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RE-REFINING OF USED LUBRICATING OIL AND TO DETERMINE RHEOLOGICAL CHARACTERISTICS: A LITERATURE REVIEW

Saket Thorat[1], Jidnesh Arekar[2], Dr. Sonali Dhokpande[3]

[1,2]Student, Department of chemical engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai, Mumbai University, India.
[3]Assistant Professor, Department of chemical engineering, Datta Meghe College of Engineering, Airoli, Navi Mumbai, Mumbai University, India.

Abstract - *"Used oil" is any synthetic or petroleum based oil that has been utilized but is unsuitable due to the presence of impurities. During usage of normal oil, impurities such as water, dirt and toxic chemicals can get mixed with the oil. Therefore, it decreases the oil quality. This can also happen due to oxidation and thermal degradation. As a result, it is crucial to substitute old oil with new oil. Disposing this used oil directly to nature causes high degree pollution. The burning of used oil produces lot of ash and carcinogens which causes environmental pollution. But by proper treatment and recovery a lot of useful product can be acquired. Taking environmental aspects into account, this review paper discusses best methods to re-refine lubricating oil and ways to obtain its characteristics. The main goal of re-refining is to remove the contaminant and impurities from the oil and to restore its original properties. This paper reviews different methods to re-refine used lubricating oil and make it suitable for further use. After re-refining, characteristics of re-refined oil are determined which includes oil's viscosity and shear stress by rheological study.*

Key Words: **re-refine, lubricant, environmental sustainability, rheology, shear rate, viscosity.**

1. INTRODUCTION

Lubricating oils are viscous liquid used for lubricating moving parts of machines, reducing friction, protecting against wear, and removing contaminants from the engine, also acting as a cleaning and anticorrosion agent [2, 3]. Lubricating oils are commonly used in industry to minimize friction and wear by forming a thin layer of oil between metallic surfaces. It also enhances the efficiency of equipment or machine. Impurities such as water, dirt, heavy metal and other additive get indulged with the oil during regular usage. These impurities are also generated due to thermal degradation or oxidation, due to which the quality of the oil gradually decreases [6]. The consistency of the used oil eventually deteriorates to the point that it has to be substituted.

Lubricating oils are obtained from petroleum – a finite product thus disposing the used oil off in nature creates an intense degree of pollution as it contains number of additives and is contaminated by impurities and residue [1,3,6]. Toxic substances and contaminants such as PCBs (polychlorinated biphenyls) make used oil so hazardous for ecosystem. When this used oil is poured into the land it penetrates the ground rapidly and causes serious ground water contamination [7]. Used oils can be recycled in a sustainable and efficient way, thus saving energy and avoiding environmental contamination. The most important used oil recycling technology is the re-refining [5]. A considerable volume of valuable material may be obtained as a result of recovery and refinement. Aside from the environmental implications, inappropriate oil disposal is a misuse of a vital resource.

Used oil has been re-refined using many techniques such as chemical treatment, physical treatment, by distillation and thin film evaporation and solvent extraction [5]. Several procedure are performed to re refine the used lubricating oil and to produce high quality base oil. Used oil may usually be re-used after reconditioning whether or not any additives are used, resulting in significant savings and reuse of valuable resource. Furthermore, various properties of this re-refined oil can be obtained by using rheological study.

Rheology is used to determine the flow behavior. Rheological analysis of oils will thus determine crucial parameters such as viscosity, density, acid number, base number, shear stress, shear rate, viscosity, and torque. This also helps in monitoring and maintaining engines by determining overall lifetime of oil [13].

2. ENVIRONMENTAL CONSCIOUSNESS

Any type of oil is potentially environmentally damaging. Most of the 25-28 million tons of used oil produced annually, is spilled into the environment. The high content of heavy metals makes oil a very hazardous pollutant commodity, such as Zn, Cu, Ni, Pb, Cr, Cd. These metals are very harmful for environment. Spillage of used oil onto soil can induce a drastic change in the environment. It ends up in sites where surface and groundwater may be contaminated. These changes can have an effect on the biological cycles in soil. In aquatic environments, oil film on water can minimize light penetration in water and thus reduce the photosynthesis rate. The production of oxygen is also limited if

photosynthesis is reduced. The decline of oxygen dissolved in water stresses animals that live in water. Also, by means of inhalation, aspiration, ingestion or skin contact, used oil can induce lipid pneumonia, oil acne, cancer of the skin and lung cancer in humans. Used lubricating oils are re-refined through a method that efficiently eliminates pollutants and restores oils to the equivalent of oil extracted from virgin stocks. As a result, used oil is a pollutant and has the ability to be recycled safely and by re-refining, thereby minimizing environmental emissions.

3. LITERATURE SURVEY

Merai Yash P. stated that used lubricating oil can pollute the environment. High amount of additives and residues are found in engine oils. This occurs due to combustion. Oil when disposed directly to nature can lead to pollution. Aside from the environmental implications, inappropriate oil disposal is a misuse of a vital resource. However, product is restored and recovered by removing the contaminants of the oil. It is possible to retrieve lube base oil of equivalent consistency. For re-refining of used lubricating oil the process involved are: dehydration, diesel stripping, distillation and condensation. Firstly, the oil is preserved to allow water and solids to detach from it, and then it is heated to 120 degrees Celsius in a closed vessel to boil off any emulsified water. This is followed by diesel stripping process. The dehydrated oil is then continuously fed into a vacuum distillation plant for fractionation in this process. During this process, we get light fuel and diesel, lubricating oil and residues. Then at last the lubricating oil fraction is passed through extraction tower in presence of n-methylpyrolidone. More resources is conserved by re-refining used oil, which benefits both the ecosystem and the economy.

Rashid Abro et al stated that lubricating oils are viscous liquids used to lubricate engine and system moving components. Petroleum-based lubricating oils are basically complex mixtures of hydrocarbon molecules. They are made from derivatives of crude oil with some chemical additives. Internal combustion engines use fuel oil as a lubricant. To prevent direct contact, lubricating oil produces a separating layer between the surfaces of neighbouring moving parts. They're used to reduce the amount of friction that occurs between moving surfaces. During normal use, dirt and metal parts from the surfaces are also deposited into lubricating oils. Dirt and metal sections from the surfaces are deposited in lubricating oils during regular usage. These impurities also consist of engine components which include iron, steel, copper, lead and other compounds of water, burnt carbon and sulphur. Also, with increase in time it loses its lubricating properties. By proper refinement the quality of the oil is regenerated to quality equal to or better than its original virgin form.

Udonne J.D. stated that lubricating oil is an important resource which is mainly used as motor oils. It mainly consists of hydrocarbon molecules with molecular weight of low viscosity of oil as low as 250 and as high as 1000. However, with increase in temperature properties like viscosity and specific gravity are decreased. Also with increase in recent environmental concerns recycling of used lubricating oil is more suitable. Recycling of waste lubricating oil mainly conserves crude oil reserves and will also lead to reduction in environmental pollution. After re-refining of used lubricating oil its quality is enhanced. Redistilling is distilling of used lubricating oil and to convert it into its original form with better quality. The used lube oil consists of yield about 80% and crude oil between 5 to 10%.

P.M.James, C.Jenson et al stated that four procedures are used to re-refine fuel oil such as water stripping, diesel stripping, filtering through carbon membrane filter, adding additives. First, the oil is heated to 120^{o} C in a glass beaker, and the water molecules in the engine oil are burned out as vapour, resulting in engine oil that resembles mud light clay. This is followed by vacuum distillation method in which ASTM d 12 method is used. The procedure is carried out at temperatures ranging from 202^{o} C to 470^{o} C, and the used engine solvent is then distilled into different fractions. For filtration, specially designed 3 layered filter is used to remove macro particle and to give clean and original color to engine oil. To have a standard physical consistency of engine oil, methyl pyrolidone is used as an additive in engine oil. The engine oil is then concentrated and separated through a liquid tower, with 92 percent engine oil and 8 percent additive. It is then concluded that the re refining process increases the kinematic viscosity, density, flash and fire point of engine oil while decreasing the calorific value. Furthermore, it was discovered that the properties of re-refined engine oil are nearly identical to the properties of engine oil used in automobiles, implying that the re-refined oil is best suited for use as engine oil.

Eman A. Emam et al stated that many methods, including acid clay treatment, distillation, solvent extraction, and hydrotreating, can be used to re-refine used oil. These methods produce different results, have different product characteristics, and have different operating costs. The first method involved solvent extraction followed by hydrotreating, while the second involved vacuum distillation followed by hydrotreating. The water and light ends were removed in the first method, and the used oil was extracted using MEK. The extracted oil was subjected to hydrotreating and further analyzed. Second technique includes three steps. Water and light ends were lowered in the first step, followed by vacuum distillation and hydrotreating treatment. The hydrotreating was done with a Ni/Mo catalyst and a silica alumina base. After that, the re refined oil was compared to virgin base oil and standard regeneration lubricating oil. When these two processes were compared, it was found that solvent extraction produced a better quality base oil than

vacuum distillation. As a result, when compared to solvent extraction, re-refining using vacuum distillation yielded the highest oil yield of around 84 percent.

H. Bridjanian et al stated that any petroleum-based or synthetic oil that has been used is referred to as "used oil." The content of oil is reduced to some degree due to thermal deterioration and oxidation. During internal combustion of engines impurities are generated. These impurities consist of unsaturated compounds, aldehyde, phenolic compounds. When used oil is released to nature, it emits a high amount of emissions. After proper re processing, the properties of re refined oil and virgin base oil can be compared. Oil can also be regenerated by following methods. To distinguish water and light compounds, used oil is heated first. Then gas oil is separated by vacuum distillation which was further passed through guard bed. Final product is obtained by hydro-treatment of base oil. Thus, by hydro-treatment all the unwanted contents are reduced/removed by which quality of oil is improved. By this method no harmful byproduct is obtained so this is environmental friendly.

Shri Kannan C et al stated that the acid clay treatment process is one of the available methods for re refining. Since, this method gives low quality of re refined oil and causes numerous problems to environment it cannot be used. So an alternative method which is eco friendly and produces much better quality of refined oil was discussed. Dehydration, vacuum distillation followed by solvent extraction, are included in this method. To remove the water content collected from used oil, it was heated to 120°C. The dehydrated oil was then vacuum distilled at 240°C and 20 mmHg. Fractions obtained during this process are light fuel, lubricating oil fraction and residue. In solvent extraction a selective aromatic solvent, Methyl Ethyl Ketone (MEK) was used. The vacuum distillation lubricating oil fraction was mixed in a 2:1 ratio with MEK. Following that, atmospheric distillation at 80°C was performed to remove MEK from the solvent mixture. To enhance the properties and make them usable, additional additives were added. Finally, the lubricating oil properties were determined and compared to the Society of Automotive Engineers standards. As a result to which significant improvement was noticed in some of the properties.

Salah Eldeen F. Hegazi et al stated that waste oil that has been treated with acetic and formic acid can be recycled and reused in engines. Acetic acid or formic acid was the primary advantage of using this product because it had no strong reaction to base oils. Because of its low reactivity with used oil, fewer additives were needed. The recycling process took place at room temperature. Firstly, used oil was mixed with acid and heated at constant temperature. Two layers were then separated after the addition of acetic or formic acid to the used oil: a transparent dark red oil and a dark black sludge at the bottom of the container. This was followed by bleaching and neutralization process and 24 hrs of sedimentation process. The resulting oil was filtered using filter cloth to obtain clear oil and the residue was discharged. This optimal condition for recycling waste lubricant oil was accomplished by varying the volumetric ratio of acetic acid in the base oil. Comparisons were made of the specific gravity, viscosity, density and chemical compositions of fresh oil, used oil and refined oils with formic and acetic acid. This resulted in properties of re refined oil equivalent to fresh oil.

Hassan Ali Durrani stated the necessity to improve the aggregation and re-processing of the oils, in order to extract useful materials. Used oil re-refining was compared with virgin base oil using various approaches to determine which is more effective. Sulfuric acid plus Bleaching Earth and the Propane extraction plus Sulfuric acid plus Bleaching Earth are commonly used methods for used oil re- processing as they involve significant amounts of residues. Hydrotreatment was preferred for removing harmful products and controlling color stability. Firstly, water was removed which was followed by catalyst being washed away by naptha and drying in an oven at 125o C for around 24 hours. Hydro-cracking catalyst (HC – 102) was used for the economic benefits. Furthermore, decoking process took place in a cylindrical furnace at a constant temperature, catalyst was loaded into the distillation column and hydrocracker gas oil was injected which resulted in required catalyst after a few hours. Thus, results were compared and it was discovered that the method was good enough with in relation to the PCB existence. Thus through this process no toxic or useless byproduct hydrocarbon were produced.

Motshumi J. Diphare et al stated that due to the surge in the automotive and other mechanical industry, the generation of waster oils is unavoidable and thus a standardized system for proper disposal of used oils should be documented and followed to avoid environmental pollutants. With about 56% of the market, automotive sector lead to maximum waste oils and the least was by industrial gear oils with 2% contribution. After extended physical use, additives such as antioxidants, detergents, anti-wear components, anti foaming agent, corrosion inhibitors, viscosity index improver, friction modifiers, metal deactivator, rust inhibitor, and emulsifying agents lost their properties. Also, the oil carries the wear chips through the system thus lead to consistent wear of the machine. With increase in focus on environmental conservation, the treatment and recycling of waste oil is important and therefore can be targeted by introducing a basic 3 stage method of reprocessing, re-refining and destruction. The reprocessing phase is simple physical settling and filtering the harmful substrate thus limiting to the uncontrolled burning of waste. A major disadvantage is that there is a demand for well-developed collection system along with extensive capital investment and costly treatment. Re-refining is essentially the use of a complex distillation method to produce a high quality base stock. Re-refining is a solid long term solution which reduces active importation of lubricating oils. The downside of this

approach is that it needs a well defined economy and hence can be a problem for under-developed economies. Under circumstances where the contamination is in high volume with Polychlorinated Byphenyl (PCB) and Polychlorinated terphenyls (PCT), incineration comes into consideration. A strict compliance should be maintained with air quality standards while implementing this method. Due to continuous emissions by incineration method, there is opposition by the government and regulatory institutions limiting its applicability. After utilization of the oil undergoes oxidation and contamination which leads to an increase in viscosity. The best method to recycle the oil in such circumstance is by re-refining the oil which brings the viscocity of the used oil close enough to the stock oil.

Isah et al stated that the used oil was acidified and bleached using activated carbon, which eliminated the aromatic content while improving the colour and quality of the oil. The raw materials and reagents mentioned in the process were sulphuric acid, waste used engine oil, fresh engine oil, activated carbon and phenolphthalein. Activated carbon was obtained from wood; impurities were washed with water and filtered with filter cloth, which was then followed by drying and heating. Firstly, used oil was mixed with sulphuric acid and heated at constant temperature. Then the oil was allowed to settle to form sediment. This was followed by bleaching and neutralization. The same bleaching process was performed using activated carbon. This was again followed by sedimentation and the filtrate was collected using filter cloth. To perform this procedure, five different formulations were considered and compared with each other. Thus, properties such as viscosity, specific gravity, density, color, API, TAN were considered. Different colors of oil were observed among fresh oil, used oil and formulated oils. The fresh oil was a yellowish green color, while the used oil was a very dark color. The acid number of the fresh oil was also lower than that of the used and regenerated oil, despite the fact that the viscosity and specific gravity were slightly higher. As a result, it was discovered that bleaching with industrial bleaching earth yields better regenerated used oil than activated carbon.

Vineet Katiyar et al stated a serious emphasis on recycling the waste oil and classification of the ecological impact. Due to the high market price of oil, there is a steady demand in reusing oil which was utilized as lube in machinery. The waste oil is disposed off through multiple outlets which directly affect the environment and the non-renewable resources. The oil used in hydraulic applications contain harmful additives which affect both humans and the environment. Due to the constant usage, the oil undergoes physical and chemical reactions and thus provides harmful contaminants as an output. Significant health implications such as lipid pneumonia, lipid granuloma and oil acne are noticeable by direct or indirect interaction with the polluted toxic waste which primarily contains PAHs. Total of 7 PAHs are classified as potential carcinogens that are rapidly absorbed upon any direct contact thus leading to cancer, anemia and cardiovascular disease. Cadmium, arsenic, chromium are some of the harmful metals that are present in varying degrees which leads to loss of lung functions and ability to resist skin infection along with adverse effect on plants. Indirect impact of oil spill can be recorded as it interrupts the penetration of oxygen into water and thereby affecting the marine environment. Dehydration, solvent treatment, clay treatment, clay filtration and blending of additives are some of the steps that can be implemented to treat the toxic oil waster. Emphasis on recycling and proper disposal of used oil should be inculcated and strictly implemented by laws governed by the countries and along the international waters to sustain the ecosystem and avoid extreme long-term adverse effects.

Santosh Kumar Kurre et al stated that lifetime time of lubricating oil is obtained by knowing different properties or parameters. Various components in virgin oil can be obtained by bench test of various oils. Base of minerals are added to enhance the properties of product. Chemical additives and heavy metals are toxic contaminants. Other heavy metals commonly present in used oil include cadmium, chromium, zinc and arsenic. When oil is directly exposed to soil it leads to contamination of surrounding soil and groundwater. When washed into water bodies used oil increases oxygen demand as hydrocarbons are decomposed. Thus, it is necessary to re-refine used oil and to know its properties. Thus, this allows us to select type of oil for different conditions. To obtain various properties of lubricating oil firstly two samples of same oil is fed into engine at same time then different methods are performed to obtain the following properties such as viscosity, density and shear stress. This method is therefore used for monitoring and maintaining vehicles and engine.

Ioana Stanciu stated that rheology is a science used to determine the flow behaviour of solid and liquid material by knowing its shear stress and velocity. Shear stress and dynamic viscosity is decreased with increase in temperature. Three and multi constant formula were used to get more accurate prediction of temperature dependence. Viscosity is the characteristic of liquid which relates shearing stress to the viscosity gradient. The Viscotester was used to test lubricating oil with viscosities varying from 10^4 to 10^6 mPa.s and shear stress ranging from 3 to 120 s-1. As a consequence, the stear stress and viscosity of used and redefined lubricating oil are obtained for contrast.

Ajay Vasishth et al investigated the relationship between viscosity and temperature at various shear rates. To determine efficiency, pressure viscosity relationship of lubricating oil is crucial. Industrial lubricating oils L1: MG20W50 (engine oil), L2: SAE20W50 (engine oil), L3: MC20W50 (mineral engine oil), L4: EP90 (gear oil), and L5: DXTIII (steering fluid) were considered as samples. Rheometer MCR302 was used to calculate shear stress ,

viscosity , and torque for all five samples at temperatures varying from 20oC to 50oC. Similarly, 100 measurement points were chosen with a period of 2 seconds and a shear rate varying from 1 to 100/s by measuring torque, shear stress, speed, and viscosity with shear rate at a constant shear rate of 10 sec-1, and 31 data points were chosen with a measuring time of 2 min. It was thus observed that dynamic viscosity versus temperature showed exponential variation for samples L1, L2, L3, and L5. However, L2 and L3 showed relatively lower variation. Dynamic viscosity was initially found to decrease with shear rate and then showing variation with shear rate for all the samples. Torque versus shear rate showed linear dependence. Shear stress versus shear rate was found to be liner, with L5 indicating the lowest slope. As a result, samples were found to behave like Newtonian fluids and to follow the Arrhenius temperature relationship.

4. CONCLUSIONS

The re-refining of waste lubricants will support both the atmosphere and the economy. Waste oil refining in order to refine base oil retains more energy than waste fuel oil reprocessing. The used engine oil was refined by numerous tests to extract water, carbon waves, resistive aromatics, light fuel, and to submit additives to boost engine oil properties. There are various method to re-refine oil such as solvent extraction using various solvent, vacuum distillation, clay treatment, chemical treatment and hydrotreatment. All of this is achieved to achieve higher quality re refined engine oil. Among all these methods vacuum distillation with hydrotreatment was found out to be more effective. The hydrotreatment process satisfies all of the necessary technological and environmental requirements for re-refined oil and has the additional economic benefit of using spent hydro-cracking catalysts rather than purchasing new hydro-treating ones. This process yields no dangerous or inefficient byproduct hydrocarbons. The recycling lubricating oil thus shows properties as comparable to that of fresh lubricating oil. Various lubricating oil properties such as viscosity, Shear Stress, shear rate, torque and density is determined by rheological study. Thus measurement of Viscosity, Shear Stress, and Torque with Temperature and measurement of Viscosity, Shear Stress, and Torque with Shear Rate shows varied results. Therefore, re refining is considered by many as a preferred option in terms of conserving resource as well as minimizing waste and reducing damage to the environment. Rheological research assists in assessing the overall lifespan of crude. As a result, the findings of this analysis would be useful in monitoring and repairing vehicles and engines.

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