to reduce tank capacity, volume of the total hydraulic system, increase of circulation ratio, increase pressure and temperature. All these parameters will increase the stress to hydraulic fluids in general which lead to reduce lifetime expectations and reduced service intervals. Because these "new" hydraulic systems apply highest stress to the fluid modern formulations should be used to guarantee trouble-free energy transfer via the fluid.

2. Base oils for hydraulic fluids

In general the traditional base oils for hydraulic fluids are so-called solvent neutrals which are obtained from base oil refineries which use atmospheric and vacuum distillation processes in combination with a solvent treatment to generate suitable so-called group I base stocks for hydraulic fluids. According to the fraction they are called SN plus the corresponding SUS viscosity, e.g. SN 150 – SN = Solvent Neutral, (which represents ISO VG 32 cut).

These SN base oil refineries are predominantly old units. Solvent treatment is no longer a very economic and ecological process and, therefore, there is a clear trend to shut down base oil capacities of solvent neutral producing base oil refineries in Europe, in Asia and in the US. At the same time new base oil units are built up which can produce more advanced hydroprocessed and dewaxed base stocks. These semi-synthetic hydroprocessed base oils are also called group II or group III base oils. Compared to SN base oils they exhibit a heavily reduced sulfur content and a higher VI and a higher grade of saturation in the molecular structure. Figure 1 shows the API classification of base oil types according to API 1509 appendix E and Figure 2 shows the base oil capacity during the years 2005 – 2012 [3].

API classification of base oil types

- Classification according API (1995) and ATIEL (Code of Practice):

	Sulphur [%]		Saturates [%]	VI
Group I:	$> 0,03$	and/or	< 90	80-119
Group II:	$\leq 0,03$	and	≥ 90	80-119
Group III:	$\leq 0,03$	and	≥ 90	≥ 120
Group IV:	Poly-alpha-olefins (PAO)			
Group V:	Other base oils (e.g. Esters)			
Group VI:	Poly-internal-olefines (PIO), new group introduced in 2003			

- Group I: Solvent Neutrals; characterisation according carbon distribution: aromatic – naphthenic – paraffinic (90 % market share)
- Group II + III: semi-synthetic products by hydrocracking / isodewaxing / hydrofinishing
- Group IV ff: fully synthetic

Figure 1: API classification of base oil types

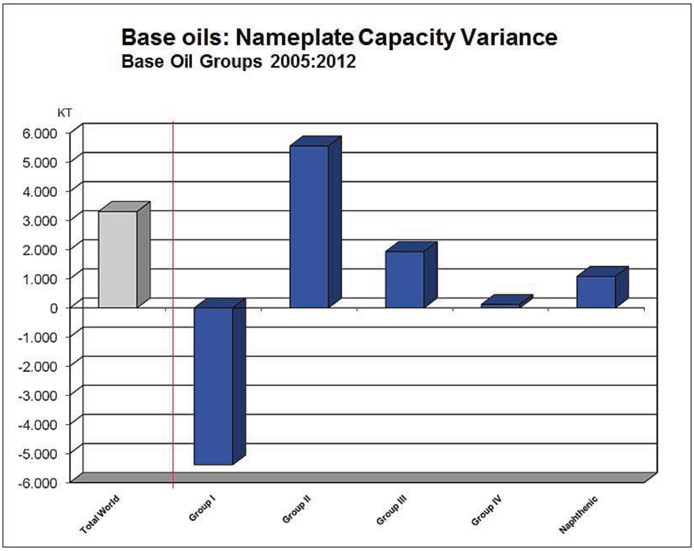

Figure 2: Base oils: Nameplate Capacity Variance, Base Oil Group 2005:2015

3. Composition of base oils

Base oils for lubricants are mixtures of hydrocarbons which are connected in paraffinic structures, naphthenic structures or in aromatic structures. The paraffinic structures are mainly linear structures whereas the aromatic and naphthenic structures are ring structures. The distribution of carbon in paraffinic, naphthenic and aromatic structures defines the type of base oils. The group I base oil consists mainly of paraffinic structures with a significant content of naphthenic and aromatic structures. The naphthenic and especially the aromatic content contributes to fluid polarity and, therefore, to solubility properties of this type of base oils. The group II and the group III are predominantly paraffinic base oils without carbons in aromatic structures but with naphthenic structures in the oil. Figure 3 shows the carbon distribution of group I base oil versus group II and group III base oils.

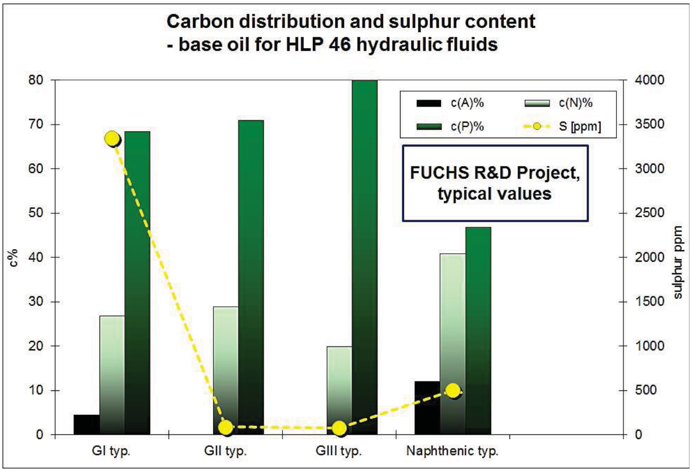

Figure 3: Carbon distribution and sulfur content – base oil for HLP 46 hydraulic fluids

There is also a special naphthenic type of base oils existing which has a high content of aromatics and naphthenics. These naphthenic base oils have a low VI, low oxidation stability, but offer a low pourpoint. Therefore, this type of base oils is especially used for low temperature hydraulic fluid specialties [2].

Figure 4 shows also the difference of base oils regarding the sulfur content. Group I base oils typically have a sulfur content between 7000 and 8000 ppm, whereas group II and group III typically have a sulfur content < 10 ppm. This sulfur is the so-called base oil sulfur.

Hydraulic fluids, ISO VG 46 – Comparison data (typical values)

Base oil type		Group I	Group II	Group III	
Product name		RENOLIN ZAF D 46 HT	RENOLIN ZAF D 46 HT PLUS	RENOLIN ZAF 46 MC	
	Unit				Test method
Colour	ASTM	1.5	1.0	0	DIN ISO 2049
Density at 15 °C	kg/m³	880	866	843	DIN 51757
Viscosity at 0 °C at 40 °C at 100 °C	 mm²/s mm²/s mm²/s	 562 46 6.8	 550 46 6.9	 412 46 8.0	DIN EN ISO 3104
Viscosity index	-	100	106	148	DIN ISO 2090
Flash point (Cleveland)	°C	230	230	238	DIN ISO 2592
Pourpoint	°C	-27	-39	-45	DIN ISO 3016
Brugger (active sulfur)	N/mm²	35	35	20 – 25	DIN 51347-2
Sulfur content base oil	ppm	~ 7000	< 10	< 10	DIN 51391-3
Sulfur content base oil + additive	ppm	~ 8400	~ 1400	300	DIN 51391-3

Figure 4: Hydraulic fluids, ISO VG 46 – Comparison data (typical values)

4. Properties of different types of base oils

The viscosity temperature properties are different with regard to different types of base oils. The low temperature properties, the viscosity index and the pour point are related to the addition of a pour point depressant and VI improver to the base oil. Figure 5 shows the viscosity at -20 °C and -10 °C, the typical VI and the pour point of different types of base oils.

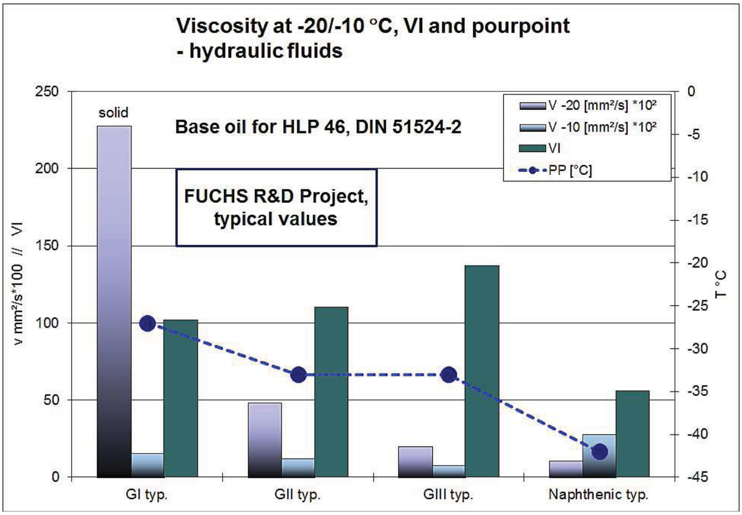

Figure 5: Viscosity at -20/-10 °C, VI and pourpoint – hydraulic fluids

The big advantage of group II and group III base oils which have improved low temperature viscosity, good cold flow properties, a shear-stable high viscosity index (especially group III base oils) and low pour points is demonstrated. The main advantage of group III base products is the shear stability in combination with the high VI of approximately 130.

5. Temperature stability of different types of base oils

The temperature stability of the different types of base oils is tested in a so-called roller test at a temperature of 135 °C. Figure 6 shows the difference in the thermal stability of these base oils.

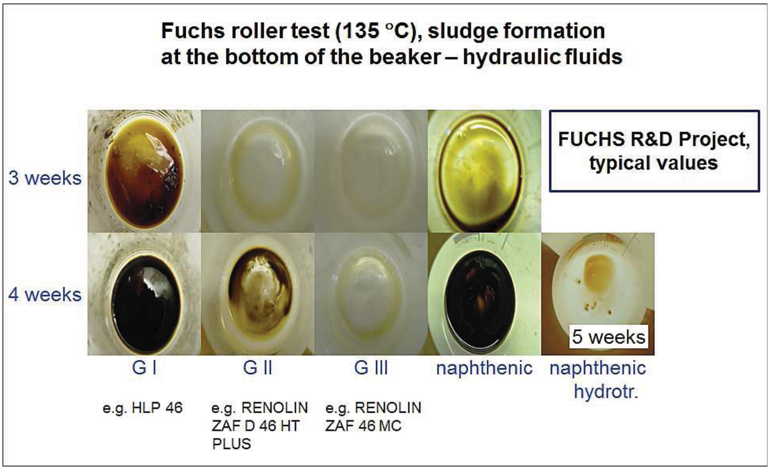

Figure 6: Fuchs roller test (135 °C), sludge formation at the bottom of the beaker - hydraulic fluids

As you can see, group II and group III based products offer higher thermal stability, lower sludge formation compared to conventional group I based hydraulic fluids (e.g. type SN based HLP 46. In the FUCHS roller test the sludge formation can be effectively reduced by using group II and group III base oils with selected additives to improve fluid properties.

6. Compatibility of new types of base oils to elastomers and sealing materials

Hydraulic systems should be leakage-free. Static and dynamic sealing is of great importance under the influence of the used hydraulic fluid. In the DIN 51524 "Minimum requirements for hydraulic fluids" there are specified values for the interaction of hydraulic fluids with sealing materials. The volume change for HLP 46 should be in a ratio between 0 up to +12% swelling with SRE NBR (**S**tandard **R**eference **E**lastomer, **N**itrilo **B**utadiene **R**ubber) materials (test conditions are 168 hours and 100 °C, SRE NBR 1). The test is conducted according to DIN 53538, part 1. Figure 7 shows the change in volume and hardness of the standard reference elastomer NBR 1 with different types of HLP 46 hydraulic fluids.

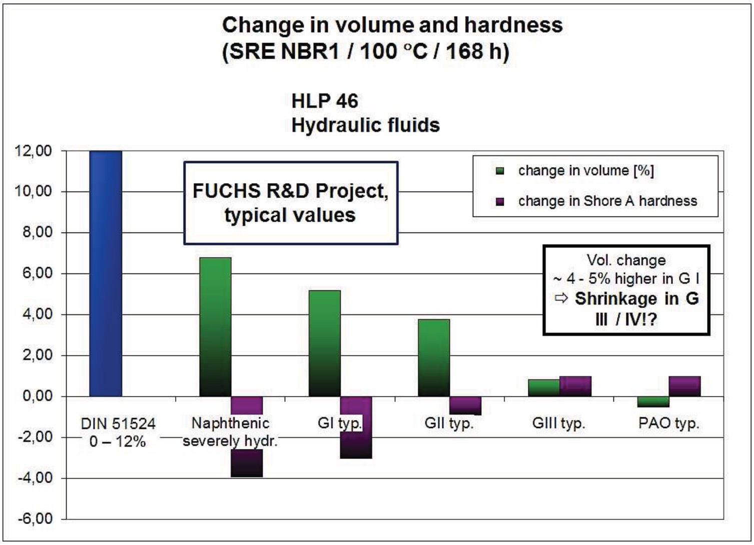

Figure 7: Change in volume and hardness (SRE NBR1 / 100 °C / 168 h)

The new base oil types, group II and group III, show different properties compared to group I. The swelling of the elastomer compound is reduced. This can be compensated in fully formulated hydraulic fluids, if needed, with special swelling agents and/or additives to generate more or less the same change in volume than usually expected from group I based fluids.

In general zinc-containing hydraulic fluids are very popular in use. The RENOLIN B 15 VG 46 is a typical robust monograde hydraulic fluid based on zincdialkyldithio-phosphate, based on group I base oil. The same additive technology has been transferred to group II base stock which is in use in Asia and in the US. The product is called RENOLIN B 46 PLUS which is the same additive composition with advanced base oils. Figure 8 shows the typical values of a group I based formulation compared to group II based formulation.

Comparison RENOLIN B 15 / RENOLIN B 46 Plus HLP 46 – in contrary (typical values)

	RENOLIN B 15 GI	RENOLIN B 46 Plus GII
V -20 [mm²/s]	solid	3860
V -10 [mm²/s]	2135	1201
V 40 [mm²/s]	46	46
V 100 [mm²/s]	6.74	6.96
VI	99	111
Density 15 °C [g/cm³]	0.879	0.865
PP [°C]	-30	-36
Colour ASTM [-]	1	0
S + additive S [ppm]	~ 4937	~ 667
Air release (LAV) 50 °C [min]	7	5.0

	RENOLIN B 15 GI	RENOLIN B 46 Plus GII
TOST lifetime (ASTM D 943) [h]	> 2000	> 4500
FZG A/8.3/90 up to LS 14 [DLS]	11	11
V 104 C wear ring | vane [mg]	33 | 2	30 | 2
ISO 13357-2 (dry filtration + wet filtration)	o.k.	o.k.
NBR1 (= 28/PX) / 168 h / 100 °C		
change in volume [%]	5.2	3.8
change in Shore A hardness	-3	-1.0
change in tensile strength [%]	-3.98	-2.81
change in ultimate elongation [%]	-8.6	-3.19

Figure 8: Comparison RENOLIN B 15 / RENOLIN B 46 PLUS HLP 46 – in contrary

The extremely good performance can be observed in the TOST (**T**urbine **O**xidation **S**tability **T**est) of the 2 fluids. By using modern hydroprocessed group II based products the TOST lifetime can be doubled or more. In general good results in field can be achieved by changing from group I to group II base oils. The different density, the different solubility of additives and oxidation products, the different additive response in these base oils should be kept in mind when formulating these modern types of fluids [4].

7. Experience from the field

Especially in Asia and in the US the usage of advanced base oil compositions is very popular due to the availability of these base stocks in these regions. In general there is good experience by using and transferring formulations from group I to group II. This applies for zinc-containing fluids as well as for zinc and ash-free types of fluids. The reduced sulfur content of group II and group III base oils improves oxidation stability, reduced sludge formation and improves lifetime of the fluids. Viscosity-temperature properties of these modern types of fluids superior to group I base oils. The price level of modern group I, group II and group III base oils is higher compared to standard group I based fluids. The trend to modern hydroprocessed group II and group III based fluids is ongoing, especially in closed systems with reduced volume and high circulation ratio [4]. This leads also to the development of new hydraulic fluids for hydraulic press systems. The new developed RENOLIN ZAF D 46 HT PLUS combines excellent antiwear/ extreme pressure performance with defined Brugger antiwear performance and excellent oxidation stability. RENOLIN ZAF D 46 HT PLUS is a modern hydraulic fluid based on hydroprocessed base oils.

8. Conclusion

The composition and structure of hydraulic fluids will change in the future to fulfill the customer expectations with regard to long lifetime, robustness and reduction in service. There is a clear trend in using hydroprocessed low sulfur base oils instead of the conventional group I socalled solvent neutral (SN) base oils. Products based on hydroprocessed base oils represent the newest generation of modern hydraulic fluids, e.g. RENOLIN B 46 PLUS, RENOLIN ZAF D 46 HT PLUS. These fluids have a balanced additive system and fulfill the newest requirements of component and machine manufacturers.

9. References

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