ORIGINAL PAPER

VISCOSITY INDEX IMPROVERS FOR MULTI-GRADE OIL OF COPOLYMERS POLYETHYLENE-PROPYLENE AND HYDROGENATED POLY (ISOPRENE-CO-STYRENE)

IOANA STANCIU[1]

Manuscript received: 09.09.2017; Accepted paper: 21.10.2017;
Published online: 30.12.2017.

Abstract. *To establish the ability of Infineum SV 260 and Paratone 8900 copolymers solutions in SAE 10W mineral oil as solvent to perform at low and high temperatures in a vehicle's engine, that is their capacity to improve the oil viscosity index, the viscosity-temperature characteristics of their 3, 3.5, 4, 4.5 and 5 % solutions were determined. The kinematic viscosities of the mineral oil SAE 10W and concentrated copolymer Infineum SV 260 and Paratone 8900 solutions were determined using a set of Schott Ubbelohde-type viscometers selected according to the values of their constants and viscosities of solutions, so that the margins of the uncertainty, inherent in the Hagebach-Couette correction, does not exceed the error allowed for the measurements. It was obtained that the both copolymer increase very much the viscosity index, as much as their concentration is higher. Infineum SV 260 produces a lower increase of viscosity indices comparative with Paratone 8900: 3.13 times for a concentration of 3%, 4.21 times for 3.5%, 4.42 times for 4%, 4.57 times for 4.5% and 4.71 times for 5% compared with 4.38, 4.7, 4.86, 5.18 and 5.33 times, respectively.*

The values of the viscosity-temperature coefficients, calculated from the kinematic viscosities of solutions at 40 and 100^oC, show also that Paratone 8900 is a better viscosity index improver than Infineum SV 260 irrespective of concentration.

Keywords: *viscosity index improvers, multi-grade.*

1. INTRODUCTION

The temperature range at which the oil is exposed in a vehicle engine is quite wide: from cold in winter with high temperatures during the summer when it is heated. Oil viscosity decreases with increasing temperature, and such a difference can be covered only by a single grade oil.

Lubrication at high temperatures has been improved with the advent of viscosity index improvers [1-5]. These polymers with low viscosity oils add their viscosity-temperature characteristic improves engineering and thicken them effectively at high temperatures [6-9]. Extends lubricating effect of a wider range of temperatures and thus called multi-grade oils.

Viscosity index is an empirical number indicating the degree of viscosity of an oil change on a given temperature range [10-12]: high value means low variation and low value - high variation. The range of VI normal chain paraffinic oils without additives is between 95 and 105. Viscosity decrease with increasing temperature can be reduced by using lubricating additives, also called viscosity index improver or viscosity modification. They ar special polymers that - add low viscosity oils - viscosity-temperature characteristics improve them.

[1] University of Bucharest, Faculty of Chemistry, Department of Physical Chemistry, 030018 Bucharest, Romania. E-mail: istanciu75@yahoo.com.

[11, 13, 15]. The additives effectively thickens the oil at all temperatures, but the increase in viscosity is more pronounced at high temperatures. The oil viscosity continues to decrease logarithmically with increasing temperature, but the slope is reduced considerably.

Extends lubricating effect so a higher temperature range and the oil turns from monograde in multigrade. The slope of the straight line log (viscosity)-log (temperature) is determined for a given polymer, the nature and concentration of the polymer, and the nature of the oil [14-16].

Importance VI can be demonstrated by considering the auto lubricants: an excessively thick VI oil when the engine is cold, start promoting rapid and prompt circulation and excessive thinning when the engine is hot, provides full lubrication and prevents consumption excessive oil [17-19].

The objective of this article is to determine the viscosity index for copolymer solutions Infineum SV 260 and Paratone 8900 or correspondence multi-grade recommended as viscosity modifiers for mineral oils. We determined their effectiveness prevailed paraffinic oil SAE 10W.

2. MATERIALS AND METHODS

2.1. MATERIALS

The copolymer polyethylene-propylene is Paratone 8900 commercialized by Exxon Chemical. The properties physical and chemical are**:** physical state – solid, form – bales and granulate, colour – natural opaque, brown in case of oil extended grades, odour – weak paraffinic, pH value – n/a, relative density – 860 – 900 kg/m^3.

The copolymer hydrogenated poly (isoprene-co-styrene) is Infineum SV 260 commercialized by Infieum UK Limited. The properties chemical and physical of copolymer hydrogenated poly (isoprene-co-styrene) are: physical state – solid, form – white solid blocks, colour – compressed crumbs, odourless, flashpoint > 150^{o}C, insoluble in water, is not material hygroscopic, stable, density (15^{o}C) – 0.272 g·cm^{-3} and none hazardous decomposition.

The oil SAE 10W is physical and chemical properties: form - homogeneous liquid, yellow-brown, odor - characteristic, density (15^{o}C) – 0.875-0.910 kg/m^3, kinematics viscosity to 40^{o}C - 90 cSt, kinemetics viscosity to 100 ^{0}C - 8 cSt, dynamic viscosity (20^{o}C) - 65 cP, viscosity index - 70-100, solubility in organic solvents, petroleum, fat, water-insoluble, flash point > 200^{o}C, melting point - (-10) ÷ (-15)^{o}C, amount of coke – 0.03 – 0.5 %. The SAE 10W oil is used so predominantly paraffinic hydrocarbons containing 75 % saturated.

2.2. METHODS

Dissolution of the two polymers in the oil SAE 10W was conducted at room temperature with gentle stirring for several weeks. Solutions of concentration 6 g / dL brew was then diluted with mineral oil SAE 10W to achieve concentrations of 3, 3.5, 4, 4.5 and 5g/dL.

The kinematic viscosities of the mineral oil SAE 10W and concentrated copolymer solutions 3, 3.5, 4, 4.5 and 5g/ dL were determined using a set of Schott Ubbelohde-type viscometers selected according to the values of their constants and viscosities of solutions, so that the margins of the uncertainty, inherent in the Hagebach-Couette correction, does not exceed the error allowed for the measurements. The measurements were carried out at 40 ±

0.1 and $100 \pm 0.1^{o}C$, according to the recommandation of ASTM D2270 [20-22]. They were possible only for 3, 3.5, 4, 4.5 and 5 g/dL solutions with the available set of viscometers.

3. RESULTS AND DISCUSSION

3.1. RESULTS

The kinematic viscosities of 3, 3.5, 4, 4.5 and 5 g/dL copolymer solutions Infineum SV 260 and Paratone 8900 in SAE 10W as solvent were measured at 40 and $100^{o}C$, according to ASTM D2270 [29-31], and the viscosity indices were determined using the ASTM D-341 diagram, shown in Figs. 1 and 2.

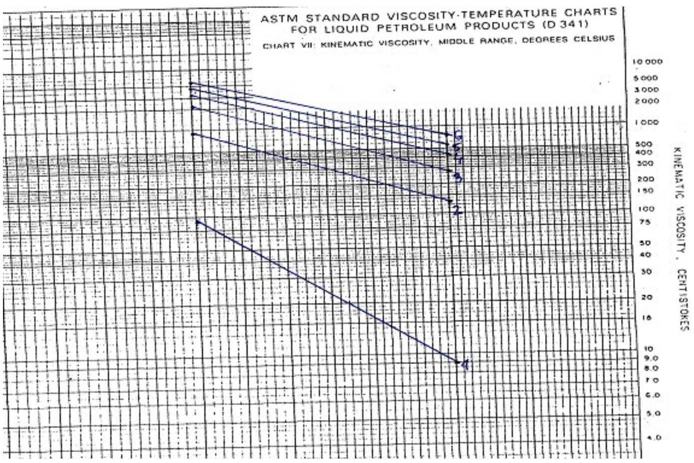

Figure 1. ASTM D-341diagram for determination of viscosity indices of SAE 10W oil and concentrated copolymer Paratone 8900 solution: 1- oil SAE 10W, 2- solution 3 %, 3- solution 3.5 %, 4 – solution 4 %, 5 – solution 4.5 % and 6 – solution 5 %.

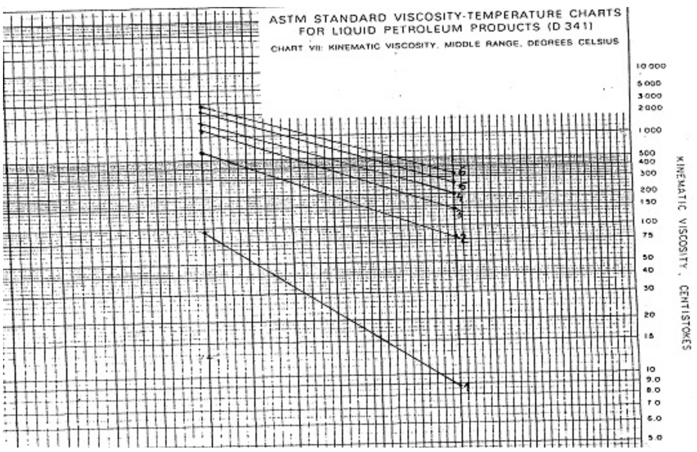

Figure 2. ASTM D-341diagram for determination of viscosity indices of SAE 10W oil and concentrated copolymer Infineum SV 260 solution: 1- oil SAE 10W, 2- solution 3 %, 3- solution 3.5 %, 4 – solution 4 %, 5 – solution 4.5 % and 6 – solution 5 %.

A copolymer solution Paratone 8900 shows a greater increase of viscosity at all concentrations. The dependences of viscosity indices on concentration of copolymers Infineum SV 260 and Paratone 8900 are shown in Fig. 3.

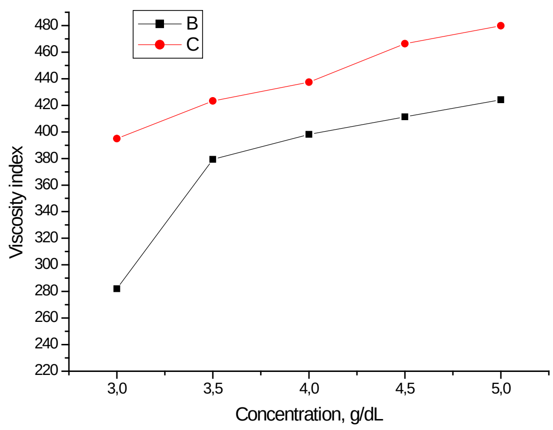

Figure 3. Dependence of viscosity indices on copolymer concentration: B – Infineum SV 260; C – Paratone 8900.

3.2. DISCUSSION

Viscosity is a measure of an oil thickness and ability to flow at certain temperatures, while viscosity index is a lubricating oil quality indicator, an arbitrary measure for the change of its kinematic viscosity with temperature and provides an insight into the oil's ability to perform at high and low temperatures [23].

The criteria for classification of mineral oils for engines take into account either the viscosity - that cause lubricating ability or performance - indicating the temperature which can be used [24-26].

The most used classification that takes into consideration the viscosity is done by Society of Automotive Engineers, SAE shortened. Based on measurements of viscosity SAE viscosity classification standard developed oils for cars J 300 [27]. According to this, classes of oils - shown in Table 1 - are defined according to dynamic and kinematic viscosity in different conditions [28].

According to Table 1 for engine oils there are two types of SAE viscosity grades: one denoted by number and "W" and the only other number. The differences between the two types of classes are the following oils: oils "W" are upper limits for the dynamic viscosity and pumping cracking at low temperatures and minimum limits kinematic viscosity at 100^{o}C, while no W oils have upper and lower for kinematic viscosity at 100^{o}C and lower limit for viscosity at operating temperature (150 ^{o}C) and shear rate (10^5 s^{-1}) large, but not for the viscosity at low temperatures. So classes W shows the performance at low temperatures and for those without W are provided only performance at high temperature.

If oils meet the requirements of only one class are called monograde, and if you meet the requirements of both classes are multi-grade. The multi-grade oils do not become too viscous at low temperatures and meet, also, the corresponding requirements class they belong to high temperatures. This means that their viscosity decreases with increasing temperature less than the grade oils.

Table 1. Viscosity grades for engine oil (from SAE J300).

SAE Viscosity Grades for Engine Oil (SAE J300) December 1999					
	Absolute Viscosity (cP)		Kinematic viscosity (cSt)		HTHS (cP) , 150°C
Grade	Maximum Cold Cranking	Minimum Cold ---Pumping	Minimum	Maximum	High-Temperature -High-Shear
0W	6200 at -35 °C	60000 at -40 °C	3.8	-	-
5W	6600 at -30 °C	60000 at -35 °C	3.8	-	-
10W	7000 at -25 °C	60000 at -30 °C	4.1	-	-
15W	7000 at -20 °C	60000 at -25 °C	5.6	-	-
20W	9500 at -15 °C	60000 at -20 °C	5.6	-	-
25W	13000 at -10 °C	60000 at -15 °C	9.3	-	-
20	-	-	5.6	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	2.9 (0W-40, 5W-40, 10W-40)
40	-	-	12.5	<16.3	3.7 (15-40, 20W-40, 25W-40, 40)
50	-	-	16.3	<21.9	3.7

The viscosity-temperature relationship shows how the viscosity of a fluid varies with the inverse temperature. From the mathematical relationship that exists between the two quantities is possible to predict fluid viscosity oil chart at any temperature within a limited range if known viscosity at two temperatures. Thus, according to ASTM Standard Viscosity-Temperature Charts for Liquid Petroleum Products, available in 6 ranges, are used [29-31]: the two known viscosity-temperature points are located on the chart and a straight line is drawn through them. The other viscosity-temperature values of the given fluid will fall on this line.

The values obtained for the viscosity indices of 3, 3.5, 4, 4.5 and 5 % Infineum SV 260 and Paratone 8900 solutions are given in Table 2, together with their kinematic viscosities at 40 and 100°C and viscosity-temperature coefficients.

Multi-grade oils typically begin as base oils. Then special oil-soluble organic polymers, called viscosity index improvers, are added in an effort to bring the difference in viscosities closer together. The viscosity still varies logarithmically with temperature, but the slope representing the change is lessened [2, 10, 12]. This slope, which represents the change in viscosity with temperature, depends on the nature and amount of the additives to the base oil.

As may be noticed in Table 2 greatly increases the viscosity index for the two copolymers, their values surpassing those of any synthetic fluid, which varies between 80 and 400 [7] produced by Paratone 8900 growth is higher than that produced by Infineum SV 260 at all concentrations. Thus, the VI of 3% Infineum SV 260 solution is 3.13 times higher than that of SAE 10W oil, the VI of 3.5% Infineum SV 260 solution is 4.21 times higher than that of SAE 10W, the VI of 4% Infineum SV 260 solution is 4.42 times higher than that of SAE 10W, the VI of 4.5% Infineum SV 260 solution is 4.57 times higher than that of SAE 10W and that of 5% solution 4.71 times, while that of 3 % Paratone 8900 solution is 4.38 times higher, that of 3.5% Paratone 8900 solution is 4.7 times higher, that of 4 % Paratone 8900 solution is 4.86 times higher, that of 4.5% Paratone solution is 5.18 times higher and that of 5% is 5.33 times.

Table 2. Values of kinematic viscosities at 40 and 100 °C, viscosity indices and viscosity-temperature coefficients

Fluid	ν, cSt		Viscosity index	Viscosity-temperature coefficient
	40 °C	100 °C		
SAE 10W	**89.41**	**8.83**	**90**	**0.9012**
Infineum SV 260				
3% solution	600	78.5	282.04	0.8691
3.5% solution	1083	138.2	379.35	0.8723
4.% solution	1564	198.4	398.17	0.8731
4.5% solution	2053	258.5	411.37	0.8740
5% solution	2536	318.3	424.15	0.8744
Paratone 8900				
3% solution	900	131.3	394.95	0.8541
3.5% solution	2012	270.2	423.31	0.8657
4% solution	3100	411.9	437.32	0.8671
4.5% solution	4289	566.1	466.33	0.8680
5% solution	5421	710.7	479.85	0.8689

As can be seen from the Figure, the values of VI of Paratone 8900 solutions increase almost linearly with concentration, whilst those of Infineum SV 260 tend towards a limiting value. This demonstrates that Paratone 8900 is a better viscosity index improver for the mineral oil SAE 10W irrespective of concentration, in accordance with the previous results [25], which shown that the viscosities of solutions of this polymer are less dependent on temperature for all the concentration, that is it is a better viscosity improver compared with Infineum SV 260.

Another indication of the change in kinematic viscosity with temperature, which is less arbitrary than the viscosity index, is the viscosity-temperature coefficient, VTC, defined by the relationship [24]:

$$VTC = (a - b)/a \tag{1}$$

where a is the viscosity (cSt) at 40°C and b – viscosity at 100°C. The calculated values of VTC are given also in Table 2. They are in accordance with the values of VI and the previously published results on the efficiency of the two copolymers as viscosity improvers obtained using the dynamic viscosities [5]. The lowest values were obtained for Paratone 8900 solutions, which prove once more that this copolymer is a better viscosity index improver.

4. CONCLUSIONS

The viscosity indices of 3, 3.5, 4, 4.5 and 5% solutions of copolymers Infineum SV 260 and Paratone 8900, recommended as viscosity index improvers, in SAE 10W mineral oil as solvent were determined using the ASTM 2270-93 diagram.

Infineum SV 260 produces a lower increase of viscosity indices comparative with Paratone 8900: 3.13 times for a concentration of 3%, 4.21 times for 3.5%, 4.42 times for 4%, 4.57 times for 4.5% and 4.71 times for 5% compared with 4.38, 4.7, 4.86, 5.18 and 5.33 times, respectively.

The values of viscosity-temperature coefficients, calculated from the kinematic viscosities of solutions at 40 and 100^oC, show also that Paratone 8900 is a better viscosity index improver than Infineum SV 260 irrespective of concentration.

REFERENCES

[1] Fernandes, C. M., Amaro, P. M., Martins, R. C., Seabra, J. H., *Tribology International*, **66**, 194, 2013.

[2] Smeeth, M., Spikes, H., Gunsel, S., *Tribology transactions*, **39**(3), 726, 1996.

[3] Gunsel, S., Smeeth, M., Spikes, H., Friction *and wear reduction by boundary film-forming viscosity index improvers* (No. 962037), SAE Technical Paper, 1996.

[4] Wang, J., Ye, Z., Zhu, S., Industrial *& engineering chemistry research*, **46**(4), 1174, 2007.

[5] Horne, W.V., Industrial *& Engineering Chemistry*, **41**(5), 952, 1949.

[6] Eckert, R.J.A., Covey, D.F., *Lubrication Science*, **1**(1), 65, 1988.

[7] Mueller, H.G., *Tribology International*, **11**(3), 189, 1978.

[8] Fan, J., Müller, M., Stöhr, T., Spikes, H. A., *Tribology Letters*, **28**(3), 287, 2007.

[9] Jukic, A., Vidovic, E., Janovic, Z., *Chemistry and Technology of Fuels and Oils*, **43(**5), 386, 2007.

[10] Port, W.S., O'Brien, J.W., Hansen, J.E., Swern, D., *Industrial & Engineering Chemistry*, **43**(9), 2105, 1951.

[11] Smeeth, M., Spikes, H., Gunsel, S., *Langmuir*, **12**(19), 4594, 1996.

[12] Kapur, G.S., Sarpal, A.S., Mazumdar, S.K., Jain, S.K., Srivastava, S.P., Bhatnagar, A.K., *Lubrication science*, **8**(1), 49, 1995.

[13] [13] Zhao, W., Rafailovich, M.H., Sokolov, J., Fetters, L.J., Plano, R., Sanyal, M.K., *Physical review letters*, **70**(10), 1453, 1993.

[14] Azim, A.A., Nasser, A.M., Ahmed, N.S., El Kafrawy, A.F., Kamal, R.S., *Petroleum Science and Technology*, **27**(1), 20, 2009.

[15] Jordan, E.F., Smith, S., Koos, R.E., Parker, W.E., Artymyshyn, B., Wrigley, A.N., *Journal of Applied Polymer Science*, **22**(6), 1509, 1978.

[16] Stambaugh, R.L., Viscosity index improvers and thickeners In *Chemistry and technology of lubricants*, Springer US., 1994.

[17] Mohamed, M.M., El Naga, A., Hamdi, H., El Meneir, M.F., *Journal of Chemical Technology and Biotechnology*, **60**(3), 283, 1994.

[18] Nassar, A.M., Ahmed, N.S., *Journal of Polymeric Materials*, **52**(9), 821, 2003.

[19] Morgan, S., Ye, Z., Subramanian, R., Zhu, S., *Polymer Engineering & Science*, **50**(5), 911, 2010.

[20] Lariviere, D., Asfour, A.F.A., Hage, A., Gao, J.Z., *Lubrication Science*, **12**(2), 133, 2000.

[21] Abdel-Azim, A.A.A., Abdel-Aziem, R.M., *Journal of Polymer Research*, **8**(2), 111, 2001.

[22] Wardle, R.W.M., Coy, R.C., Cann, P.M., Spikes, H.A., *Lubrication Science*, **3**(1), 45, 1990.

[23] Smeeth, M., PhD Thesis *The behaviour of viscosity index improvers in lubricated contacts*, Imperial College London, University of London, 1998.

[24] Hillman, D.E., Lindley, H.M., Paul, J.I., Pickles, D., *British Polymer Journal*, **7**(6), 397, 1975.

[25] Nassar, A.M., *Petroleum Science and Technology*, **26**(5), 514, 2008.

[26] Nassar, A.M., Ahmed, N.S., Kamal, R.S., Abdel Azim, A.A.A., El-Nagdy, E.I., *Petroleum science and technology*, **23**(5-6), 537, 2005.
[27] Nassar, A.M., *Petroleum Science and Technology*, **26**(5), 523, 2008.
[28] Nassar, A.M., Ahmed, N.S., *International Journal of Polymeric Materials*, **55**(11), 947, 2006.
[29] Sharma, S.K., Forster, N.H., Gschwender, L.J., *Tribology transactions*, **36**(4), 555, 1993.
[30] Dardin, A., *Proceedings of the 12th International Colloquium of Tribology*, 631, 2000.
[31] Elisabeth, B.M., *Journal of Analytical Atomic Spectrometry*, **7**(2), 127, 1992.