

Investigation of shear stability of commercial polymer of viscosity index improver for determination of engine oil optimal formulation

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ABSTRACT

The lubricating oils in each mechanical device are affected by shear forces. Polymers in lubricating oils engine, in particular, undergo many changes because of the influence of the applied forces. Awareness of these changes can help us to design optimal formulations. In this work, shear stability of four commercial was studied. Calculation of various parameters about viscosity in the enhancing were performed and compared. The results of this study can be used for optimizing the usage of polymers in engine oil.

Keywords: Shear stability; polymers Viscosity index; Engine oil

1. INTRODUCTION

Lubricating oils in any mechanical device are affected by shear forces [1-5]. The amount of shear force applied to the oil depends on the environment where the oil is directly related to it such as piston, ring and cylinder [6-8]. These mechanical forces have caused to pull chain until it no longer has the force tolerance and this leads to the breakdown of chains and the creation chains with lower molecular weight. Reduction of polymer chain length leads to a permanent decrease in oil viscosity at all temperatures [9-11].

Unlike the usual shear loss which is a kind of reversible phenomenon for the viscosity of an oil (temporary loss), the loss of permanent viscosity is a kind of irreversible damage for the viscosity of the oil [12-16]. Hence, when a motor oil is used for commercial applications, this loss of viscosity should calculate.

When engine oils containing viscosity enhancing additives are affected by extreme shear force, two phenomena is occurred:

A) Temporary viscosity loss [17-19]: The viscosity of engine oils change by application the shear force (non-Newtonian fluids). The reason of the loss of oil viscosity is due to the flow of polymeric macromolecules. The result is a temporary reduction of oil viscosity. This phenomenon is reversible and when shear forces were removed the polymer chains are restored to their original state and again the viscosity increases.

B) Permanent viscosity loss [20-24]: when a polymer chain in solution encounters with a great deal of shear and tensile forces, due to the chain cannot be in the direction of current and applied forces fully, It eventually breaks down into

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smaller units.

In this study, to investigate the shear stability of Olefin copolymers used as oil viscosity enhancing, various parameters were measured and calculated.

2. EXPERIMENTAL SECTION

The polymers used accompanied with some of their properties are listed in Table 1.

Polymeric solutions contain about 70 to 30 ratio of SN150 and SN500 oils as well as 1% polymeric weight.

3. RESULTS AND DISCUSSION

1-3. Viscosity changes at two temperatures 40 °C and 100 °C

Viscosity changes at two temperatures 40 °C and 100 °C before and after shear stability test have been presented in diagrams 1 and 2. Keltan polymer provides the highest viscosity at temperatures 40 °C and 100 °C for oil. Vicotech, Paratone and

HiTEC polymers are in the following ranks. By applying mechanical cutting of these polymeric solutions, significant changes in specificity of increasing the viscosity of these polymers occurs. It was observed that by cutting, viscosity at both 100 °C to 40 °C temperatures for all polymers were reduced, which this loss in viscosity was permanent.

The reason is due to the mechanical stresses, polymer chains have been broken and their dimensions have been reduced and this phenomenon will be irreversible for viscosity [25]. Maximum changes at both 40 °C and 100 °C temperatures was related to keltan and minimum was related to HiTEC. Among these two polymers, Paratone and Viscotech polymers behaved similarly, though viscosity changes in these two was a little more for Viscotech polymer.

Table 1. Characteristics of the studied materials

The amount of Ethylene (Weight percent)	Molecular weight (calculated)	Type	shape	polymer
49	171683 (Narrow distribution)	Linear olefin copolymer	White pattern	HiTECH 5780
50	172860	Linear olefin copolymer	Granol	Paratone 8900
71	214900	Linear olefin copolymer	Granol	Viscotech 7558
49	407888	Linear olefin copolymer	White pattern	Keltan 3200

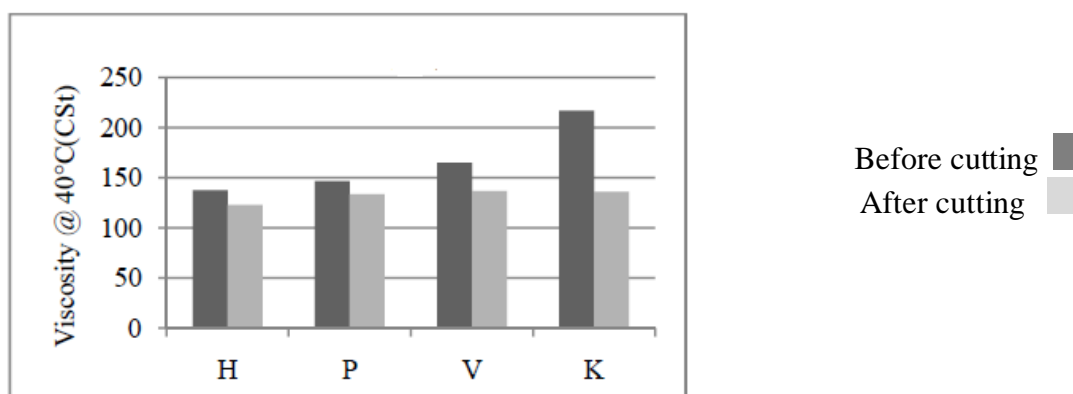


Fig.1. Comparison of viscosity at 40°C before and after mechanical cutting.

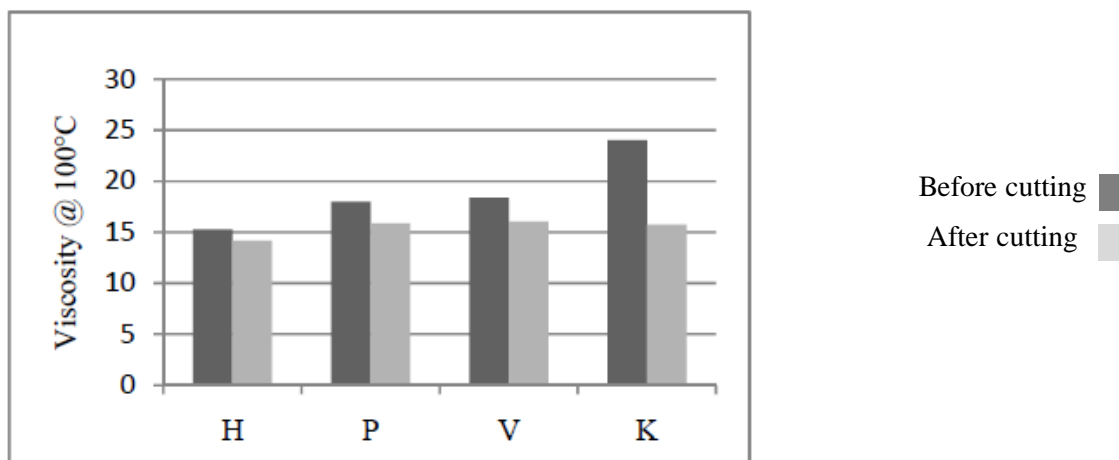


Fig.2. Comparison of viscosity at 100°C before and after mechanical cutting.

2-3 Variations in viscosity index before and after mechanical cutting

It is enough to get a better conclusion on the viscosity index values, polymer solutions before and after the shear test was calculated and compared to each other. Accordingly, before performing the test, HiTEC and Keltan have provided highest and lowest viscosity index for the oil respectively.

Also, after these two polymers, Paratone and Viscotech are in second and third orders. Order of improvement of viscosity index after cutting for these polymers changes as follows: $P > V > K > H$

However, it should be noted that the viscosity index values of these solutions

Approaches together and it is within the range of 113-120 approximately. However, the range of viscosity index variations has been in 113-137.

It can be seen at first glance that mechanical cutting can make significant changes

For the polymers, as these polymers have initially many differences in condensation strength and viscosity index enhancement with each other, but they behave similarly with mechanical cutting.

In other words, these polymers have a more similar Chain and structural dimensions after testing.

Most occurred changes are related to viscosity index of Keltan polymer while least one is related to HiTEC polymer. Both of Paratone and viscotech, which have in similar behavior in the earlier stages, there is a significant difference in index viscosity values after mechanical cutting. According to Fig 3, the rate of viscosity index of Paratone and viscotech polymers is about 8.7% and 1.3% respectively.

A further decrease in the viscosity index means that the oil during the operating period has longer and higher temperature sensitivity [26-29]. In other words, the task of a polymer as a reducing agent of oil temperature sensitivity, becoming less pale.

The other important parameters that can be used as an evaluation of shear stability of polymers in solution, is a waste of viscosity. Fig 4 shows a comparison of the four polymers.

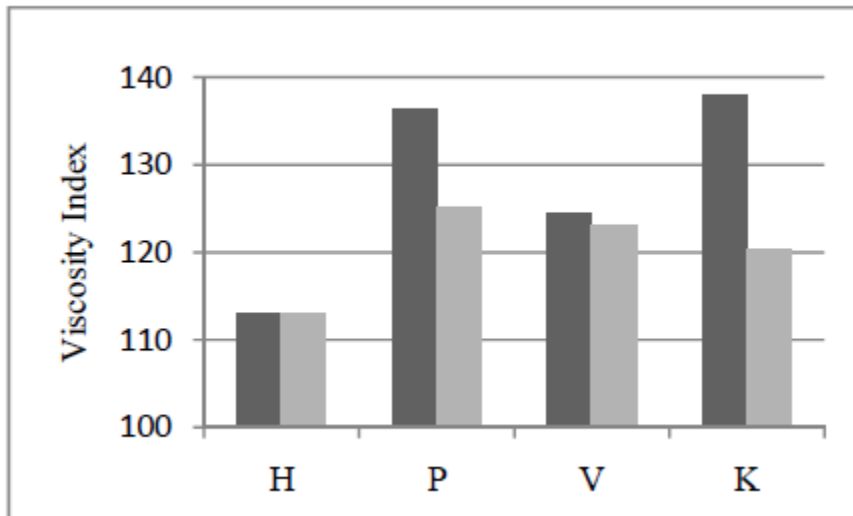


Fig. 3. Comparison of polymers in terms of viscosity index before and after mechanical cutting

Before cutting
 After cutting

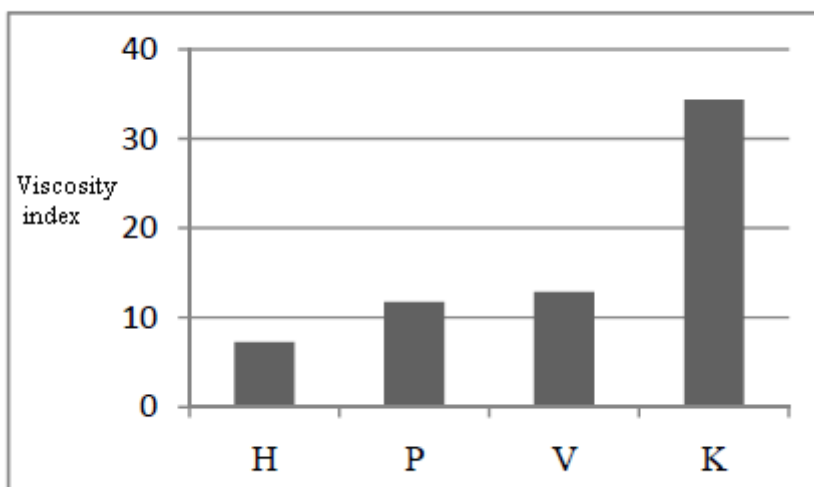


Fig. 4. Comparison of polymers in terms of the loss viscosity index.

Finally, these polymers can be characterized in terms of shear stability and shear stability index. In shear stability, the higher percentages indicated higher shear stability of the polymer while, there is an inverse trend in shear stability index. based on Fig 5, the maximum and minimum shear stability is related to

Hitech, and Keltan respectively, while Viscotech and Paratone are similar behavior. In terms of shear stability index, the classification in terms of suitable performance, similar to the shear stability parameter can be provided: $H > P \geq V > K$.

According to the presented topics, the shear stability of the polymers can be

attributed to their molecular weight. The effect of the molecular weight on the chemical structure and concentration of the polymer is remarkable.

Viscosity loss due to mechanical cutting depends on molecular weight, molecular weight distribution, ethylene to propylene ratio and branching degree. According to the molecular weight of these polymers, their molecular weight was evaluated using the solubility method and Mark-Huynk equation. Among these polymers, Keltan has highest molecular weight and lowest shear stability. Also, Keltan has the lowest molecular weight and the highest shear stability. So it can be concluded that the shear of the polymers in the solution has inverse relationship with molecular weight. According to Table 2, highest molecular weight variations is related to Keltan, while lowest one is related to HiTECH. Moreover, variation of specific viscosity (η_{sp}) at 100°C confirms this fact. It should be noted that the specific viscosity is a

measure of the polymer chain dimensions in the solution.

4- CONCLUSION

From the present studies, It can be noted that the presented parameters consistent and compatible to each other evaluate the shear efficiency of the polymers and significant deviation in the obtained values are not observed with respect to any other parameter. The results show despite the high concentration power of Keltan, in terms of Keltan stability, it is very weak in terms of shear stability, but Paratone and Viscotech are more optimistic. Also, HiTECH has equilibrium conditions interms of concentration power, but it is very excellent in terms of shear stability. In general, it can be concluded that the resistance against permanent shear forces for a viscosity-enhancing polymer depends on the initial size of the molecule (molecular weight) significantly [30].

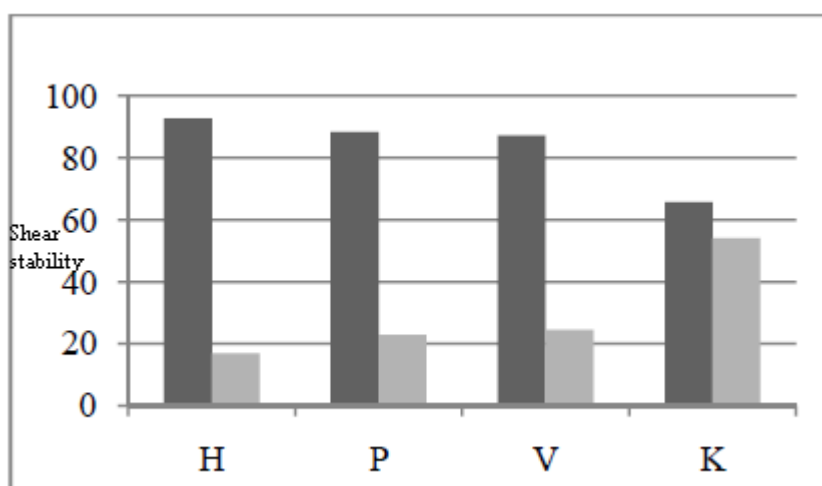


Fig. 5. Comparison of shear stability and its index for various polymers.

Table 2. Variation of molecular weight and specific viscosity after cutting

$\Delta\eta_{sp}$ @ 100°C	Variation of molecular weight (%)	polymer
0.1257	28.6	HiTEC
0.2697	38.17	Viscotech
0.2411	22.73	Paratone
0.9429	65.5	Keltan

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