CHARACTERISTICS OF VACUUM DISTILLATION FRACTIONS DEPENDING ON THE CHARACTERISTICS OF THE INPUT HYDROCRACKED BASE OIL RAW MATERIAL OF THE MODRIČA OIL REFINERY

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ABSTRACT
Hydrocracked base oil raw material (BORM) is the basis for the production of hydrocracked base oils (HC-base oils) in the company „Modriča Oil Refinery", which is engaged in the production of HC-base oils, various motor and industrial lubricating oils, and lubricating greases. The production of the mentioned HC-base oils consists of four production units, the first of which (hydrocracking) is located in Bosanski Brod, and the other three (vacuum distillation, deparaffinization,and final processing - bleaching) are located within the Modrič Oil Refinery. The aim of this work was to analyze the influence of different physicochemical characteristics of BORM, which undergoes certain production processes, on the quality of its distillates. Distillation curves are also presented in the paper, based on which the temperature regime of the vacuum column is monitored and set, and different yields of fractions can be obtained. The obtained results for all tested parameters of the obtained fractions using two different base oil raw materials are within the limits prescribed by the internal standard.

1. INTRODUCTION

In the past, pure mineral oils, or oil distillates without any additives, were sufficient for the lubrication of all types of mechanical systems. However, modern mechanical systems require lubricants with improved properties, which pure mineral oils cannot have, and in addition, from an ecological point of view, conditions in terms of toxicity and environmental protectionare set. Hydrocracked base oils are increasingly used for the production of different groups of lubricants because they are characterized by a high viscosity index, excellent oxidation stability, low content of sulfur and aromatic hydrocarbons, and low volatility. The most important group of liquid lubricants, motor oils, in today's formulations, require hydrocracked base oils of medium and higher viscosity, lower volatility, and higher viscosity index. In the case of hydraulic oils for special purposes, the demand for hydrocracked base oils of medium gradations has increased. On the other hand, base oils of lower viscosity are most often used to formulate water-soluble agents for metal processing [1]. The use of hydrocracked base oils in the formulations of motor and industrial oils ensures outstanding technical characteristics of finished products and compliance with valid European standards in the field of environmental protection [2]. Base oils form the basis of all lubricants - lubricating oils and lubricating greases and significantly influence their basic properties. They are divided into: mineral and synthetic. Mineral oils are produced by refining petroleum, and synthetic oils are by chemical synthesis from different components. The advantages of synthetic base oils are biodegradability and non-toxicity and they have a longer service life, i.e. lower maintenance costs, but the main obstacle to more intensive development is the high cost of synthetic lubricants production. Internationally accepted motor oil specifications have been developed that serve engine and vehicle manufacturers, lubricant manufacturers, additive manufacturers, and motor oil users. The specifications are based on appropriate test procedures (tests), which were developed on representative engines, reference fuels, and oils [3]. They differ in API (American Petroleum Institute) classification of base oils, ACEA classification of base oils (Association des Constructeurs Européens d'Automobiles), and SAE (Society of Automotive Engineers) classification of motor oils according to viscosity grades. For the latest models of engines and vehicles, and according to the latest specifications of the quality of motor oils, base oils with significantly improved characteristics, with as little volatility as possible, ever cleaner combustion and low sulfur content, as well as having a low price, are required. All these requirements can be met with hydrocracked and synthetic base oils. Hydrocracked base oils are becoming more and more important, in terms of required characteristics and are very close to synthetic ones, but their prices are significantly lower than synthetic ones.

1.1. Production of hydrocracked base oils

The modern way of producing base oils is the application of only catalytic processes (eg hydrocracking - catalytic conversion of n-paraffin –hydro finishing). The product created in this way is clean and stable because molecules with poor lubricating properties have been converted into high-quality molecules. Also, this kind of technology is flexible and less sensitive to the quality of crude oil [1]. The advantage of the technology of hydrocracked (HC) base oils is that that all compounds, which from a technical and ecological point of view are undesirable in oils, are transformed into technically very desirable compounds, have a low content of sulfur and aromatic hydrocarbons and very low volatility [4]. Base oils obtained by hydrogen treatment processes are characterized by a low content of unsaturated compounds and hetero-elements, which provides them with not only a technical but also an ecological advantage [5]. Hydrocracking is a two-stage process that combines catalytic cracking and hydrogenation, where heavier fractions are split in the presence of hydrogen, to obtain more desirable products.

The production of HC base oils consists of the following production units:
atmospheric distillation of crude oil,

- vacuum distillation of the atmospheric residue,
- hydrocracking plant,
- vacuum distillation plant,
- deparaffinization plant,
- finishing-whitening unit.

Figure 1 shows the scheme of the domestic production process of hydrocracked base oilsBrod-Modriča oil complex.

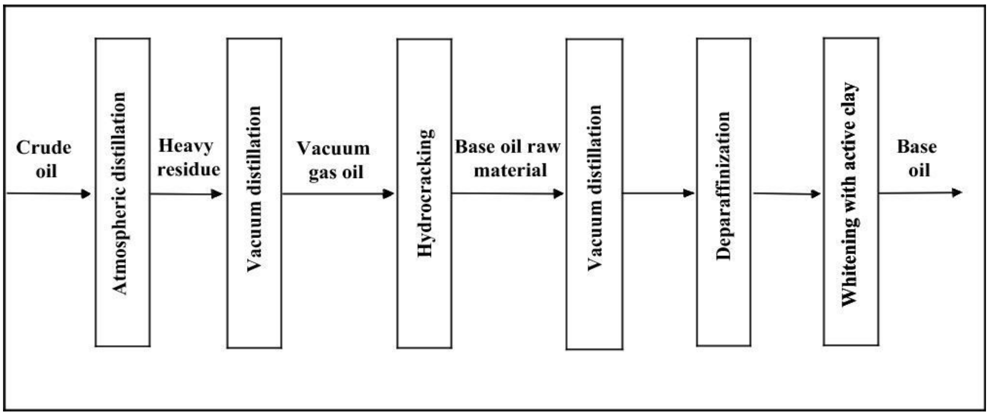

Figure 1. Block diagram of the process of obtaining hydrocracked base oils

It is important to emphasize that two products from vacuum distillation, heavy and light vacuum gas oil, are mixed and sent to the hydrocracking plant (ISOMAX), and the hydrocracking product contains light gaseous hydrocarbons, gasoline fraction, diesel fuel fraction, and the rest of the distillation represents the base oil raw material (BORM) that „Modriča Oil Refinery" uses as a basic raw material for the production of HC base oils [6].
A vacuum distillation column is basically a rectification column. Distillation of the base oil stock is carried out in a vacuum column at reduced pressure. Figure 2 shows the vacuum distillation of BORM and the resulting products.

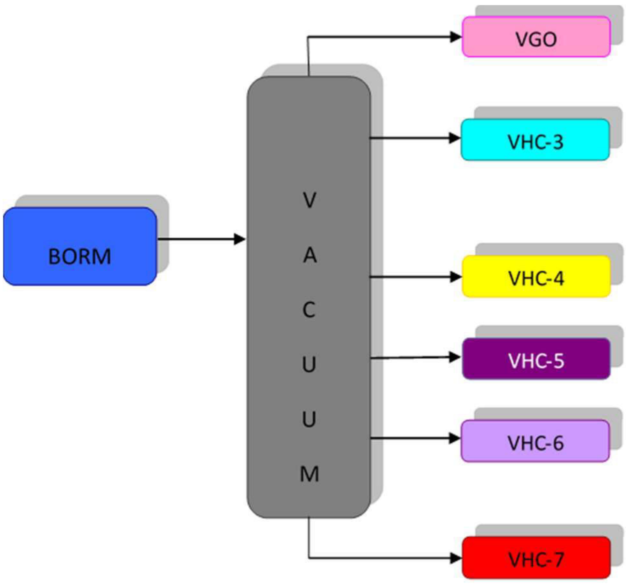

Figure 2. Block diagram of vacuum column flows
Legend: VGO - Vacuum gas oil; VHC-3 – leaves the column at 185 °C; VHC-4 - leaves the column at 220-230 °C; VHC-5 - leaves the column at 250°C; VHC-6 - leaves the column at 280 °C; VHC-7 - leaves the column at 320-350 °C

2. EXPERIMENTAL PART

The experimental part of the work was done in the company „Modriča Oil Refinery" a.d. and includes the analysis of two base oil raw materials, as well as the analysis of their fractions.

2.1 Material and methods

Two basic oil raw materials and their fractions were used for the analysis, and the following parameters were determined:

- Determination of kinematic viscosity,
- Calculation of viscosity index from kinematic viscosity,
- Determining the pour point,
- Determining the flash point in an open container,
- Fractional distillation at reduced pressure.

The kinematic viscosity was determined according to the ISO 3104:2002 standard. Viscosity index (VI) is a number used to characterize changes in kinematic viscosity with temperature changes and was determined according to the BAS ISO 2909:2003 standard. Determination of the pour point was done according to the standard BAS ISO 3016. Determination of the flash point in an open container was done according to the standard BAS ISO 2592:2002.

Base oils are fractionated according to strict viscosity specifications with a controlled volatility, especially follow-viscosity oils. Vacuum distillation apparatus was used for the analysis, applying the method of fractional distillation at reduced pressure - ASTM D1160.Figure 3 shows the apparatus for vacuum distillation.

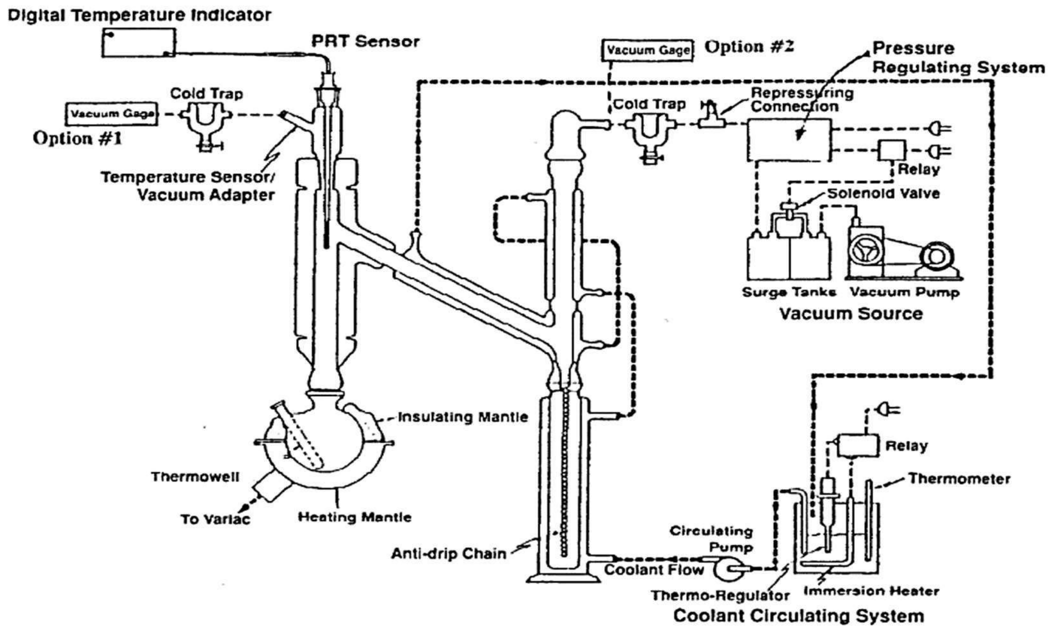

Figure 3. Vacuum distillation apparatus

3. RESULTS AND DISCUSSION

Tables 1 and 2 show the results of the determination of kinematic viscosity.

Table 1. Viscosity values for BORM1 and its fractions

Characteristic	BORM1	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
υ 40°C [mm^2/s]	21,60	10,01	12,81	19,59	28,57	30,23	49,78
υ 100°C [mm^2/s]	4,47	3,10	3,12	4,22	5,61	5,81	8,31

Table 2. Viscosity values for BORM1 and its fractions

Characteristic	BORM2	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
υ 40°C [mm^2/s]	21,23	10,05	12,63	18,62	24,42	33,40	43,10
υ 100°C [mm^2/s]	4,49	2,64	3,16	4,13	5,14	6,23	7,47

It can be concluded that HC-7 has the highest viscosity values, which means that it has a higher resistance to flow, that is, it flows harder compared to the other vacuums analyzed. Viscosity values play an important role when choosing a lubricating oil, considering that it affects many production specifications, the correct operation of equipment, the quality of lubrication, and thus the wear of parts.Tables 3 and 4 show the results of the viscosity index for BORM1 and BORM 2 and their fractions.

Table 3. Viscosity index for BORM1 and its fractions

Characteristic	BORM1	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
VI	118	101	103	121	139	138	141

Table 4. Viscosity index for BORM2 and its fractions

Characteristic	BORM2	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
VI	123	103	110	126	143	139	141

Based on the results, it can be seen that the heaviest fraction of the vacuum column HC-7 is also the fraction with the highest viscosity index, which means that it shows a smaller change in viscosity with temperature change compared to oils with a lower viscosity index. Tables 5 and 6 show the results of the pour point for BORM1 and BORM2 and their fractions.

Table 5. Pour point for BORM1 and its fractions

Characteristic	BORM1	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
PP (°C)	30	13	14	29	35	38	49

Table 6. Pour point for BORM2 and its fractions

Characteristic	BORM2	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
PP (°C)	33	15	17	30	35	40	41

It can be concluded that fractions from the lower floors of the vacuum column have the highest pour points, that is, the two heaviest fractions HC-6 and HC-7 have the highest values. Determining the pour point is an important characteristic, especially in areas with low temperatures. It is necessary to ensure that the oil maintains the required working properties, in order to prevent possible damage to the engine. Tables 7 and 8 show the flash point results for the analyzed samples.

Table 7. Flashpoint results for BORM1 and its fractions

Characteristic	BORM1	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
FP(°C)	222	190	200	230	250	254	274

Table 8. Flashpoint results for BORM2 and its fractions

Characteristic	BORM2	VGO	HC-3	HC-4	HC-5	HC-6	HC-7
FP(°C)	201	192	207	228	246	251	260

It can be concluded that the fractions from the lower floors of the vacuum column, HC-6, and HC-7, have the highest flash point values. Determining the flash point is important for reliable information on the properties of the petroleum product, for assessing its quality, as well as for transportation and storage due to the risk of fire.

Table 9 shows the measured fractional distillation values at reduced pressure for BORM1, as wellas for its fractions.

Table 9. Distillation of BORM1 and its fractions

DISTILLATION	BORM1	HC-3	HC-4	HC-5	HC-6	HC-7
Start	342	359	406	409	417	423
5%v/v	375	380	420	441	454	468
10%v/v	387	391	430	456	457	482
20%v/v	400	394	438	470	465	503
30%v/v	411	396	441	475	476	516
40%v/v	420	401	443	477	485	528
50%v/v	429	405	447	484	491	540
60%v/v	437	408	450	492	498	552
70%v/v	450	413	455	500	503	562
80%v/v	466	418	458	506	511	576
90%v/v	487	427	462	516	522	593
95%v/v	507	430	463	530	538	603
98%v/v	507	439	466	530	541	606
End	537	444	478	544	550	606

Figure 4 shows a comparison of the distillation curves of BORM1 and its fractions.

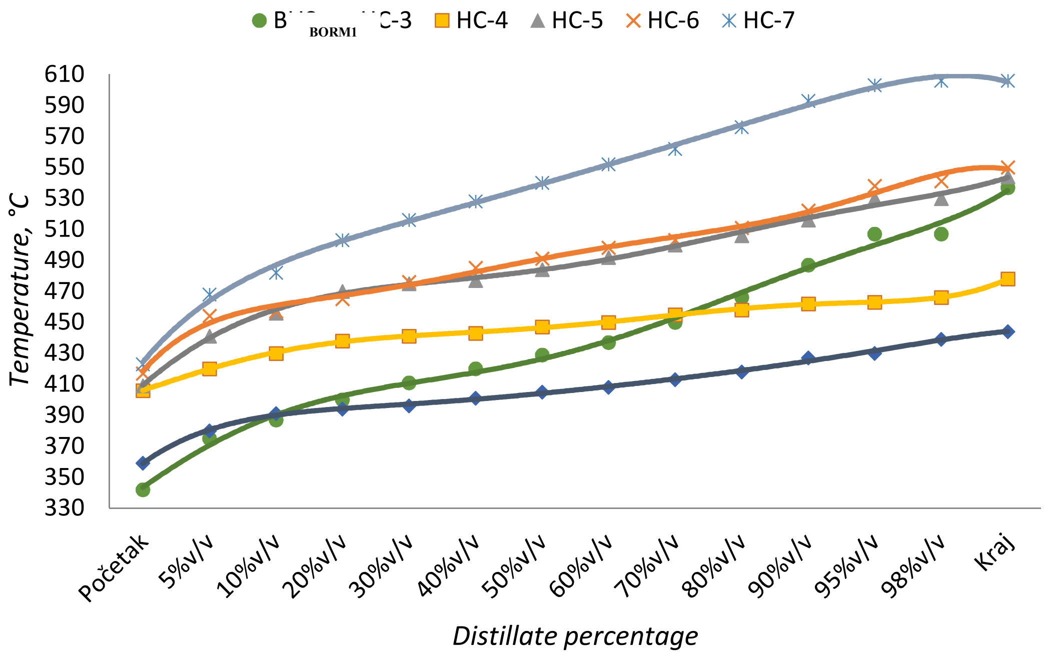

Figure 4. Comparison of the distillation curves of BORM1 and its fractions

Based on the results and the distillation curves shown in Figure 4, it can be seen that fractions VHC-3, VHC-4, and VHC-7 can be almost completely separated by the distillation process, while fractions VHC-5 and VHC-6 contain impurities of each other, i.e. do not have the so-called clean cut.
Based on the initial boiling temperatures and final boiling temperatures of the fractions, it can be concluded that the lightest fraction (a fraction with lower viscosity) is VHC-3, and the heaviest (fraction with higher viscosity) is VHC-7. Fraction VHC-4 has the narrowest

temperature range of extraction from BORM1, which can be seen on its distillation curve. This means that this fraction contains components that have similar physical properties.

Table 10 shows the measured values of fractional distillation at reduced pressure for BORM2, as well as for its fractions.

Table 10. Distillation of BORM2 and its fractions

DISTILLATION	BORM2	HC-3	HC-4	HC-5	HC-6	HC-7
Start	340	339	387	431	429	432
5% v/v	373	358	413	440	456	454
10% v/v	387	374	421	462	477	475
20% v/v	400	385	428	472	499	494
30% v/v	411	391	434	483	513	501
40% v/v	420	393	435	499	522	516
50% v/v	429	398	440	504	533	523
60% v/v	437	401	444	511	540	532
70% v/v	450	409	448	517	551	539
80% v/v	466	417	454	523	556	553
90% v/v	490	429	464	530	561	562
95% v/v	516	435	474	535	567	576
98% v/v	519	438	476	539	570	579
End	546	454	480	553	570	584

Figure 5 shows a comparison of distillation curves for BORM2 and its fractions.

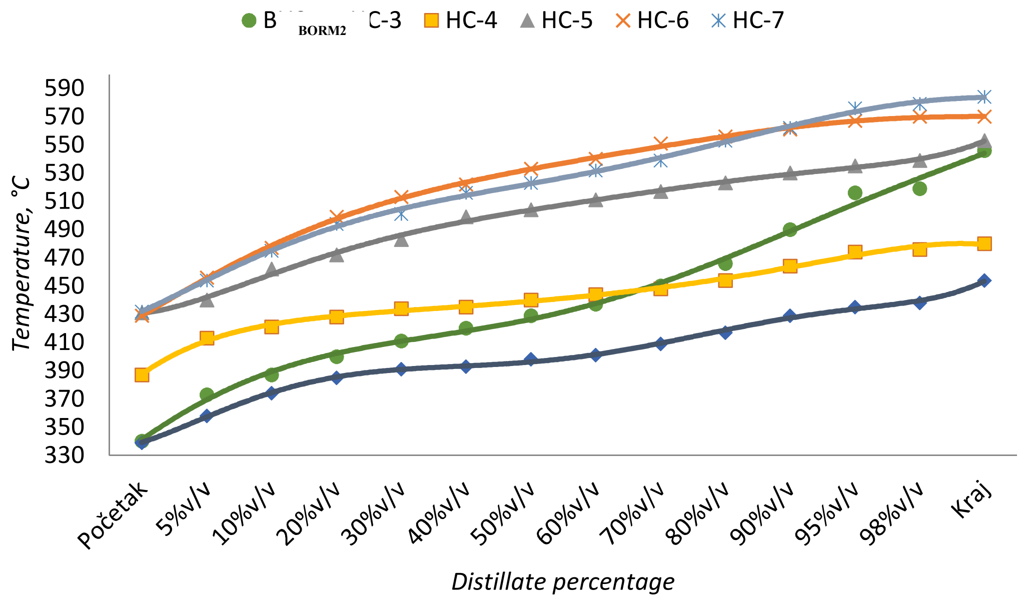

Figure 5. Comparison of the distillation curves of BORM2 and its fractions

Based on the results and the comparative presentation of the distillation curves in Figure 5, it can be concluded that fractions VHC-3, VHC-4, and VHC-5 can be almost completely separated by the distillation process, while fractions VHC-6 and VHC-7 contain impurities of each other. Based on the initial boiling temperatures and final boiling temperatures of the fractions, it can be concluded that the lightest fraction (a fraction with lower viscosity) is VHC-3, and the heaviest (fraction with higher viscosity) is VHC-7. Fraction VHC-4 has the narrowest temperature range of extraction from BORM2, which can be seen on its distillation curve. This means that this fraction contains components that have similar physical properties.

4. CONCLUSION

The results of research of physicochemical characteristics in laboratory conditions: kinematic viscosity, viscosity index, pour point, flash point, as well as the distillation range for both base oil raw materials and their fractions contribute to the reduction of technological process costs and the optimization of technological parameters. The values for BORM1 and BORM2 differ very little and the characteristics of the obtained fractions are within the limits prescribed by the internal standard.

Hydrocracked base oils can meet the strict requirements of modern mechanical systems with a high viscosity index, the ability to lubricate in a wide temperature range, a low pour point, and very high thermal and oxidation stability. With a longer interval of use, they are more environmentally friendly.

5. REFERENCES

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