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Viscosity Index Improvers for Engine Oils: An Overview

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Abstract
Umpteen number of lube oils are available which can be used affectively in order to provide the desired lubrication. In the automotive and related industries engine oils are commonly used for lubrication purposes. Viscosity Index (VI) Improver has found its main commercial uses as additives to engine oil and its examples are power steering fluid, modern internal-combustion engines, industrial gear oils, turbine engine oils (stationary and aircraft), and aircraft piston engine oils. Viscosity Index improvers are added in the engine oils to reach the desired VI. By the studies, the occurrence of maximum VI depends on the lube oil used and the type and concentration of viscosity index improver.

Keywords
Lube oil, Viscosity index, Viscosity index improvers.

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I. Introduction

The exponential rise of vehicles on road has lead to the simplicity in transportation, commutation and several other means. For the smooth operations of these vehicles, the wear and tear of the engines should be minimum or negligible. Maintenance of these engines depends upon several factors, such as – good fuels, proper lubrication, and timely maintenance and with advancement in technology the engine modification should be adopted properly. Since it has been well established fact that lubrication of the engine play a significant role in the life of engine. As the lubrication oil provides the smoothness of the engine. Lubricating oil is an important liquid used to reduce scraping, abrasions and friction of the tribological pieces of machine parts by putting a film of material between rubbings surface, thereby reducing the amount of wear metals in the machine oil **[1, 2]**. However, the stringent environment regulation adopted by environment agencies has lead to the development of lubricating oil. This leads the researchers around the globe to develop such lubricating oils which can perform in severe operational conditions. Synthetic lubricants are produced via chemical synthesis. Selected chemical could be blended with the lube oils which changes certain specific properties. One of the important parameter is viscosity index. Viscosity of liquids is much greater than those of gases at the same temperature. It is the essential requirement of engine lube oil that it must have low enough viscosity at low temperature and high enough viscosity at high temperature for the smooth operation of engine. Therefore, the viscosity changes with temperature must be minimum. The comparison of kinematic viscosity of the fluid to that of two reference fluids at 40ºC and 100ºC is generally adopted. Viscosity index improvers can be regarded as the key to high performance multigrade oil. They are generally oil soluble polymers. The addition of these soluble polymers can enhance the viscosity of the oil. Oils containing *VI* improver can achieve viscosity index upto 150.The viscosity of engine oils increases with increase in temperature because engine oils includes additives developed to reduce changes in viscosity. As the number of polymers increases with the increase in concentration of *VI* improvers (polymers), the Viscosity index of the oil also increases.

Lubrication is the strategy practiced by interposing a substance called a lubricant between them to reduce friction between surfaces in proximity and moving relative to each other. Lubrication can be a solid (example. MoS_2), solid/liquid dispersion (example. oil or water), liquid/liquid dispersion or a gas. Lube oils are servomesh SP 220, servoneum 100, servopress 68, servocut 335, SAE oils etc. Lubrication is the procedure to minimize friction of certain sticky or greasy substances. Substances used to lubricate the surface are oils and grease in common. Grease is composed of oil and thickening agent, while the oil is the one which actually lubricates. Where oils can be synthetic, vegetable or mineral-based also a combination of these. The application determines which oil should be used. In extreme conditions, synthetic oils can be used. Where in the case of environment, vegetable oils may be utilized. Oil-containing lubricants have additives in the base oil which enhance, add or suppress properties.

1.1 Types of Lubriction
There are mainly 3 types of lubrication: boundary, mixed and full film. Full-film lubrication can be seen into two forms: hydrodynamic and elastohydrodynamic.

1.1.1 Hydrodynamic lubrication
It happens when two surfaces in sliding motion, relative to each other, are fully separated by fluid film. Elastohydrodynamic lubrication is same but happens when the surfaces are in a rolling motion, relative to each other. The elastohydrodynamic film layer is much thinner than that of hydrodynamic lubrication, & the pressure on the film is greater. It is called elastohydrodynamic because the film deforms the rolling surface to lubricate it.

1.1.2 Boundary lubrication
It occurs where there are frequent starts and stops, and where shock-load conditions are present. Some oils have extreme-pressure or anti-wear additives to protect surfaces in the event that full films cannot be achieved due to speed or other factors. These additives cling to metal surfaces and form layer that protects the metal from wear. It causes high friction, heat and other undesirable effects.

1.1.3 Mixed lubrication
It is a cross between boundary and hydrodynamic. While the bulk of the surfaces are separated by lubricating layer, the asperities still make contact with each other. This is where the additives come into play.

Table 1: Properties of lube oil fraction

Serial No.	Specification	Lube Oil Fraction
1	Specific Gravity @ 60/60 ºF	0.91705
2	Viscosity, Cst, @ 40 ºC	118.00
3	Viscosity, Cst, @ 100 ºC	9.39
4	Viscosity Index	26
5	COC Flash Point, ºC	242
6	Pour Point, ºC	25
7	Color ASTM – D 1500, @ 50 ºC	5.5
8	Sulfur Content, % wt.	3.073

1.2 Viscosity
Viscosity of oil is taken to be the most important factor when selecting a lubricant. Viscosity is a measure of internal resistance of a fluid to the force causing that fluid to flow. Viscosity can be calculated by Saybolt Viscometer, Angler's Viscometer, Ostwald Viscometer, Kinematic Viscometer and Redwood Viscometer. There are mainly two types of viscosity: absolute viscosity that is used more commonly in medicine, cosmetics, and cooking, and kinematic viscosity that is more often used in the automotive industry. Absolute viscosity measures the resistance of fluid to a force that is acting upon it to make it flow. Kinematic viscosity measures this resistance as relative to density of the substance. It is calculated as absolute viscosity divided by the density. But most importantly we have to see how the temperature affects the viscosity of the lube oil. The viscosity of an oil is its ability to flow or its internal resistance to flow. When oil film forms between a bearing and a shaft, some of the molecules of oil are attracted towards surface of the shaft, while other oil molecules are attracted towards the bearing surface. This is known to be shear rate and is affected by the oil's viscosity and operating temperatures. Multigrade oil with a lower viscosity will generally have higher potential shear rate, while single viscosity oil will generally have a lower potential shear rate.

Since oil with lower viscosity and high potential shear rate must maintain sufficient oil film, it is quite obvious that as the temperatures rise, the oil film may fail and metal-to-metal contact may occur. If the oil viscosity is too high with a low potential shear rate, the internal resistance to flow will going to increase the temperature dramatically, causing an overheated condition, which can also cause breakdown of the oil film and oxidation of the oil. Hence, it is noted that oils be selected by always taking the operating temperature of the equipment into account.

1.2.1 Why viscosity decrease with increasing temperature
Due to the decrease in intermolecular attractions, the viscosity of the oil decrease with increase of temperature. At higher temperature, oil must have sufficient viscosity to carry loads. Hence heavier oils are used at higher temperature. Similarly, light oils are used at low ambient temperature.

1.3 Viscosity Index
The major property of lubricating oil is its viscosity. Major lubricating oils are refined and synthetic. Production of refined oils are from crude oil refinery. Production of synthetic lubricants is via chemical synthesis. Selected chemicals are to be blended with the lubricating oils to impart specific properties. Resistance of a lubricant to change of viscosity with temperature is known by its *VI* which is an arbitrary number i.e. calculated from the known viscosities at two widely different temperatures. Normal range of viscosity index is from 0 to 100, Oils with high *VI* could be seen excessive thinning at high temperatures at the same time oils of

low *VI* resist an extremely thinning at high temperatures. *VI* of the paraffinic based lubricants is mostly greater than that of the naphthenic based ones. *VI* is a method of measuring a fluid's viscosity change in relation to temperature. The higher the *VI*, the smaller the relative viscosity changes with temperature. *VI* improvers are additives that increase the fluid's viscosity with its useful temperature range **[2]**.

1.4 Viscosity Index Improver

We use Viscosity Index Improvers to increase Viscosity Index of the oil. *VI* is a measure for the change of viscosity with variations in temperature. The lower the *VI*, the greater the change of viscosity of the oil with respect to temperature and vice versa. The viscosity of a lubricant is related to its ability to reduce friction. Mainly, the least viscous lubricant which still forces the two moving surfaces apart is desired. When lubricant is too viscous, it may take a large amount of energy to pass around. When it is too thin, the surfaces may come into contact, increasing friction. Viscosity index improvers can be refered as the symbol to high performance multigrade oil. They are actually oil soluble polymers. The added polymeric molecules interacting with the base oil by affecting its final viscosity. Oils containing *VI* improver can reach viscosity index upto 150 **[3]**. Viscosity index improvers are polyiosprene-cis, polybutadiene rubber, methylmethacrylate, olefins etc.

VI improvers are mostly high molecular weight polymers with main chain of flexible structure **[4]**. The polymer chains interactions are more intense than the solvent interactions, base oil interactions and polymer chains interactions, under low temperatures. Thus, the polymer configuration has slight influence on lubricant viscosity. With increasing temperature, the polymer chains interactions are decreased, compensating lubricant viscosity reduction **[5]**.

The lubricant base oils performance is governed by their rheological properties e.g. low temperature fluidity, viscosity and viscosity temperature relationship. For example, to provide an efficient performance at low and at high temperatures, an engine lubricant should have good low temperature fluidity and minimal variation so fits viscosity with temperature. Through the addition of appropriate performance polymers, commonly called additives, the properties of these base oils can be boost. The additives are mixed with in these base oils to impart additional desirable properties already present in them. In addition, additives play an important role in compounding of lubricants for steam turbines, gas turbines, jet air craft turbines, rail road and marine diesel engines, air craft piston engines, stationary piston engines, and relatively low-power two-cycle engines. They are also used in compounding hydraulic oils, industrial gear lubricants, and cutting oils **[6]**.

VI improver also known as viscosity modifier are long chain, high molecular weight polymers used to resist the change of viscosity of the oil by increasing the relative viscosity of oil more at high temperatures than at low temperatures.

1.4.1 Function of viscosity index improver

The performance of *VI* improver is very often expressed in terms of Viscosity Index, which is an arbitrary number that indicates the resistance of a lubricant to viscosity change with temperatureFor a given temperature change, the higher the *VI*, the less the viscosity of an oil varies. The *VI* improver efficiency depends on the behavior of the polymer molecules in the oil, where the parameters of polymer solubility, molecular weight and shear degradation resistance are determinant. Also investigated and stated here was the oil thickening property of the polymer, which is a direct measure of percent increase in the viscosity of the base stocks for adding the unit amount of weight. This property can also be taken as the measure of the degree to which the polymer interacts with the base stock, the greater the thickening property; the greater the level of interaction.

With the growing demand for high-quality lubricating oils to withstand the extreme operating conditions of the modern gasoline and diesel engines, it becomes evident that the selected crudes were no longer sufficient in either quantity or quality to supply the demand. Therefore, it was obvious that the petroleum industry would have to resort to some means for separation of the desirable and undesirable component of lubricating oil stocks **[8]**.

Better oils by maintaining an ample viscosity at high temperature allows minimizing friction and wears between interacting surfaces. Viscosity index improvers are usually polymers that serve this particular purpose. These polymer molecules adopt a coiled aggregation in cold condition so that their effect on viscosity is minimized but with increasing temperature, the polymer chains tend to straighten out thereby leading to the increase in viscosity. Viscosity index is an arbitrary number that indicates this effect of change of temperature on the kinematic viscosity of oil, where a higher VI signifies a lower rate of change of viscosity with temperature. Acrylates and methacrylates are among the well recognized viscosity modifier and pour point depressant from years. Many works have been done on them where polymerization of two monomers has been considered. The introduction of a third monomer in the polymer moiety can introduce some new properties and features to the polymer **[9]**.

1.4.2 More information about Viscosity index improvers

They are used in formulation of multigrade lubricating oils for numerous applications including crankcase engine oils, transmission and hydraulic fluids, gear oils, and other lubricants. *VI* improvers are high molecular weight, oil-soluble polymers, which provide increased viscosity at higher temperatures and minimally contribute to viscosity at lower temperatures. The automobile lubricant market has recently experienced a phase of intense transition. New emissions legislation is resulting in new engine designs and after treatment systems that will require development of new generation of advanced engine lubricants in order to meet the performance demands of the future. Oils are formulated to improve fuel economy as well as to provide thermal and oxidative stability at higher operation temperatures. The size of the polymer molecule affects the thickening of lubricating oil at all temperatures: the larger the coil size, the higher the thickening power. However, the random coil is highly distorted as polymers experience high shear stress in the equipment. In extreme cases (shear rate higher than 104 sec^{-1}), bond energies can be exceeded and the polymer chain breaks. If it happens, the molecular weight of the polymer decreases, which causes the reduction of solution viscosity and the *VI* improver efficiency **[10]**.

1.4.3 Polymers used as viscosity index improver

Some types of polymers generally used commercially as *VI* improvers are (i) polyisobutylenes (PIB), (ii) esters of styrene-maleic anhydride copolymers, (iii) hydrogenated styrene-isoprene copolymers and (iv) polyalkyl methacrylates (PMA). *VI* improvers are commercially available in the form of solutions in oil, in concentrations ranging between 5 and 70% depending on the actual viscosity of the polymer, so that they can be pumped in blending plants. Certain polymers are also commercialized in powder or granular form. Polymers commercialized today are classed in two main categories, non-dispersant and dispersant hydrocarbon polymers, and non-dispersant and dispersant ester polymers.

Modern internal-combustion engines need multigrade engine oils with a high *VI*. Such a high *VI* is hard to achieve by traditional processing of fractions of petroleum. Hence, to obtain the desired *VI*, *VI* improvers are added in the mineral base oils. Today's lubricating oil demand is for excellent oxidation stability, superior low temperature efficiency, low volatility, low carbon-forming propensity, good viscosity and improved additive response. Several methods for describing the changes in viscosity with temperature for lubricating oils have been suggested. With its advantages and drawbacks, the *VI* is commonly used to describe the oil quality. A high *VI* shows a relatively minor increase in temperature viscosity, and vice versa. The quality base oils are free of reactive hydrocarbons and other impurities which contribute to lubricants being degraded in operation. Hydro-processing route can be conveniently fulfilled to the current requirement of high performance base oils. Commercial oils for internal combustion engines are usually engine oils of various grades of *VI* between 150 and 200. VI improvers are then applied to base oils to enhance the viscometric and rheological properties. Such chemical additives modify the rate at which viscosity varies with temperature **[11]**.

1.5 VI Improvers Widely Used In Engine Oils

In addition to the standard viscosity control properties, certain viscosity index improver compositions are selected to include pour point depressant and/or dispersancy. Improvers Dispersant / *VI* are widely used, particularly in engine oils and automatic transmission fluids. Incorporation of the dispersancy into a polymer involves a carefully engineered addition of strongly polar function groups such as amines, alcohols or amides. The mode of incorporation depends largely on the base polymer **[15]**.

One of the basic criteria of engine lubricating oil is that it must have a low enough viscosity at low temperatures to help start cold and a sufficiently high viscosity at high temperatures to preserve the characteristics of the load bearing. It is therefore desirable to have a fluid whose viscosity-temperature dependence is small. There are many ways of expressing the variation of viscosity with temperature. One of the most widely used in the lubricating field is viscosity index . The method involves comparing the kinematic viscosity of the fluid to that of two reference fluids at 40˚C and 100˚C. The higher the *VI* of a fluid, the smaller the viscosity-temperature dependence as compared to the reference fluids. The importance of *VI* as a measure of base oil quality has been established by the American Petroleum Institute (API) by establishing a group classification system that differentiates base oils by saturates content, % sulfur and *VI*. Generated by sophisticated refining techniques, API Group III mineral oils and API Group IV synthetic oils give higher *VI* characteristics than traditional Group I and Group II oils. The *VI* of both natural and synthetic base oils has been improved for several decades by the introduction of polymeric viscosity modifiers. The commonly known mechanism of how polymers improve *VI* is that polymers increase the fluid's viscosity proportionately more at higher temperatures than at lower temperatures due to expansion of the polymer coil with increased temperature. Surprisingly, there are only sparse studies on the solution properties of *VI* and the effects of temperature despite the extensive commercial applications in engine oils and other lubricating fluids **[16]**.

1.6 Types of Additives

The need to reduce friction and thereby improve the operating efficiency of lubricated machine components has led in recent years to increased interest in the use and the mechanisms of action of friction-modifying additives, i.e. lubricant additives that provide low friction in boundary and mixed lubrication conditions. Two main types of such additive are widely employed, organic friction modifiers, which are generally long chain surfactants such as amides and partial esters, and organomolybdenum compounds. Organic friction modifiers are classically believed to form vertically-oriented, adsorbed monolayers on polar surfaces, which prevent adhesion of contacting asperities and provide a low strength plane of shear between opposing methyl-terminated alkyl chains. However, it has also been suggested that when water and oxygen is present, some organic friction modifiers may also generate insoluble metallic salts that accumulate on rubbing surfaces to form protective viscous layers **[17]**.

Additives are synthetic chemicals that can improve or add performances of lubricants. Some additives impart new and useful properties to the lubricant; some boost already present properties, while others serve to decrease the rate at which undesirable changes occur in the substance throughout its service life. *VI* Improvers is one of the essential types of additives commonly known as viscosity modifier. The Viscosity Index is an measure of the viscosity transition as the temperature increases. With a given temperature change, the higher the *VI*, the less the viscosity of an oil varies. The improvers of the viscosity index are used to restrict the rate of viscosity change with the temperature. These improvers have no effect on low-temperature oil viscosity. However, the improvers when heated cause the oil viscosity to increase within the restricted range permitted by the additive form and concentration. This consistency is most noticeable when applying motor oils of several grades. Viscosity index improves efficiency by rising relative oil viscosity at high temperatures more than at low temperatures. This is usually the result of modifying the physical structure of the polymer with increasing mixture temperature. The polymer molecule in solution is thought to exist as a random coil which is swollen by the solvent of the lube oil. The molecule's volume dictates the increase in viscosity. For cold oil the polymer molecules adopt a coiled shape to mitigate their effect on viscosity. The molecules appear to straighten out in hot oil, and the interaction between these long molecules with higher volume and oil causes a proportionally higher thickening effect, which in turn increases the oil's *VI*. For most purposes, an ideal lubricant should possess the same viscosity at all temperatures. Viscosity index improvers are added to lubricating oils to make them conform more closely to the ideal lubricant **[18]**.

1.7 Viscosity Dependency on Temperature

The viscosity index of a lubricant, which evaluates the lubricant's viscosity dependency on temperature, is a critical parameter that defines the quality and application temperature range of a lubricant. Lubricants of high VI value possess better maintained viscosity constancy in a broad temperature range and are preferred in most mechanical systems. Polymers are widely used as *VI* improvers for lubricant formulation. The addition of a small quantity of polymer based *VI* improver, which possesses viscosity thickening power as a result of its high molecular weight, is able to minimize viscosity variation over a wide temperature range, increase the *VI*, improve the quality, and broaden the application temperature range of lubricants. The molecular weight and macromolecular chain architecture of a polymer are the key parameters that govern its ability to thicken lubricants. A polymer with higher molecular weight and narrower molecular weight distribution usually possesses stronger thickening powers **[19]**.

In complex systems, where the lubricant has to perform a multiplicity of functions, it is important that the additive added to improve lubricant work in one component has no detritus effect on other components. Lubricating oil additives differ in quantity and quality according to the purpose they are needed for. When introduced into base lubricating fluids, these additives are compounds or mixtures that complement their natural characteristics and enhance their field service efficiency in existing applications. Today, multifunctional additives play a major role in the technology of engine oils. Thus, research throughout the world is increasingly directed toward producing additives with more than one purpose (i.e., multifunctional additives). *VI* improvers modify the rate of change of viscosity with temperature (i.e., they cause a minimal increase in engine oil viscosity at low temperature, but cause considerable increase at high temperature). Various compounds, generally polymeric ones, have already been proposed as additives for lubricating oils.

Performance of viscosity index improvers depends on the behavior of the polymer molecules in the oil. The most important parameters are solubility of polymers, molecular weight and resistance to shear degradation. Through solution the polymer molecule lives as a random chain, which is swollen by the lube oil solvent. The solubility of polymers usually increases with higher temperatures as the polymer molecules migrate from tight coils to an open configuration which is larger. This increase in volume causes increases of the viscosity of the oil, which offsets the normal reduction in viscosity with increasing temperature. The present work aims to preparation of copolymers of alkyl acrylates with different moles of styrene and evaluated the prepared compounds as viscosity index improvers for lube oil **[20]**.

1.8 The Importance of Viscosity Index Improvers

If improvers in viscosity are applied to oils with low viscosity, they effectively thicken the oil as temperature increases. This ensures the lubricating effect of mineral oils can be spread over a broader range of temperatures. *VI* improvers are polymeric molecules that are sensitive to temperature. The molecule chain contracts at low temperatures, which does not affect the viscosity of the fluid. At high temperatures, the chain relaxes and an increase in viscosity occurs.

1.9 Properties of Viscosity Index Improver

Some of the specifications of engine lubricating oil is that at low temperatures it must have a low enough viscosity to assist in cold starting and a sufficiently high viscosity at high temperatures to preserve its load-bearing properties. The *VI* is one method that is commonly used in the lubricating sector to measure the viscosity variance with temperature. The VI of both mineral and synthetic base oils can be improved by the addition of polymeric *VI* improvers.

In the 1990s, it was shown that solutions of polyisoprene and also some commercial, dispersancy-boosting viscosity modifiers were able to form thick boundary films on polar surfaces and that these films could greatly reduce friction in low speed conditions. This behaviour appeared to result from the physical adsorption of polymeric molecules on polar surfaces to form layers having higher polymer concentration than the bulk solutions and thus higher viscosity. These viscous layers had thicknesses, which corresponded approximately to the random coil diameters of the molecules, i.e. between 10 and 30 nm increasing with molecular weight. The practical effect of such adsorbed, viscous layers was to continue to maintain a hydrodynamic film, and correspondingly low friction, even down to entrainment speeds at which negligible hydrodynamic film was predicted on the basis of polymer solution viscosity. Polymers whose stability with temperature varies very little work as thickeners, but are not efficient improvers in viscosity temperature as those polymers whose solubility is weak at low temperature but strong at high temperature. Rising molecular weight from polymer also raises the amount of polymer in an oil solution. Consequently, a higher molecular weight polymer will import a higher viscosity index than a lower molecular weight polymer of the same chemical type. Viscosity index improvers are more effective in increasing the viscosity order of low-viscosity oils and become progressively less effective as the viscosity of the base oil increases **[21]**.

Main properties of *VI* Improvers are specified as follows **[22]**:

a) Excellent fuel economy performance
b) Strong stay-in-grade performance for long drain intervals
c) Small cold-viscosity contribution to extraordinary volatility
d) Good output on low temperatures without compromising high temperature safety

1.10 Applications of Viscosity Index Improver

Some dissolved polymers may act as effective friction modifiers. Actually, polymeric additives known as viscosity index improvers or viscosity inhibitors are used in virtually all multigrade engine oils and in many transmission and hydraulic oils, whose main function is to adjust the bulk rheological properties of the fluids in which they are blended. They are also often used with nitrogen-based groups for use in engine oils to have soot dispersion properties and thus increase the traditional dispersant additives used in these lubricants.

a) Multigrade engine oils
b) Gear oils
c) Automatic transmission fluids
d) Power steering fluids
e) Greases
f) Automobiles
g) Various hydraulic fluids

1.11 Advantages of Viscosity Index Improver

The biggest advantage of viscosity index improver is when we add it in lube oils, the viscosity index of the lube oil increases. If improvers in viscosity are applied to oils with low viscosity, they effectively thicken the oil as temperature increases. This ensures the lubricating effect of oils can be spread over a broader range of temperatures.

1.12 Disadvantages of Viscosity Index Improver

They are susceptible to mechanical shear. Unfortunately, improvers to the viscosity index have several disadvantages. The only drawback is that they are vulnerable to mechanical shear. When referring to the slinky example, a stretched-out slinky cut in half by mechanical processes is easily pictured to create two shorter slinky processes. As the additive is shaved regularly, it loses the ability to function at higher temperatures as a more viscous fluid. Higher molecular weight polymers make thickeners stronger, but they appear to have less mechanical shear resistance. Lower molecular weight polymers are more shear-resistant, but do not improve viscosity at higher temperatures as effectively and must therefore be used in greater quantities.

Table:

1.13 Viscosity Index Improvers (Polymers) Used are
1.13.1 Methyl Methacrylate

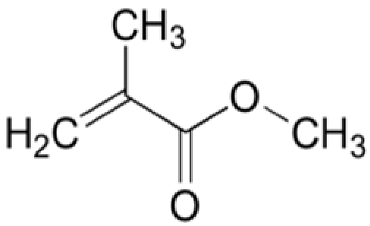

Figure 1. Schematic representation of Methyl Methacrylate.

Methyl methacrylate is a clear liquid with a fruity flavor. Methyl methacrylate is almost exclusively used in the production of methyl methacrylate polymers or copolymers used in the production of acrylic sheets and molds, transparent plastics, extrusion powders, printing inks, floor polishes, dental restorations, adhesive cements and surgical implants. Methyl methacrylate is a reactive chemical that requires careful storage and handling. It is stable on specified conditions of storage. Heat will cause polymerisation. To prevent polymerisation inhibitors are added to the methyl methacrylate monomer. The oxygen concentration in the vapor space must be at least 5 per cent for the inhibitor to be successful. Pack products in stainless steel, carbon steel, glass or aluminium containers. Prevent interaction with acids, bases, oxidizing agents, reduction agents, UV light (ultraviolet light present in sunlight) and organic peroxides.

1.13.2 Polybutadiene (PBR)

The second largest amount of synthetic rubber produced is polybutadiene (PBR), next to styrene-butadiene rubber (SBR). In 1999, consumption had been about 1,953,000 metric tons worldwide. Polybutadiene is primarily used in tyres, with more than 70 per cent of the polymer created going into treads and sidewalls. Due to its low glass transition temperature (Tg), Cured BR provides excellent abrasion resistance (good tread wear) and low rolling resistance (good fuel economy). The low Tg, usually < –90C, is a product of the low polybutadiene "vinyl" material, to be discussed below. Nevertheless, low Tg often results in poor wet traction properties, so for tread compounds, polybutadiene is typically mixed with other elastomers such as natural rubber or styrene-butadiene rubber. In addition, due to its excellent durability, about 20,000 metric tons of "high cis" polybutadiene are used annually in golf ball cores This application is increasing as the golf ball industry appears to be shifting away from conventional wound ball technology into solid core two-piece construction.

1.13.3 High Cis Polybutadiene

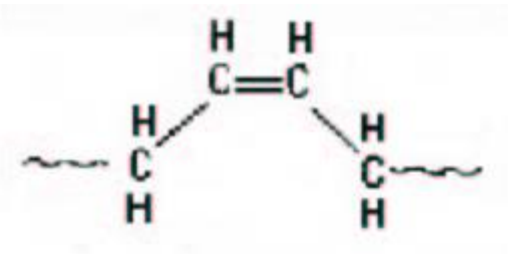

Figure 2. Schematic representation of a high cis polybutadiene.

Typically, high cis polybutadiene will have cis content > 95 percent, which results in better "green power" and improved resistance to cut growth in the cured product. Green strength, which is the strength of the uncured rubber material, is essential for the process of building the tyre, and for the performance of the tyre, growth resistance to cutting is required. Cut growth resistance is the resistance to a tear or crack propagation during a complex process such as a tyre's flexing in use. Golf ball cores are healed with peroxides which tend to make the vinyl units a very hard and slow golf ball "over cure." The neodymium catalyst system produces the highest cis content of around 99 percent and also allows the most linear chain structure (no branching) producing a polymer with the best tensile and hysteresis properties (low heat build-up) of all the high cis forms.

1.13.4 High Trans Polybutadiene

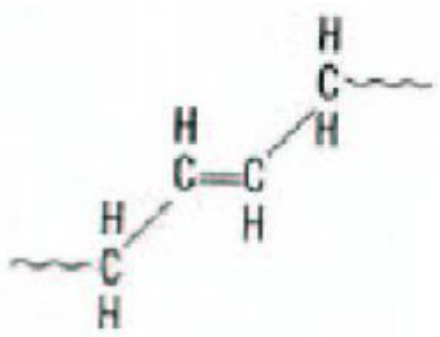

Figure 3. Schematic representation of trans 1,4 polybutadiene.

High trans polybutadiene is a strongly trans polyisoprene or balata-like crystalline plastic substance used in golf ball coverings. Remember below, that the main polymer chain is on opposite sides of the internal carbon-carbon double bond in the trans configuration. Trans polybutadiene has an estimated melting point of 80°C. It is made from transition metal catalysts similar to the high cis (La, Nd, and Ni) process. Such catalysts will use the solution cycle to create polymers with > 90 percent trans configuration again. Thanks to its low cost, durability and special properties, polybutadiene is and will continue to be a high volume rubber for use in tyres, toughened plastics and golf balls. When new markets expand, new, higher-performance polybutadiene grades will need to be produced using both the alkyllithium and the Ziegler systems **[22]**.

II. Conclusion

In this overview, we discussed about the *VI* improver developments for the foreseeable future which would likely to be evolutionary and market-driven. Enormous research effort has been made to find maximum *VI* for the engine oil. One must assume that engines will continue the trend of increasing operating temperatures. This will place continued pressure on the thermal oxidative stability of *VI* improvers. It will also result in volatility being an increasingly important issue. By the studies we can observe that the occurrence of maximum VI depends on the lube oil used and the type and concentration of *VI* improver. We have discussed about some *VI* improvers i.e. Methylmethacrylate (MMA) and Polybutadiene rubber (PBR) for the engine oils.

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