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Studies on Reuse of Re-Refined Used Automotive Lubricating Oil

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Abstract

Today the used oil is discarded into the ground or landfills which neither protects the environment nor conserves it resource value. The used oil poured into the land penetrates the ground rapidly and causes serious ground water contamination. The burning of used oil in kilns and incinerators produces lots of ash and carcinogens causing environmental pollution. Refining of used oil can produce more valuable products and can prevent pollution. The refining of used lubricating oil minimizes the dependence on virgin base oil to produce fresh lubricating oil. The objective of re-refining is to remove the degraded additives and contaminants and to restore the properties of the oil identical to the standards provided by SAE (Society of Automotive Engineers). The available method for re-refining is the acid clay treatment process. It involves the treatment of used oil with strong acids followed by treatment with clay. This method produces acid sludge and causes numerous environmental problems. Also the quality of re-refined oil is very low. This method cannot be used due to the stringent pollution control board norms. The present study focuses on the development of an alternative method that is ecofriendly and produces good quality refined oil. The used oil is collected from automobile service stations and the oil is subjected to dehydration, vacuum distillation followed by solvent extraction. The solvent used in solvent extraction is recovered by atmospheric distillation. Finally, additives are added to the re-refined oil. The properties of lubricating oil like density, viscosity, viscosity index, flash point, fire point, pour point, cloud pointand total acid number were determined and compared with the standards provided by the Society of Automotive Engineers.

Keywords: Lubricating oil, dehydration, vacuum distillation, solvent extraction, additives.

Introduction

The lubricating oil acts as a lubricating medium for various automobile parts such as engines and gearboxes. The primary function of lubricating oil is to reduce friction and to provide a heat transfer medium. It also inhibits corrosion and carries away the metal wear parts. The lubricating oil itself doesn't undergo any changes after use but it gets dirty due the addition of combustion products, degraded additives, water and other dust particles during its time inside the engine. The dirt added to the lubricating oil can be obviated and the oil can be restored to its original state. At present the used oil is disposed by pouring into ground, water bodies or used as fuel leading to serious environmental problems. Apart from the environmental problems, the refining of used oil can produce a valuable resource, which is wasted. This in turn increases the need to drill for more crude oil. The crude oil contains more impurities than the used oil and the production of lubricating oil from crude oil is much costlier than refining of used oil[1].

In automobiles the lubricating oils are changed for every 5000 kilometers. During the time of oil inside the engine, the properties of the lubricating oil such as viscosity, specific gravity, flash point, pour point.., gets reduced due to the continuous addition of heat. The additive gets degraded and goes into the oil in the form of sludge along with metal wear parts. Water goes into the oil as a result of combustion and finally the oil becomes unfit for use in the automobile engines and needs replacement. Although used lubricating oil signifies a small percentage of petroleum waste, its environmental impact is very unlimited. Recycling has become an adequate treatment of oil through the use of exact processes, thereby allowing the recovery of the part not burned, which is separated from the residue. Among the numerous processes established for recycling, the acid/Clay process is one of the eldest and is accepted. In the acid/clay process, non-sodium bentonite is used in the laststep for decolorization of the recovered oil, binding free cations[2].

Very few numbers of studies have been carried out using used engine oil. The refined oil produced by acid clay treatment process contains higher acid content, which causes corrosion and reduces the self-life of the automobile engines[3]. The improper disposal of waste engine oil such as dumping into ground or into water bodies poses the risk of soil and groundwater contamination[4]. Using the waste engine oil as fuel releases toxic substances and pollutants into the environment[5]. Refining the used engine oil can preclude the environmental problems and in addition the refining is economically beneficial[6,7,8]. Vacuum distillation and hydrogenation are the alternative methods by which the used oil can be refined[9].

The amount of crude oil required to produce a certain volume of lubricating oil is nearly 9 times higher to produce the same volume of lubricating oil from used oil[10]. Various methods have been employed to carry out the refining of used oil[11,12,13]. Recycling technology is the most important used oil re-refining The refining process involves the removal of contaminants and dirts by distillation, acid treatment[13,14], solvent extraction[15], clay treatment, hydrogenation[16], or combination of these processes. The refined oil produced by this method have different properties and operational cost.

The present work involves the re-refining of used automotive oil collected from automobile service station. The used lubricating oil is subjected to dehydration, vacuum distillation followed by solvent extraction. In addition, additives are added in the above sequential process and the properties of the final lubricating oil are determined. The properties are then compared with the standards provided by the Society of Automotive Engineers (SAE) to determine the reliability of using the re-refined oils in automobile engines.

Material and Methods

The used oil collected is heated at a temperature of 120°C to remove the water added to the oil during combustion. The experimental setup of dehydration is shown in figure 1. Then the dehydrated oil is vacuum distilled at a temperature of 240°C and pressure 20 mmHg. The experimental setup of the vacuum distillation is shown in figure 2. The fractions obtained are as follows:

Figure-1
Dehydration

Light fuel oil: The light fuel oil produced at a temperature of 140°C. The light fuel oil can be used as fuel source for heating.

Lubricating oil: At 240°C, the lubricating oil fraction is obtained. The lubricating oil vapor is condensed and sent for next stage.

Figure-2
Vacuum Distillation

Residue: The remaining oil at this temperature (240°C) contains the dirt, degraded additives, metal wear parts and combustion products like carbon and is collected as residue. The residue is in the form similar to that of tar, which can be used as a construction material.

Solvent extraction: Methyl Ethyl Ketone (MEK) is a selective aromatic solvent employed in the solvent extraction process. The lubricating oil fraction obtained by vacuum distillation is mixed by agitation with MEK in the ratio 2:1.The lubricating oil and solvent mixture is allowed to settle in the separation flask for four hours. The aromatic content and degraded additives present in the lubricating oil fraction settle at the bottom and the lubricating oil fraction and solvent mixture layer forms at the top. The bottom layer is similar to the residue obtained in the vacuum distillation and the top layer of lubricating oil and solvent mixture is subjected to atmospheric distillation.

The atmospheric distillation is carried out at a temperature of 80°C which is the boiling point of MEK. The MEK vapor produced is condensed and is again used as a solvent by blending with the fresh solvent. The lubricating oil produced at this stage is similar to that of the base lubricating oil. Additives have to be added to the lubricating oil produced from the above sequential process to further improve the properties and to make them eligible for use in automobile engines. Zinc Dialkyl Dithiosulphate is the common additive added to the lubricating oil. Zinc Dialkyl Dithiosulphate is available as a salt and is added to the lubricating oil while heating. The heating and mixing ensures the complete mixing of the additive with the lubricating oil. 200 grams of additive is added to 1 liter of lubricating oil. The lubricating oil produced at this stage is identical to the commercially available lubricating oil and can be used in the automobile engines subjected to the addition of specialized additives.

Properties: Density and specific gravity: Density is the ratio of mass of a substance to the volume of the substance. Specific gravity is the ratio of density of substance to the density of water determined at the same temperature. The level of impurities in the used oil is indicated by the density and specific gravity. The specific gravity increases with the increase of aromatic content in the oil. Used engine oil has higher density and specific gravity due to the presence of contaminants in it.

Viscosity: Viscosity is the resistance offered to the flow of fluid. Viscosity testing of oil indicates the presence of contaminants in it. The viscosity of the lubricating oil decreases due to the addition of fuel, water and other contaminants added to it during its time inside the engine. Viscosity of the oil plays a cardinal role in reducing friction and it should be high.

Viscosity index: Viscosity index is a number that indicates the change in viscosity at different temperatures. If the viscosity index is high, the viscosity change with the temperature is less. This means that the oil has higher thermal stability and provides good engine protection.

Flash point: Flash point is the minimum temperature at which the vapor produced by heating the oil produces a momentary flame when introduced to an ignition source. A low value of flash point indicates the addition of volatile products to the lubricating oil and the presence of contaminants. Flash point is determined by Cleveland open cup apparatus method. The oil is taken in the open cup and heated. The temperature at which the vapor given out by the heating oil catches fire momentarily when exposed to the ignition source is noted as flash point temperature.

Fire point: Fire point is the minimum temperature at which the vapor produced by heating the oil continues to burn when introduced to an ignition source. The fire point of oil indicates the maximum temperature up to which the lubricating oil is efficacious. With the continued usage of oil in the engine, the oil gets contaminate with the impurities and leads to a decrease in the fire point. This is undesirable and the oil needs to be replaced when the fire point temperature reaches a lowest value.

Pour point: The pour point is the minimum temperature at which the oil can flow freely inside the engine. The lubricating oil contains waxes and paraffins, which causes the oil to solidify at lower temperatures. The oil should have higher pour point or else the flow of oil into the oil pump and into the various engine parts is affected at low temperatures.

Cloud point: Cloud point temperature indicates the presence of wax in the lubricating oil, which forms a cloudy appearance. The presence of high volume of wax stymies the flow of oil inside the engine and blocks the fuel injectors at cold temperatures. The cloud point temperature is determined by cooling the oil sample and noting the temperature at which a cloudy appearance is formed.

Aniline point: The aniline point refers to a temperature at which equal amount of aniline and the lubricating oil mixes completely. The aniline point is a measure of aromatic content present in the oil. The aniline and oil are taken in a test tube in equal volume. The test tube is heated while stirring until a homogenous mixture is obtained and then the test tube is cooled. The two phases separate out and the temperature is noted as aniline point.

Total acid number: The Total Acid Number (TAN) indicates the amount of acid content present in the oil. The TAN is the amount of potassium hydroxide required to neutralize the acid present in one gram of the oil. The engine oil undergoes oxidation at elevated temperatures producing carbonyl products and carboxylic acid. Higher TAN indicates the higher acid content and the oil needs replacement.

Results and Discussion

Used oil contains valuable resource of recoverable base oil into which the degraded additives, water and contaminants have mixed. The present study involves the refining of used lubricating oil by dehydration, vacuum distillation, solvent extraction and atmospheric distillation. Additive is added to the final lubricating oil to further improve its properties. The comparison of properties of used lubricating oil and fresh lubricating oil is shown in figure 3 and 4.

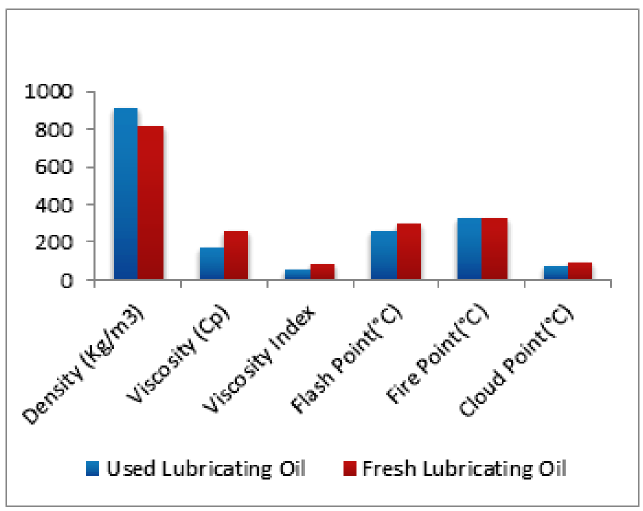

Figure-3
Comparison of properties of used oil and fresh oil

The density difference between the used and fresh lubricating oil indicates the presence of contaminants and sludge present in the used lubricating oil. The continual use of oil by the engine and sustained operation of engine at high temperatures reduces the viscosity of the oil considerably. The viscosity reduced from 258 Cp for fresh lubricating oil to 167 Cp for the used lubricating oil. When the viscosity is lower, the heat exchange property of the oil becomes ineffective and the oil needs replacement. There is a significant difference in the viscosity index between used lubricating oil (51°C) and the fresh lubricating oil (85°C). The lower viscosity index for the used lubricating oil indicates the lower protection of engine at high temperatures.

The flash point and fire point temperature for used lubricating oil is 260°C and 323°C respectively which is lower in comparison with the fresh lubricating oil. The lower value of flash and fire point indicates the presence of volatile impurities in the used lubricating oil.

The minimum temperature at which the oil flows freely is called pour point. The pour point is an important point to consider in the colder climate where the oil should not become highly viscous or freeze which stymies the oil circulation. Obviously, as the oil gets contaminated, the pour point decreases considerably. The pour point is -10°C for used lubricating oil and -18°C for fresh oil. Thus the oil with lower pour point causes trouble in the oil circulation and is unfit for further use. The cloud point is the below which a haziness is formed. The clouds point of the lubricating oil decreases due to the continuous addition of heat in the automobile engine.

The aniline point for the used lubricating oil is 14°C which is 6°C higher than the fresh lubricating oil. The higher value of aniline point indicates the presence of aromatic impurities in the used lubricating oil. The TAN for used lubricating oil is 10.0505 mg/g, which are nineteen folds higher than the fresh lubricating oil. Such a high acid value causes the corrosion of the metal parts of the engine and reduces the life of the engines.

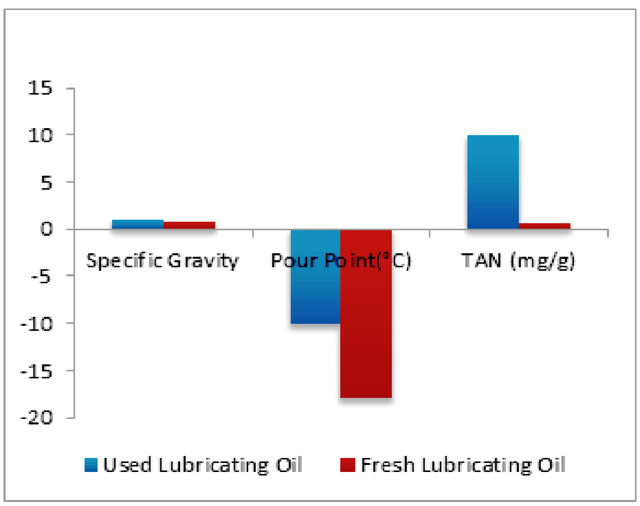

Figure-4
Comparison of properties of used oil and fresh oil

From figure 3 and 4, it becomes clear that all the properties of the fresh lubricating oil undergo a considerable change during the time the oil spends in the engine. This change is due to the addition of heat. The lubricating oil does not losses its properties. It is possible to restore the original properties by refining and removing the contaminants.

The used oil is subjected to dehydration, vacuum distillation and solvent extraction. Then additive is added to the lubricating oil obtained after the recovery of solvent from the lubricating oil.

Figure 5 and 6 shows the comparison of properties of refined oil produced after solvent extraction with SAE standards. The density of the refined lubricating oil got reduced to 866 Kg/m^3 from 910 $Kg/m^{3,}$ which shows that the refining process removed the impurities present in the used lubricating oil. The Viscosity increased from 167 Cp to 212 Cp and the viscosity index increased from 51 to 78 after refining. This increase in the viscosity and viscosity index telltales that the refined oil is more suitable to use at high temperatures and the refined oil can be used in the automobile engine.

The flash point of the oil shows an increase of 4°C which is still lower in comparison with the fresh engine oil. Also the fire point for the refined oil got reduced to 310°C from 323°C. It can be improved by the addition of additives to the refined oil, which improves the properties of the lubricating oil.

The Pour point of the refined oil is -14°C which is 4°C higher than the used lubricating oil. The cloud point improved from 70°C to 88°C after refining which is beneficial as it prevents the formation of a cloudy mass inside the oil at lower temperatures. The aniline point shows a reduction of 1°C which is still a significant improvement in the property of the lubricating oil. The TAN for used lubricating oil is very high (10.0505 mg/g) and refining removed most of the acid content in the used oil. The TAN after refining is 0.5766 mg/g, which is analogous to the fresh lubricating oil.

From figure 5, the density of the lubricating oil is slightly lower in comparison with the SAE standards. The viscosity of the refined oil (212 Cp) is slightly greater than the SAE 20 minimum requirement of 200 – 400 Cp. The viscosity index for refined oil is 78, which is in the accepted range of SAE 20 (70 – 103). The flash point temperature is 10°C lower than the accepted SAE standard. The fire point temperature for refined oil is 310°C which meets the SAE 30 requirement. The SAE standards specifies the cloud point temperature for lubricating oil as 100°C for SAE 20 but the refined oil has a Cloud point temperature of 88°C and needs improvement.

From figure 6, the specific gravity of the refined oil is a fraction lower than the SAE 20 standard. The pour point of the refined oil is -14°C which is very much lower than the SAE standard of -20°C. The refining process significantly removed the acid content and the TAN of refined oil is 0.5766 mg/g, which is in the accepted standards of SAE 20.

The lubricating oil produced at this stage needs improvement and the common lubricating oil additive Zinc DialkylDithiosulphate is added to the refined oil. The properties of the refined oil were determined after the addition of additives and its value. The comparison of SAE standards with the refined oil after the addition of additives is shown in Figure 7, 8 and 9

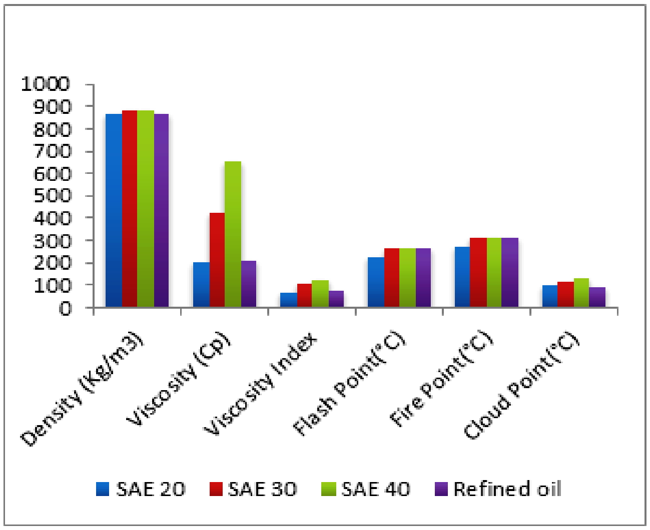

Figure-5
Comparison of SAE standards and refined oil

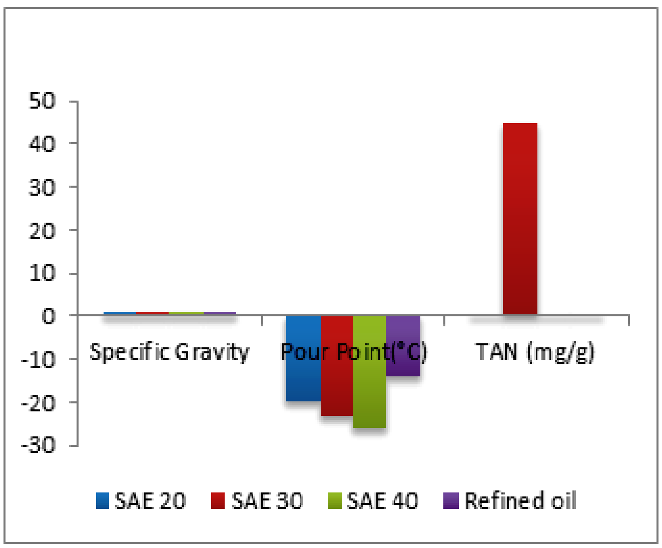

Figure-6
Comparison of SAE standards and refined oil

The addition of additive improved all the properties of the refined oil. The figure 7 shows that the density improved from 866 Kg/m^3 to 884 Kg/m^{3,} which falls in the range of SAE standards SAE 30. The viscosity of the oil increased from212 Cp to 266 Cp.

The figure 8 shows that flash point improved from 264 °C to 266°C which is in the range of SAE standards SAE 30. The cloud point temperature increased from 88°C to 105°C which is in accordance with the SAE 20 standards.

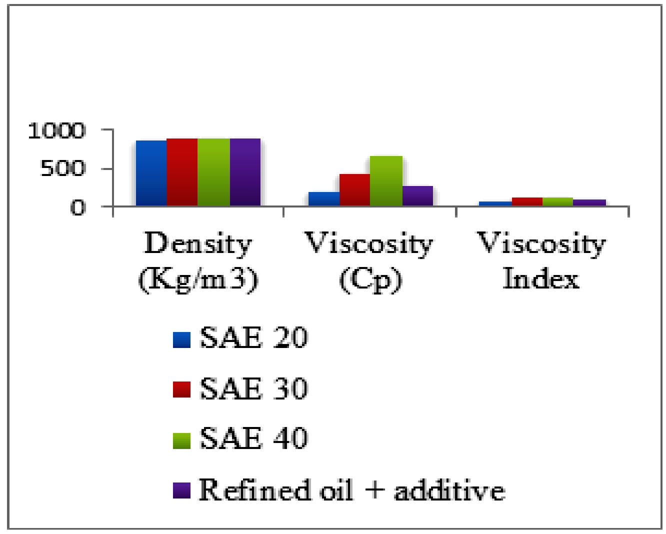

Figure-7
Comparison of SAE standards and refined oil after addition of additive

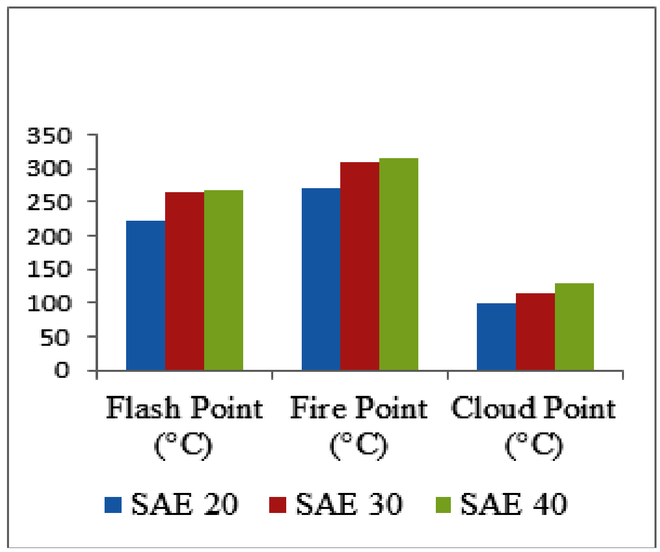

Figure-8
Comparison of SAE standards and refined oil after addition of additive

The figure 9 shows that the pour point temperature of the refined oil after mixing with additive increased from 14°C to -22°C. Now, the pour point temperature falls in the range of SAE 30 standards. This enables the use of the refined oil from our process at low temperatures.

The properties of refined oil produced by the process employed in this study are above the requirements of SAE standards SAE 20. Thus, the used oil can be successfully re-refined and with the addition of additives to the refined oil, it can be used as lubricating oil in automobile engines instead of the use of fresh lubricating oil produced from the refining of crude oil.

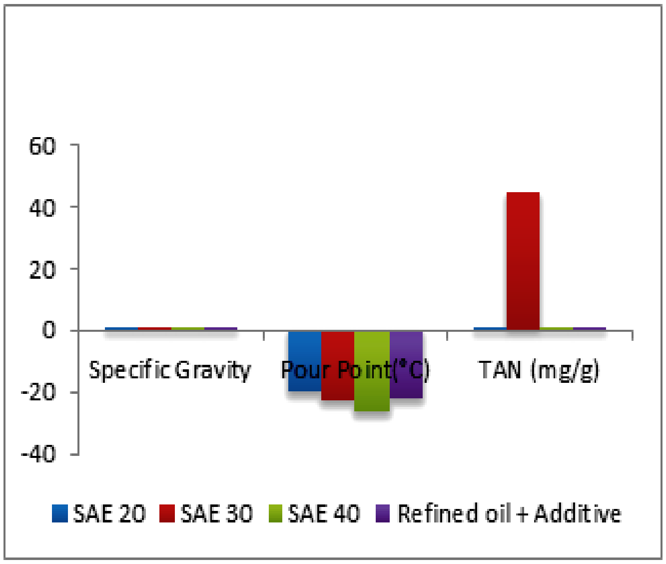

Figure-9
Comparison of SAE standards and refined oil after addition of additive

Table 1 shows the cost analysis for the production 1000 liters of lubricating oil from used oil. The capital cost is Rs.4,60,000 and the production cost for 1000 liters of lubricating oil is Rs.1,37,000. Whereas the cost of production of 1000 liters of fresh lubricating oil is Rs.3,20,000.

Table-1
Cost Analysis

Cost	Amount in Rupees
Capital Cost	4,60,000
Raw Material Cost	1,25,000
Operating and Maintenance Cost	12,000
Total Production Cost	1,37,000

Conclusion

The waste engine oil is collected and refined for its reuse.The process in the treatment involves vacuum distillation followed by solvent extraction.The addition of additives improves the efficiency of the lubricating oil.The refined lubricating oil shows properties as comparable to that of fresh lubricating oil. The density, specific gravity, viscosity, viscosity index flash point, fire point, pour point cloud point, aniline point and TAN were 910 Kg/m^3, 0.910, 167 Cp, 51, 260°C, 323°C, -10°C, 70°C, 14°C and 10.05 mg/g respectively. After refining, these properties improved to 884 Kg/m^3, 0.884, 266 Cp, 81, 276°C, 313°C, -22°C, 105°C, 11°C and 0.53 mg/g respectively. These properties are well within the SAE standards and can be reused in engines.The cost analysis shows that cost for production of lubricating oil from crude oil is approximately 1.5 times costlier than the oil produced from used oil.

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