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Viscosity Improvers for Multi-Grade Oils

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Abstract

To establish the ability of INFINEUM SV 260 and KELTAN 4200 copolymers solutions in SAE W10 mineral oil as solvent to perform at low and high temperatures in a vehicle's engine, that is their capacity to improve the oil's viscosity index, the viscosity/ temperature characteristics of their 3 and 6% solutions were determined. It was obtained that the both copolymer increase very much the viscosity index, as much as their concentration is higher. The highest effect was obtained using KELTAN 4200, the increase of viscosity indices being as high as 2.83 times for 3% solution and 4.28 times for 6%, while using INFINEUM SV 260 it was 2.39 and 3.35 times respectively. The viscosity-temperature coefficients, calculated from their kinematic viscosities at 40 and 100^{o}C, show also that KELTAN 4200 is a better viscosity index improver than INFINEUM SV 260.

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

Introduction

The temperature range an oil is exposed to in vehicles is usually wide: from cold ambient temperatures in the winter before starting up to hot operating temperatures when it is fully warmed up in hot summer weather. As the viscosity of oils decreases with increasing temperature, this difference is too large to be covered by a single-grade mineral oil.

High temperature lubrication can be improved with the advent of oil viscosity index improvers or modifiers. These are polymers that, added to low viscosity oils, effectively thicken them as temperature increases, improving the viscosity/temperature characteristics [1, 16]. Thus the lubricating effect of mineral oils is extended across a wider temperature range and they are called multi-grade oils.

The decrease in viscosity with temperature in commercial lubricant products is described by the viscosity index, VI. This is an empirical number indicating the rate of change in viscosity of an oil within a given temperature range [2, 16]: high numbers indicate a low change, while low ones a relatively large change. These numbers can only be compared within a viscosity range. VI is not an indication of how well the oil resists thermal breakdown.

An ideal oil for most purposes is one that maintains a constant viscosity throughout the temperature changes [3, 16].

The importance of the VI can be shown by considering automotive lubricants: an oil having high VI resists excessive thickening when the motor is cold, promoting rapid starting and prompt circulation, and resists excessive thinning when the engine is hot, providing full lubrication and preventing excessive oil consumption.

The object of the present paper is the determination of viscosity indices or multigrade correspondence of some INFINEUM SV 260 and KELTAN 4200 copolymers solutions – recommanded as viscosity improvers for multi-grade mineral oils – for which the global and partial solubility parameters and radii of interaction spheres [4,16] and rheological behaviour of concentrated solutions [5,16] were determined, to estimate their efficiency as viscosity index improvers for the low viscosity mineral oil SAE 10W.

Experimental Details

Viscosity indices were determined for INFINEUM SV 260 and KELTAN 4200 copolymers concentrated solutions. The characteristics of the two copolymers and of the mineral oil SAE 10W were presented in a previous paper [4, 16].

Dissolution of polymers in SAE 10W was realized at room temperature with gentle shaking now and then. Solutions having the concentration of 12 g/dL were prepared and than they were diluted at 10, 6 and 3 g/dL.

The kinematic viscosities of the mineral oil and concentrated copolymer 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. The measurements were carried out at 40 ± 0.1 and 97 ± 0.1^{o}C, according to the recommandation of ASTM D2270 [6,16], but they were possible only for 3 and 6 g/dL solutions with the available set of viscometers.

Results

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 kinematic viscosity with temperature. It provides an insight into an oil's ability to perform at high and low temperatures [3, 16].

The viscosity index scale was set up by the Society of Automotive Engineers, SAE. Two temperatures were chosen arbitrarily for reference: 40 and 100°C, the last meant to approximate the operating temperature to which motor oil is exposed in an engine. The original scale only stretched between 0 (worst oil) and 100 (best oil), but since the conception of the scale better oils have also been produced, leading to VIs higher than 100 (VI of synthetic oils ranges from 80 to over 400 [7, 16]).

SAE, based on viscosity measure, has created the viscosity classification standards for engine oil: J300 [8, 16]. Under this standard, a collection of viscosity grades are defined in terms of limits on different measures of viscosity. Table 1 shows these limits for each grade [9, 16].

According to Table 1, there are two types of SAE viscosity grades: one designated as "W", and the other designated only by a number. The difference between the two types of viscosity grades engine oils is that "W" have upper limits on low-temperature cranking and pumping viscosities, and a lower limit on kinematic viscosity, while those without W have upper and lower limits on kinematic viscosity at 100^{o}C and high-temperature high-shear rate viscosity, HTHS, at 150^{o}C, but have no low-temperature viscosity limits. So, W grades pertain to low-temperature performance (W means winter), whereas non-W grades relate only to high-temperature performance.

An engine oil is classified as single grade when it meets only W or only non-W grade requirements, whiles those that meet the requirements of both are called multi-grade.
The difference between a multi-grade and a single grade oil is that the multi-grade must not become too viscous at low temperatures, while still meeting the requirements of its high temperature grade, that means that a multi-grade oil exhibit less viscosity change with temperature than a single-grade one.

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

Grade	**Cold cranking, CCS**	**Cold pumping, MRV**	**Kinematic viscosity, 100°C**		**HTHS*, 150°C**
Unit	cP at T°C	cP at T°C	cSt	cSt	cP
	Maximum	Minimum	Minimum	Maximum	Minimum
0W	6200 at -35	60000 at -40	3.8	-	-
5W	6600 at -30	60000 at -35	3.8	-	-
10W	7000 at -25	60000 at -30	4.1	-	-
15W	7000 at -20	60000 at -25	5.6	-	-
20W	9500 at -15	60000 at -20	5.6	-	-
25W	13000 at -10	60000 at -15	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?	-	-	-	-	-

The viscosity-temperature relationship represents the manner in which the viscosity of a given fluid varies inversely with temperature. Given the mathematical relationship existing between these two quantities, it is possible to predict graphically the viscosity of a petroleum fluid at any temperature within a limited range if the viscosities at two other temperatures are determined. For this purpose are the ASTM Standard Viscosity-Temperature Charts for Liquid Petroleum Products, available in 6 ranges, are used [10, 16]: 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.

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 [1, 11, 12, 16]. This slope, which represents the change in viscosity with temperature, depends on the nature and amount of the additives to the base oil.

The dynamic viscosities of INFINEUM SV 260 and KELTAN 4200 copolymers concentrated solutions (3, 6, 10 and 12 g/dL) decrease with temperature following the Andrade equation [13, 16]. The lowest slope was obtained for 3 g/dL solutions in the case of the first copolymer and 12 g/dL followed by 3 g/dL for the last one [5, 16]. At the same time, the slopes of logarithmic decrease of viscosity with increasing temperature are higher for INFINEUM SV 260 than for

KELTAN 4200 irrespective of concentration, which suggests that the last copolymer is a better viscosity index improver.

Determination of kinematic viscosities of SAE 10W and 3 and 6 g/dL copolymer solutions were done at 40 and 97°C and the viscosity indices were determined using the ASTM 2270-93 diagram.

The following viscosity indices were obtained: 90 for SAE 10W; 215 for 3% Infineum SV 260 solution; 302 for 6% Infineum SV 260 solution; 255 for 3% Keltan 4200 solution and 385 for 6% Keltan 4200 solution.

Also, the value of VI obtained for SAE 10W is in accordance with literature data, for most paraffinic, solvent-refined mineral-based industrial oils, typical VIs falling in the range of 90 to 105 [13, 16] .

The values obtained for the viscosity indices of 3 and 6% INFINEUM SV 260 and KELTAN 4200 solutions are given in Table 2, together with their kinematic viscosities at 40 and 97°C and viscosity-temperature coefficients.

Table 2. VALUES OF KINEMATIC VISCOSITIES AT 40 AND 97°C, VISCOSITY INDICES AND VISCOSITY-TEMPERATURE COEFFICIENTS

Fluid	ν, cSt		Viscosity index	Viscosity-temperature coefficient
	40°C	97°C		
SAE 10W	89.41	8.83	90	0.9012
INFINEUM SV 260				
3% solution	600	78.49	215	0.8692
6% solution	3500.00	436.5	302	0.8753
KELTAN 4200				
3% solution	900	131.33	255	0.8541
6% solution	7500	1110.0	385	0.8519

As can be seen from the Table 2, the two copolymers increase dramatically the values of VI, approaching them to those of synthetic fluids, which range from 80 to over 400 [7, 16], but the increase produced by KELTAN 4200 is much higher than that given by INFINEUM SV 260 for the both concentration. Thus, the VI of 3% INFINEUM SV 260 solution is 2.39 times higher than that of SAE 10W oil and that of 6% solution 3.35 times, while that of 3% KELTAN 4200 solution is 2.83 times higher and that of 6% 4.28 times. At the same time, the viscosity indices increase with increasing concentration 1.47 times for the first copolymer and 1.51 times for the second one.

The values obtained for KELTAN 4200 solutions are much higher than those obtained for INFINEUM SV 260 ones, increasing almost linearly with concentration for the first copolymer and tending towards a limiting value for the second one, as can be seen in Figure 1.

The values of VI of KELTAN 420 solutions increase almost linearly with concentration, whilst those of INFINEUM SV 260 tend towards a limiting value. The higher the concentration, the higher the differences between the viscosity indices of the two copolymer solutions. This demonstrates that KELTAN 4200 is a better viscosity index improver for the mineral oil SAE 10W irrespective of concentration, in accordance with the previous results [5, 16], 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.

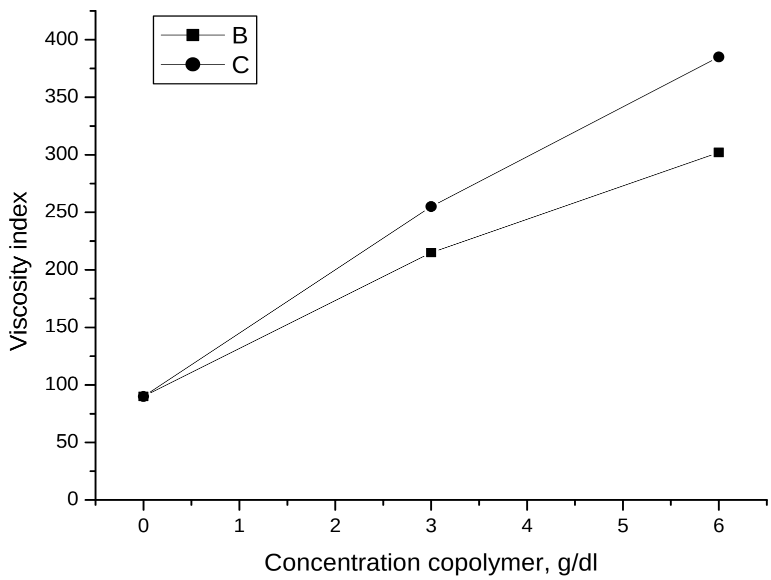

Fig. 1. Dependence of viscosity indices on copolymer concentration:
B – INFINEUM SV 260; C – KELTAN 4200

A less arbitrary indication of the change in viscosity with temperature is the viscosity-temperature coefficient, VCT [14,16], given by the relationship:

$$VCT = (A - B)/A \quad (1)$$

where A is the viscosity (cSt) at 40°C and b – viscosity at 100°C. The lower the viscosity-temperature coefficient, the higher the VI. The lower the viscosity-temperature coefficient, the higher the viscosity index. 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, 16]. The lowest values were obtained for KELTAN 4200 solutions, which prove once more that this copolymer is a better viscosity index improver.

Conclusions

The viscosity indices of 3 and 6% solutions of copolymers INFINEUM SV 260 and KELTAN 4200, 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 KELTAN 4200: 2.39 times for a concentration of 3% and 3.35 times for 6%, compared with 2.83 and 4.28 times, respectively.
The values of viscosity-temperature coefficients, calculated from the kinematic viscosities of solutions at 40 and 100°C, show also that KELTAN 4200 is a better viscosity index improver than INFINEUM SV 260 irrespective of concentration [16].

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Indicii de viscozitate ai unor uleiuri multigrad

Rezumat

În cadrul acestui articol este prezentata determinarea indicilor de viscozitate ai unor uleiuri aditivate cu polimerii KELTAN 4200 şi INFINEUM SV 260 cu diagrama ASTM D 2270-9. Cel mai eficient copolimer pentru transformarea SAE 10W in ulei multigrad este KELTAN 4200, deoarece creşterea I.V. este mai mare la ambele concentratii.