Vietnam Journal of Catalysis and Adsorption
Tạp chí xúc tác và hấp phụ Việt Nam

http://jca.edu.vn

Some results of investigating the physico-chemical and electrical properties of oil fraction which is separated from base oil SN 100

Nguyen Ngoc Linh[1], Do Dinh Trung[2*], Le Quoc Pham[2], Cong Ngoc Thang[3]

[1] *Faculty of Pharmacy, Thanh Do University, Km 15, 32 Road, Hanoi, VIETNAM*
[2] *Institute of Tropical Durability, Joint Vietnam-Russia Tropical Science and Technology Research Center, 63 Nguyen Van Huyen, Hanoi, VIETNAM*
[3] *Faculty of Petroleum and Energy, Hanoi University of Mining and Geology, 18 Vien Road, Hanoi, VIETNAM.*
**Email: trungdodinh@mail.ru*

ARTICLE INFO

Received: 04/07/2024
Accepted: 06/09/2024
Published: 30/09/2024

Keywords:
Base oil SN 100; silica gel; breakdown voltage; moisture resistance testing.

ABSTRACT

The article presents some results of investigating the effective adsorption ratio of base oil SN 100 on silica gel, determination of physico-chemical, electrical properties, and voltage stability of the oil fraction which is separated from base oil SN 100 by adsorption method on silica gel with the appropriate ratio of silica gel/base oil SN 100 = 140/100. Kinematic viscosity, flash point (closed cup), total acid number, and pour point were determined according to ASTM D445, ASTM D93-20, ASTM D974-22, and GOST 20287-91. The breakdown voltage was determined according to IEC 61086-2:2004. Voltage stability was evaluated by accelerated moisture resistance test. The determination results show that the physico-chemical and electrical properties of the oil portion which seperated from adsorption on silica gel reach the required values (according to the standard MIL-1-46058C), it allows use to make turbine oil and preservation oil for electrical and electronic equipment subject to high breakdown voltage.

1. Introduction

In Vietnam's climatic conditions such as salt vapor, high air humidity, high temperature, etc., causes serious corrosion, reduces performance and reduces the life of electronic circuits and equipment [1, 2]. Therefore, using coatings to prevent contact of the above devices with the climatic environment is the most effective solution today.

Dielectric liquids play an important role in the production and preservation of electrical and electronic equipment in the aerospace industry. The technical parameters of this liquid are more demanding such as oxidation stability, high dielectric strength, good thermal conductivity and heat resistance [3]. Therefore, the base oils for the production of these fluids must also meet the above requirements.

Base oil SN 100 is widely intended for use in lubricants production. Those applications are mould oil, transmission fluids, gear oils, metals working fluids, hydraulic oils, transformer oils, etc. The main components of the above oils include paraffinic, naphthenic and aromatic compounds [4]. Silica gel adsorbents are widely used for not only their high physical but also chemical adsorption properties, making them a conspicuous choice to convert base oil into different products [5, 6]. The polarity of hydrocarbons increases in the order of paraffinic hydrocarbons, naphthalenic hydrocarbons, and finally aromatic hydrocarbons. As polarity increases, the

https://doi.org/10.62239/jca.2024.053

adsorption capacity of the hydrocarbons also rises, due to the influence of Van der Waals forces. Thus, the adsorption capacity of hydrocarbons follows the same order: paraffinic hydrocarbons, naphthalenic hydrocarbons, and aromatic hydrocarbons [7]. The adsorption of hydrocarbon increased with the polarity, because of Van der Waals forces. In addition, silica gel is less costly than other adsorption materials [8]. In this study, silica gel was used to adsorb the base oil, which contains mostly naphthenic compounds and a small amount of aromatic compounds, with outstanding physicochemical properties such as oxidation resistance and low-temperature pour point [4, 9 - 11]. Additionally, naphthenic oil contains much less wax than a comparable paraffinic oil, so which gives them much better low-temperature pour point compared to paraffinic oil, this portion can be used as a raw material to produce transformer oil, turbine oil, and preservative oil for electronic circuits and electrical equipment.

2. Materials and methods

2.1. Materials

The specifications of base oil SN 100 (Narmak trade S.R.O, Szech Republic) are given in Table 1.

Table 1. Physico-chemical properties of base oil SN 100

Property	Typical value	Test method
Density at 20 °C, g/cm^3	0.862	PN-EN ISO 3675
Kinematic viscosity, cSt - at 40 °C - at 100 °C	 20.1 4.03	PN-ISO 3140
Viscosity index	96	PN-79/C-04013
Flash point (closed cup), °C	201	PN-EN ISO 2719
Base number, mgKOH/g	0.01	PN-85/C-04066
Pour point, °C	-15	PN-ISO 3016

Silica gel (Xilong Scientific, China, pore size: 3 - 10 nm; surface area: 200 - 800 m^2/g); acetone (Xilong Scientific, China);

Separatory funnel 500 mL (Duran, Germany); glass beaker 500 mL (Duran, Germany); graduated glass measuring cylinder 250 mL; appropriate distillation systems.

2.2. Adsorption and desorption of base oil SN 100 on silica gel

In this study, the appropriate silica gel content for effective adsorption of portion NP was investigated. The contents of base oil SN 100, silica gel and acetone used in this study are presented in Table 2.

Table 2. Composition of survey materials

Base oil SN 100, g	Silica gel, g	Acetone, g	
		1st time	2nd time
100	80	60	60
100	100	60	60
100	120	60	60
100	140	60	60
100	160	60	60

Silica gel is dried at a temperature of 150 - 180 °C for 4 - 5 hours, then set at room temperature. Weighting silica gel, putting it into a separating funnel, then base oil SN 100 was added on the top of silica gel. Shaking the separatory funnel for 30 minutes. Leaving it at room temperature for 24 hours, then separating the part of oil which is not adsorbed on silica gel, this portion is denoted as PP. The adsorbed portion on silica gel was eluted twice with acetone. Atmospheric distilling the mixture after desorption at temperature of 56 - 57 °C to remove acetone. Continuing vacuum distillation at 80 °C to remove water. Vacuum distillation was stopped at the point when no water droplets were observed appearing in the distillate-receiving flask, the resulting part is denoted as NP.

2.3. Analysis methods

Kinematic viscosity determined according to ASTM D445-23 [12] by instrument DP Petrotest.

Flash point determined according to ASTM D93-20 [13].

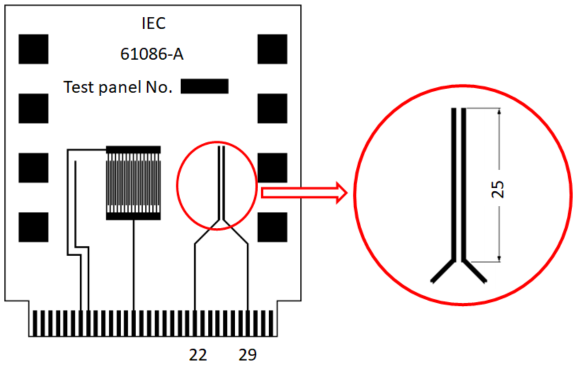
Total acid number determined according to ASTM D974-22 [14].

Viscosity index determined according to ASTM D2270 [15] (Standard practice for calculating viscosity index from kinematic viscosity at 40 °C and 100 °C)

Pour point determined according to GOST 20287-91 [16] by instrument UTZ-60M.

The samples used for moisture resistance test according to MIL-1-46058C [17] and method 106G of MIL-STD-202G [18]. The panel test shall be as in Figure 1a. It comprises a "Y" electrode for measurement of breakdown voltage. The breakdown voltage of the coating in the moisture resistance test is determined according to IEC 61086-2:2004 [19]. Images of the breakdown voltage determination device and measurement samples are illustrated in Figure 1b.

https://doi.org/10.62239/jca.2024.053



(a)

(b)

Figure 1: (a). "Y" pattern for moisture resistance test and (b). Device for determining breakdown voltage and samples

3. Results and discussion

3.1. Effect of silica gel on adsorption efficiency

Base oils obtain three main components: paraffinic, naphthenic and aromatic compounds. Studies, although, have shown that aromatic substances have a stronger adsorption ability than naphthenes on silica gel [4, 9]. The amount of aromatic substances in base oils, however, is usually small (<3.5 wt.%). Therefore, the adsorbed portion on silica gel contains mostly naphthenic compounds and a small part of aromatic compounds (portion NP), while the unadsorbed portion on silica gel contains mostly paraffinic compounds and a small part of naphthenic compounds (portion PP).

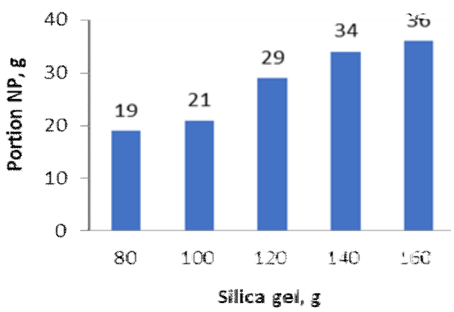


Figure 2. Correlation between mass of silica gel and mass of portion NP

Figure 2 summarizes the results of separating portions from base oil SN 100 using silica gel. The results in Figure 2 show that, when increasing the amount of silica gel, the content of portion NP adsorbed on silica gel also increases. When using 140 g of adsorbent silica gel, 34 g of fraction NP is obtained, thus the mass of portion NP increases by 17.24 % compared to when using 120 g of silica gel. When increasing the amount of silica gel to 160 g, the mass of the portion NP increases slightly (up 5.88 % compared to when using 120 g of silica gel). If increasing of silica gel continued, the adsorption efficiency of portion NP on silica gel will increase little or not at all. This means that the adsorbed portion NP is nearly saturated on the silica gel surface or no more naphthenic compounds remaining. In this study, therefore, the appropriate mass ratio of silica gel and base oil SN 100 to use is the ratio silica gel/base oil = 140/100. The portion NP separated from this survey ratio was used for electrical properties studies.

3.2. Evaluation of physicochemical properties of fractions separated from base oil SN 100

The characteristic properties of the base oil SN 100 and the fractions which separated from this base oil (portions NP and PP) were determined. Those are the kinematic viscosity (at 40 °C and 100 °C), viscosity index, flash point (closed up), total acid number, and pour point. The determination results are summarized in Table 3.

Table 3. Physico-chemical properties of fractions

Typical properties	Values		
	NP	PP	SN 100
Kinematic viscosity, cSt			
- at 40 °C	6.904	9.862	9.607
- at 100 °C	2.242	2.665	2.598
Viscosity index	146	115	101
Flash point (Closed cup), °C	192	198	192
Total acid number, mg KOH/g	0.15	0.10	0.13
Pour point, °C	-36	-33	-33

The results in Table 3 show that, the viscosity index of portions NP and PP is significantly improved. The viscosity index of the portion NP reaches 146, for portion PP it is 115, while this property of base oil SN 100 is 101. This shows that the portions separated from the base oil (portion NP and PP) have less viscosity changes with temperature compared to the base oil SN 100, and ability of these portions to maintain viscosity in wider temperature range than base oil SN 100 with low viscosity index (reaching value is 101).

The pour point is another important criterion of lubricating oil. The results in Table 3 show that the portion NP has a lower pour point (-36 ^oC) than the base oil SN 100 and the portion PP (-33 ^oC). The portion NP shows the advantage of being able to be used at low temperatures (no lower than -36 ^oC) but still retains its liquid state and maintains optimal distribution properties to the lubrication points.

3.3. Investigation of electrical characteristics

Insulating oil is widely used in high voltage electrical equipment, such as transformers, power transformers, filled capacitors, etc. Therefore, this oil needs to be a good electrical insulator, good thermal conductivity and chemical stability at high temperatures.

The breakdown voltage of oil refers to the maximum voltage this oil can withstand under test conditions. This is an extremely important characteristic for protective coatings for electronic circuits.

The moisture resistance test for 10 cycles, each cycle includes 24 hours, was conducted in this study. Time to determine breakdown voltage after 1, 3, 7 and 10 cycles. The results of determining the breakdown voltage are summarized in Table 4.

Table 4. Breakdown voltage value of coating NP in moisture resistance test.

Type of sample	Time of moisture resistance test	Breakdown voltage, kV
T.0	Initial sample	2.81
T.1	After 24 hours (1 cycle)	2.80
T.3	After 72 hours (3 cycles)	2.22
T.7	After 168 hours (7 cycles)	1.94
T.10	After 240 hours (10 cycles)	1.93

The results of the moisture resistance test in Table 4 showed that, the breakdown voltage of coating NP decreased over time compared to the initial sample. At the 10th cycle, the breakdown voltage value reaches 1.93 kV. According to the MIL-1-46058C standard, a protective coating that can accept voltage above 1.5 kV without breakdown is considered to meet the requirements. Results obtained in the study should be subjected to appropriate statistical methods and presented clearly.

4. Conclusion

This study has determined the appropriate ratio of silica gel used to effectively adsorb the portion containing mostly naphthenic molecule and partly aromatic molecule (portion NP), that ratio is silica gel/base oil SN 100 = 140/100.

The portion adsorbed on silica gel and separated has outstanding characteristics such as viscosity index of 146, flash point (closed cup) of 192 ^oC, pour point of -36 ^oC. With these superior properties, it allows this portion to be used as a initial materials or mixed with higher quality oil as a raw material to make turbine oil, bringing higher efficiency and economic benefits compared to base oil SN 100.

Based on the results of moisture resistance test, it was established that the adsorbed portion on silica gel which separated from base oil SN 100 is highly breakdown voltage. This portion meets the requirements for use in high voltage electrical equipment, as protection for electronic circuits and electronic equipment. The data obtained from these studies can be used to develop recommendations for the protection of electronic parts of aircraft, military and other equipment in the future.

Acknowledgments

The authors would like to thank Institute of Chemistry - Material and the system Vilas 938 of Institute of Tropical Durability for providing support in equipment to perform this research.

References

1. Kamila Piotrowska, Rajan Ambat. IEEE Transactions on Components, Packaging and Manufacturing Technology, 10(10) (2020), 1617-1635. https://doi.org/10.1109/TCPMT.2020.3005933
2. Wong E. H., Koh S. W., Lee K. H, Rajoo. IEEE Transactions on Components, Packaging and Manufacturing Technology, 25(3) (2002), 223-230. https://doi.org/10.1109/TEPM.2002.804613
3. Bella H. Chudnovsky. Proceedings of the fifty-first IEE Holm conference on electrical contacts, Chicago USA, (2005) 107-114. https://doi.org/10.1109/Holm.2005.1518230.
4. Hazelwood R. N., Frey, R. M. and Broecker, J. B.. J. Electrochem. Soc, 102(4) (1955), 170-175. https://doi.org/10.1149/1.2430019
5. Vira Sabadash, Vitaliy Lysko. J. Ecol. Eng. 2023; 24(10):40-46. https://doi.org/10.12911/22998993/169997
6. Rossi M, Gianazza M, Alamprese C, Stanga F. Food Chem. 82(2003):291–296. https://doi.org/10.1016/S0308-8146(02)00551-4
7. Zho Cao et al. Chemical engineering Journal. Vol.420(3) (2021), 127578. https://doi.org/10.1016/j.cej.2020.127578

8. Hung-Yu Chen and I-Tzu Lo. Appl. Sci. 2022, 12(23), 11955; https://doi.org/10.3390/app122311955
9. Insley P. Jones, Oldwick N. J.. Method of improving lubricating oil by adsorption on silica gel. United states patent office 2.572.866, (1951)
10. Kajdas C. Lubricants. Science and technology publishing house, Hanoi - 1993 (Translated from Vietnamese).
11. Biryukov V. P. Lubricants, fuels and technical fluids. Moscow - 2008. (Translated from Russia Federation).
12. ASTM D445-23. Standard test method for kinematic viscosity of transparent and opaque liquids (and calculation of dynamic viscosity).
13. ASTM D93-20. Standard test methods for flash point by Pensky-Martens closed cup tester.
14. ASTM D974-22. Standard test method for acid and base number by color-indicator titration.
15. ASTM D2270-10 (2016). Standard practice for calculating viscosity index from kinematic viscosity at 40 °C and 100 °C.
16. GOST 20287-91. Petroleum products. Methods of test for flow point and pour point.
17. MIL-1-46058C (1972). Military specification: Insulating compound, electrical (for coating printed circuita assemblies).
18. MIL-STD-202G, Method 106G (2002). Moisture resistance.
19. IEC 61086-2:2004. Coatings for loaded printed wire boards (conformal coatings) - Part 2: Methods of test.