PROCESS AND SYSTEM FOR RECOVERING BASE OIL FROM LUBRICATION OIL THAT CONTAINS CONTAMINANTS THEREIN

Field of the Invention

[0001] The present invention generally relates to the disposal of spent lubrication oil, and more particularly to processes and systems for regeneration of spent lubrication oil into multiple fractions including base oil by employing rectification and multi-stage molecular distillations.

Background of the Invention

[0002] The refinery process of crude oil produces a fraction of oil that is suitable for lubricating purposes, called base oil. In practice, the base oil is obtained and separated into fractions in the vacuum distillation column which is fed by the residue of an atmospheric column. Generally, only about 3-5% of the crude oil is suitable for being used as base oil. Due to various viscosity requirements for different lubricating purposes, the base oil must not be either too volatile or too viscous.

[0003] As its term suggests, the base oil is used as the base for formulating lubrication oil. To improve the quality of the lubrication oil are added multiple additives. The additives include antioxidants, detergents, dispersing additives without ash, antiwear additives, additives improving the Viscosity Index, additives for lowering the pour point, antirust and anticorrosion additives, and antifoam additives.

[0004] Industries use many types of lubrication oils including engine lubrication oil, hydraulic oil, transformer oil, turbine oil, compressor oil, marine oil, and the like. After lubrication oils reach their usage life span, they are disposed as spent lubrication oil (waste oil).

[0005] Spent lubrication oils from various sources or applications have different characteristics and contain a cohort of contaminants. When lubrication oil is used, it is being contaminated by extraneous contaminants introduced from the surrounding air and the engine. Contaminants from the air include dust, dirt, and moisture; and air itself may be considered as a contaminant since it might cause foaming of the oil. The contaminants from the engine include the metallic particles resulting from wear of the engine,

carbonaceous particles due to incomplete fuel combustion, metallic oxides present as corrosion products of metals, water from leakage of the cooling system, water as a product of fuel combustion, and fuel or fuel additives or their byproducts, which might have entered the crankcase of engines.

[0006] During lubrication oil usage many matters may be formed causing the deterioration of the lubrication oil. The examples of the formed matters include sludge, lacquer, and oil-soluble products. Sludge denotes a mixture of oil, water, dust, dirt, and carbon particles that result from the incomplete combustion of the fuels. Sludge may be deposited on various parts of the engine or may remain ascolloidal dispersions in the oil. Lacquer refers to a hard or gummy substance that may be deposited on engine parts as a result of subjecting sludge in the oil to high temperature operation. Oil-soluble products generated by oil oxidation which remain in the oil and cannot be filtered out, will be deposited on the engine parts. The quantity and distribution of engine deposits vary widely, depending on the conditions at which the engine is operated in. At low crankcase temperatures, carbonaceous deposits originate mainly from incomplete combustion products of the fuel and not from lubrication oil. In contrast, at high temperatures, the increase in lacquer and sludge deposits may be caused by the lubrication oils.

[0007] The properties of lubrication oil are affected by any contaminants that may occur during operation. For example, water, even in small amounts causes rusting of iron or steel. Water also results in the forming of water sludge (emulsions) which may clog oil passages, pump valves and other oil handling equipment, may contribute to foaming problems, and may lower the electricity insulation property of lubrication oil. Furthermore, solid particles such as dirt, dust, grit and metallic fragments cause excessive wear, scoring of bearing surface, and possible failure due to seizing of metal fatigue. In addition, sludge deposits may clog small oil passages and clearances; lacquers or varnish cause the sticking of valves, and may adversely affect the continuous operation of oil pump. Finally, liquid contaminants such as unburned fuel from engines may dilute the lubrication oil which may then reduce their viscosity beyond a safe load. Contamination of the lubrication oil with heavier oil may increase its viscosity and may interfere with the oil circulation, affecting the lubricating valve and heat transfer capacity.

[0008] Current methods for treating spent lubrication oil include processing the spent lubrication oil into fuel oil by simple processing and blending, acid treatment,

conventional distillation, solvent extraction, and ultrafiltration. Problems arising from acid treatment include environmental issues associated with the disposal of acid sludge and spent earth, low product yield (45–65%) and incomplete removal of metals, especially lead. For conventional distillation, the main problems encountered are plugging of the lines, fractionators and furnace tubes due to formation of a resinous material that fouls the equipment, cracking of molecular due to high distillation temperature and polymerization to form solid substance. Conventional distillation processes do not improve the dark color of the products obtained. Solvent extraction processes have the problems of high operating cost, complexity of the process and generation of secondary waste, e.g. waste solvent and waste water. Ultrafiltration is still in experimental stage and the main problem encountered is the fouling of membranes and incapability to manage the flash point of the products.

[0009] There is a need to provide a process for recovering base oil from lubrication oil that contains contaminants therein that overcomes or at least ameliorates one or more of the disadvantages described above. There is also a need to provide a system for recovering base oil from lubrication oil that contains contaminants therein which at least reduces the drawbacks discussed above.

Summary

[0010] According to a first aspect, there is provided a process of recovering base oil from lubrication oil that contains contaminants therein, the process comprises the steps of: (i) extracting a light diesel fraction from the lubrication oil; and (ii) distilling the lubricating oil under vacuum conditions after said extracting step (i) to obtain a base oil that is substantially free of said contaminants.

[0011] In one embodiment, the distilling step (ii) comprises molecular distillation. The molecular distillation may comprise multi-stage molecular distillation. In one embodiment, the multi-stage molecular distillation is performed from two to five stages. The temperature in each stage of the multi-stage molecular distillation may be increased sequentially. In addition, the pressure in each stage of the multi-stage molecular distillation may be decreased sequentially.

In one embodiment, the extracting step (i) comprises removing of non-light diesel from the light diesel fraction to obtain a substantially pure light diesel fuel. Ine another embodiment, the process as disclosed herein, further comprising the step of removing at least part of said

contaminants from the lubrication oil before said extracting step (i). The light diesel fraction may comprise liquid hydrocarbons with chain lengths of from about 5 to about 18, i.e. C_5 to C_{18}. The light diesel fraction may comprise petrol and light diesel fuel. In one embodiment, the light diesel fuel comprises hydrocarbons having carbon numbers of from about 13 to about 18, i.e. C_{13} to C_{18}. In another embodiment, the petrol fuel comprises hydrocarbons having carbon numbers of from about 5 to about 12, i.e. C_5 to C_{12}. **[ECSF Comments: Please check and let us know if the above carbon ranges are acceptable. If we do not hear back from you on these carbon ranges, we will assume that the same is acceptable and will proceed to file the application with the above definitions.]**

[0012] The removing step as disclosed above may comprise at least one of sedimentation, precipitation, centrifugation, dehydration, deodorization and chemical treatment. In one embodiment, at least 85% by weight of said base oil is recovered.

[0013] According to a second aspect, there is provided a system for recovering base oil from lubrication oil that contains contaminants therein, the system comprises: an extractor for extracting a light diesel fraction from the lubrication oil; and a distiller for distilling the lubricating oil, after said light diesel fraction has been extracted therefrom, under vacuum conditions to obtain a base oil that is substantially free of said contaminants.

[0014] In one embodiment, the distiller is in fluid communication with said extractor. The distiller may comprise a plurality of molecular distillation units. The distiller may also comprise two to five molecular distillation units. In one embodiement, the plurality of molecular distillation units is arranged in series.

[0015] In one embodiment, the system as disclosed herein, further comprises a dehydrator for removing water from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor. In addition, the system may further comprising a filter for removing solid contaminants from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor. The system may also further comprising a precipitator for precipitating contaminants from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor. The system may also further comprising a centrifugator for centrifuging solid contaminants from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor. In one embodiment, the system further comprises a deodorizer for removing odor from the lubrication oil that contains

contaminants therein, before said lubrication oil is being fed into the extractor. In one embodiment, the system further comprising means for generating vacuum conditions in said distillation unit. The system may also further comprise a condenser disposed within said distillation unit for condensing the base oil which is substantially free of said contaminants.

[0016] In one embodiment , there is provided a process for treatment of spent lubrication oil. The process may comprise the steps of pretreating the spent lubrication oil, rectifying the pre-treated spent lubrication oil to recover a light diesel fraction from the spent lubrication oil to reduce or eliminate interference in subsequent molecular distillation caused by the light diesel fraction, and performing multi-stage molecular distillations of the rectified spent lubrication oil to recover multi-grades of base oil, such that the recovered light diesel fraction and base oils obtained can be used for further applications, and the remaining of the spent lubrication oil can be discharged.

[0017] In another embodiment of the process, the step of pretreating includes operations of sedimentation and precipitation to remove large particles or contaminants, centrifuge to remove particles and free water, vacuum for dehydration and deodorization, and/or application of chemicals for enhancements.

[0018] In another embodiment of the process, in the step of rectifying the recovered light diesel fraction includes petrol, light diesel or some hydrocarbon substance.

[0019] In another embodiment of the process, in the step of performing multi-stage molecular distillation, the molecular distillation is preferably performed in two or three stages.

[0020] In another embodiment of the process, in the step of performing multi-stage molecular distillation, the distillation performance is determined by operation temperature, pressure and distance between a condenser surface and evaporator surface.

[0021] In another embodiment of the process, in the step of performing multi-stage molecular distillation the operation temperature is increased sequentially in a series of molecular distillation steps, and the operation pressure is decreased sequentially in the series of molecular distillation steps,.

[0022] Another embodiment of the present invention provides a system for regeneration of spent lubrication oil. The system comprises a pretreatment unit for pretreating the spent lubrication oil, a rectification unit fluidly coupled with the

pretreatment unit, for rectifying the pre-treated spent lubrication oil to recover a light diesel fraction from the spent lubrication oil to reduce or eliminate interference in subsequent molecular distillation caused by the light diesel fraction, and a multi-stage molecular distillation unit fluidly coupled with the rectification unit, for performing multi-stage molecular distillations of the rectified spent lubrication oil to recover multi-grades of base oil, such that the recovered light diesel fraction and base oils obtained can be used for further applications, and the remaining of the spent lubrication oil can be discharged.

[0023] In another embodiment of the system, the pretreatment unit is configured to perform operations of sedimentation and precipitation to remove large particles or contaminants, centrifuge to remove particles and free water, vacuum for dehydration and deodorization, and/or application of chemicals for enhancements.

[0024] In another embodiment of the system, the recovered light diesel fraction includes petrol, light diesel or some hydrocarbon substance.

[0025] In another embodiment of the system, the multi-stage molecular distillation unit is preferably configured to perform two or three stages of molecular distillation.

[0026] In another embodiment of the system, in the multi-stage molecular distillation unit the operation temperature is increased sequentially in a series of molecular distillation, and the operation pressure is decreased sequentially in the series of molecular distillation.

[0027] In another embodiment of the system, the multi-stage molecular distillation unit comprises a plurality of molecular distillation stage, where each of the plurality of molecular distillation stage comprises a molecular distillation column having a material inlet that is located at the top of the column and connected to a material feeding pump for receiving the spent lubrication oil to be treated, where the molecular distillation column has a heating means configured to substantially heat up the molecular distillation column evenly, a vacuum means coupled with the molecular distillation column to provide high vacuum within the molecular distillation column, and a condensing means disposed within the molecular distillation column for condensing the desired fraction of distillate.

[0028] One advantage of the present disclosure is the production of multi-grade base oils from a single process with a multi-stage molecular distillation design. This maximizes the value of recycled product and provides greater flexibility in lubrication product manufacturing.

[0029] The objectives and other advantages of the present disclosure will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings.

Definitions

[0030] The following words and terms used herein shall have the meaning indicated:

[0031] The term "contaminants" as used herein refers broadly to substances that are non-base oil constituents and in particular to constituents which are the product or by-products of the oil after it has been used in an engine. Typical contaminants include, but are not limited to, water, metallic fragments, dirt, dust, grit, sludge and heavy oil.

[0032] The term "light diesel fraction" as used herein refers broadly to liquid hydrocarbons having carbon chain lengths of from about 5 carbons to about 18 carbons.

[0033] The term "petrol" as it is commonly used also covers a product from the petroleum industry which contains as the main fraction hydrocarbons boiling in the gasoline range, further characterised by the octane numbers expressing the quality of the fuel when used in gasoline motors (internal combustion engines). Some additives may be added to the hydrocarbons to obtain certain further qualities for the gasoline product. It is well known that gasoline products with low octane numbers can be blended with gasoline products with high octane numbers for the purpose of yielding satisfactory overall octane numbers. As used herein the term petrol shall refer to the wide range of hydrocarbons boiling in the gasoline boiling range of 120° C. to 200° C. and holding proper gasoline qualities, either alone or in mixture with other sources of gasoline. The quality requirements are primarily met by hydrocarbons with a carbon number of 5 or more, for short C_5. Typically, petrol has carbon chain lengths of from about 5 carbons to about 12 carbons.

[0034] The term "light diesel fuel" as used herein refers broadly to liquid hydrocarbons having carbon chain lengths of from about 13 carbons to about 18 carbons, more preferably from about 13 carbons to about 15 carbons.

[ECSF Comments: Please check and let us know if the above definitions and carbon ranges are acceptable. If we do not hear back from you on these definitions and

carbon ranges, we will assume that the same is acceptable and will proceed to file the application with the above definitions.]

[0035] The term "heavy oil" as used herein refers broadly to liquid hydrocarbons having carbon chain lengths greater than about 18 carbons.

[0036] The word "substantially" does not exclude "completely" e.g. a composition which is "substantially free" from Y may be completely free from Y. Where necessary, the word "substantially" may be omitted from the definition of the invention.

[0037] Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

[0038] As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

[0039] Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Brief Description of the Drawings

[0040] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0041] FIG 1 is a functional block flowchart of the process for regeneration of spent lubrication oil in accordance with one embodiment of the present invention.

[0042] FIG 2 shows a schematic block diagram of the system for regeneration of spent lubrication oil in accordance with one embodiment of the present invention.

[0043] FIG 3 shows an exemplary cross-section view of the molecular distillation column in accordance with one embodiment of the present invention.

Detailed Description of the Invention

[0044] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0045] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties, into this application in order to more fully describe the state of art to which this invention pertains.

[0046] While the description will relate to many specific elements and techniques in order to better illustrate the principles of the present invention, it is to be appreciated that the present invention is not limited to the specific descriptions. The present invention can be practiced with variations to any specific elements and techniques without departing from the principles of the present invention. At the same time, many details and specifics that their omissions will not affect the practices of the present invention will be omitted from the description in order not to obscure the principles of the present invention.

[0047] One embodiment of the present disclosure provides a process for treatment of spent lubrication oil. Briefly, the process may comprise pre-treatment of the spent lubrication oil, rectification of the pre-treated spent lubrication oil, and multi-stage molecular distillation of the rectified spent lubrication oil. As explained in detail hereinafter, the integration of the rectification operation into the regeneration process provides a prerequisite for the optimal performance of the molecular distillation, resulting in high rate recovery and high quality of the regenerated base oils.

[0048] Now referring to FIG 1, there is provided a process for regeneration of spent lubrication oil in accordance with one embodiment of the present invention. The process **100** comprises waste oil pretreatments **1**, rectification **2**, 1st stage molecular distillation **3**, 2nd stage molecular distillation **4**, 3rd stage molecular distillation **5**, and disposal of final residue oil **6**. It is to be appreciated that the process for regeneration of

waste oil of the present invention is not limited to the three stages of molecular distillation; it can have two stages, or more stages depending upon the requirements of the qualities of the regenerated base oils.

[0049] The pretreatments **1** include any suitable means or operations that is needed to get the un-pretreated waste oil into a condition where the waste oil is ready for rectification and molecular distillation. The pretreatments **1** include sedimentation and precipitation to remove large particles or contaminants, centrifuge to remove particles and free water, vacuum system for dehydration and deodorization, and application of chemicals for enhancements.

[0050] The rectification **2** separates the light diesel fraction **21** from the waste oil, where the light diesel fraction includes petrol, light diesel or some hydrocarbon substance depending upon the composition of the waste oil. The inventors of the present invention discovered that un-rectified waste oil is not suitable for molecular distillation because the existence in the waste oil of the light diesel fraction that is very volatile and non-stable affects/destroys the high and stable vacuum required for optimal molecular distillation, resulting in poor quality of the regenerated base oils. Without being bound by any particular theory or explanation, it is believed that the light diesel fraction creates turbulence so as to affect/destroy the high and stable vacuum condition in the molecular distillation. Rectification column is used to remove mixed volatile hydrocarbon substances and is therefore capable of achieving the above-mentioned purpose.

[0051] The 1st stage molecular distillation **3** regenerates the first fraction base oil (base oil grade A **31**). Molecular distillation (short path distillation) is characterized by short exposure of the distilled liquid to elevated temperatures, high vacuum in the distillation space, and small distance between the condenser surface and evaporator surface; thus the operation temperature and pressure are the critical parameters for optimal molecular distillations. In addition, the distance from the evaporation surface and condensing surface is also one of the important design parameters. The short residence of the liquid on the evaporating cylinder, in the order of a few seconds to 1 min, is guaranteed by distributing the liquid in the form of a uniform thin film. By reducing the pressure of non-condensable gas in the evaporator to lower than 0-10 Pa, a reduction in distillation temperatures can be obtained. Molecular distillation shows promise in the separation, purification and concentration of natural products, usually composed of complex and

thermally sensitive molecules. The base oil grade A **31** is usually the lightest fraction of the regenerated base oils.

[0052] The 2nd stage molecular distillation **4** regenerates the second fraction of the base oils (base oil grade B **41**). Depending on the quality and composition of waste oil and the demand for different grades of base oil, the multi-stage molecular distillation employs two or more molecular distillation columns that are configured in series to generate different grades of base oil by operating each stage under different working conditions. Principally, in a multi-stage molecular distillation, a prior stage uses lower operation temperature than a subsequent stage; e.g., 1st stage molecular distillation operates at a temperature of 200°C, and 2nd stage molecular distillation at a temperature of 240°C. Therefore, the fraction of base oil from the prior column is lighter and ready to be used, and the residue waste oil is further treated in the subsequent column. In this manner, the base oil recovered can be fractioned into different grades.

[0053] The 3rd stage molecular distillation **5** regenerates the final fraction of the base oils (base oil grade C **51**) and final residue oil **6**. The final residue oil **6** after the multi-stage molecular distillation is then transferred into a residue tank for proper disposal. The base oil grade C **51** is the heaviest fraction of the regenerated base oils. The 3rd stage molecular distillation **5** operates at the highest temperature. During the process, the operation pressure is decreased sequentially, which also means that the operation vacuum requirements are higher sequentially.

[0054] The advantage of multi-stage molecular distillation process is that relative highly pure base oil can be produced as product. The impurities and contaminants that exist initially in the waste oil are concentrated and retained in the residue and discharged from the system at the end of the treatment. A range of different grades of base oils with different properties, e.g. viscosity, flash point, are produced from the system.

[0055] In the multi-stage molecular distillation, the number of molecular distillation stages is preferably from 2 to 5. More preferably, 2 or 3 stages of molecular distillations are used in spent lubrication oil treatment.

[0056] The operating conditions of each molecular distillation column, e.g. temperature, vacuum pressure, material residential time, are determined basing on the targeted distillation fraction requirement.

[0057] Another embodiment of the present disclosure provides a system for regeneration of spent lubrication oil. Briefly, the system comprises a pretreatment unit, a rectification unit, and a multi-stage molecular distillation unit. The pretreatment unit functions to remove large precipitates and odor from the waste oil so that the pretreated waste oil is suitable for rectification. The rectification unit is fluidly coupled with the pretreatment unit to receive the pretreated waste oil, and functions to separate a light diesel fraction from the waste oil so that the rectified waste oil is suitable for molecular distillation. The multi-stage molecular distillation unit is fluidly coupled with the rectification unit and has two or more molecular distillation columns that are so configured to operate in a sequential manner, where each molecular distillation column operates at a different temperature, pressure or material residential time; such that each molecular distillation column functions to separate a fraction of base oil with a characteristic specification. To save costs, each molecular distillation column may be the same for convenient manufacturing and installation. Each molecular distillation column may have its own configuration so that they can operate at different conditions for producing different base oils.

[0058] Now referring to FIG 2, there is provided a schematic block diagram of the system for spent lubrication oil regeneration in accordance with one embodiment of the system disclosed herein. It is to be noted that the pretreatment unit is not shown in the system **200** of FIG 2, and that the molecular distillation unit has three molecular distillation columns. All of these details are shown for purpose of illustrating the principles of the present disclosure.

[0059] The composition of the waste oil is still very complex even after of pretreatment processes like dehydration and deodorization. The light diesel fraction is removed with the rectification process to decrease the flash point of the waste oil, and at the same time improve the efficiency of vacuum system for the following molecular distillation process. The main component in the waste oil is base oil that can be extracted and fractionated into different grades using a series of molecular distillation columns. In the early stage of molecular distillation, lower distillation temperature is carried out. The base oil distillate is the lighter fraction of all base oils. It has lower viscosity and lower flash point. The intermediate stages of molecular distillation use higher distillation temperatures. The base oil distillates from intermediate stages are with intermediate

viscosities and flash points. The last stages of molecular distillation use highest operation temperatures and produce heavy fractions of base oil with high viscosities and high flash points.

[0060] The residue waste oil from the upper stage of molecular distillation column is used as feed material for the next stage of molecular distillation column. In the way of series connection, all grades of base oil are extracted according to the design parameters. The final residue is discharged for disposal.

[0061] The presently disclosed process or system operates under highly vacuum conditions (0.1Pa-80Pa) at the designated temperature. IDifferent grades of base oil based on the difference in molecular free length that is ultimate determined by the molecular weight can be produced. The presently disclosed process or system has the advantages of efficient liquid thin film forming, avoidance of liquid being stuck on distillation surface, short residential time of liquid in the reactor, low distillation temperature and high distillation efficiency. At the same time, the vacuum system further removes trace amount of very light substance that may have leaked through the rectification process. It also serves as an enhanced deodorization process. The presently disclosed process or system avoids problems like thermal cracking, polymerization, carbonization and equipment chocking that are commonly encountered in conventional distillation processes. The recovery rate of base oil is normally above 85%. Further, secondary pollutions, e.g. waste acid, wastewater, acidic residue are not generated.

[0062] Molecular distillation under low temperature and high vacuum is not only able to distillate more efficiently but also to better preserve the quality of the base oil products. It also has better energy efficiency. The system for regeneration of spent lubrication oil is controlled by an auto-control system, which will further enhance the smooth operation of the system.

[0063] Now referring to FIG 2, the exemplary molecular distillation column **DZ101** has a material inlet that is located at the top of the column and connected to the material feeding pump **P103** for receiving the waste oil to be treated. Trace amount of lighter than the targeted distillate fraction substance is extracted from an outlet located on the top of the molecular distillation column **DZ101** and is captured by a vapor trap. The heating medium is connected to the heating blanket of the molecular portion of the column. The vacuum system is connected to the vacuum valve located at the lower portion of the

molecular distillation column. The cooling water is connected through the inlet valve and outlet valves located at the bottom of the column. The targeted distillate fraction and the residue waste oil are connected to the effluent pumps through outlet valves.

[0064] Now referring to FIG 3, there is provided an exemplary cross-section view of the molecular distillation column in accordance with one embodiment of the present invention. The molecular distillation column comprises an outer heating means **301** for controlling the temperature within the molecular distillation column, a plurality (e.g., 4) of film forming devices **302** disposed onto the inner surface of the heating means **301** for spreading the waste oil so as to cause the waste oil to form a film **305** onto the inner surface of the heating means, a condensing core **303** in conjunction with an arc **304** to be configured to form a structure for condensing the evaporated waste oil fraction to produce different base oil grades. The materials for making each component of the molecular distillation column are apparent to one skilled in the art.

[0065] The pre-treated waste oil is drawn by the feeding pump to 1st stage molecular distillation column. The waste oil is spread out evenly by a spreader to form a uniform thin film on the evaporation surface in the molecular distillation column. The targeted fraction of base oil is distilled and condensed by the condensing core and flow through the fractionate outlet to the semi-product tank. Trace amounts of substances, lighter than the targeted distillate fraction is drawn with the vacuum system to the distillate vapor trap integrated with the vacuum system. The remaining liquid on the evaporation surface comprises the residue waste oil and flows through the residue outlet and is pumped to the next stage. The process is repeated for each molecular distillation column until the required stages of processing are achieved.

[0066] The following examples are provided for the sole purpose of illustrating the principles of the present disclosure; they are by no means intended to limit the scope of the present invention.

[0067] Example1

[0068] Example 1 of the regeneration of spent lubrication oil will be described in connection with the system **200** with three stages of molecular distillations as shown in FIG 2.

[0069] After pretreatments with dehydration and deodorization, the pre-treated waste oil in the storage tank **V101** was pumped by the pump **P102** to the rectification

column **RC101** to remove the light diesel fraction, where the light diesel vapor was condensed by the condenser **EX101** and transferred to the storage tank **V102** and further transferred for any suitable purpose by the pump **P101**.

[0070] The residue waste oil after rectification treatment was pumped by the pump **P103** to the 1st stage molecular distillation **DZ101**. The 1st stage molecular distillation was operated at the temperature of about 200°C and the vacuum pressure of about 80Pa, where the distillation range was from about 370 - 450°C, and the product recovery rate was about 27%. The flash point and viscosity specifications of the product are in compliance with the MVI 100 base oil specifications. In operation, the distillate from molecular **DZ101** was condensed by the condensing core of **DZ101** and was transferred to the storage tank **V103** from which the fraction was pumped out by the pump **P104** as base oil 1. The specifications of the base oil 1 and its comparison with MVI 100 base oil are summarized below in Table 1. Any trace amount of very light fraction was extracted by the vacuum system, and condensed and trapped by **EX102**. The residue waste oil was transferred into the storage tank **V104.**

[0071] The residue waste oil after the 1st stage molecular distillation was then transferred to the 2nd stage molecular distillation **DZ102** by the pump **P105**. The 2nd stage molecular distillation was operated at the temperature of about 240°C and the vacuum pressure of about 5 Pa, where the distillation range was from about 450 – 500 °C, and the product recovery rate was about 46%. The viscosity and flash point specifications of the product are in compliance with MVI 250 base oil specifications. In operation, the distillate from the 2nd stage molecular distillation **DZ102** was condensed by the condensing core of **DZ102** and as transferred into the storage tank **V105** from which the fraction was pumped out by the pump **P106** as base oil 2. The specifications of the base oil 2 and its comparison with MVI 250 base oil are summarized below in Table 2. Any trace amount of very light fraction was extracted by the vacuum system, and condensed and trapped by **EX103**. The residue waste oil was transferred into the storage tank **V106**.

[0072] The residue waste oil after the 2nd stage molecular distillation was then transferred to the 3rd stage molecular distillation **DZ103** by the pump **P107**. The 3rd stage molecular distillation was operated at the temperature of about 330°C and the vacuum pressure of about 3 Pa, where the distillation range was from about 500 – 540 °C, and the product recovery rate was about 19%. The viscosity and flash point specifications of the

product are in compliance with MVI 350 base oil specifications. In operation, the distillate from the 3rd stage molecular distillation **DZ103** was condensed by the condensing core of **DZ103** and as transferred into the storage tank **V107** from which the fraction was pumped out by the pump **P108** as base oil 3. The specifications of the base oil 3 and its comparison with MVI 350 base oil are summarized below in Table 3. Any trace amount of very light fraction was extracted by the vacuum system, and condensed and trapped by **EX104**. The residue waste oil was transferred into the storage tank **V108**.

[0073] The final residue from the 3rd stage of molecular distillation column **DZ103** was discharged by the pump **P109**. The quantity of final residue was about 7.8%.

[0074] Table 1. The comparison of the specifications of the base oil 1 from the 1st stage of molecular distillation column **DZ101** with that of MVI 100

[0075]

Item	Product from 1st stage	MVI 100	Testing Method
Appearance	Yellowish, transparent	Transparent	Visual
Smell	Insignificant	-	Smell
Viscosity (40°C)/($mm^2.s^{-1}$)/CST	20.7	18 - 21	ASTM D445
Viscosity (100°C)/($mm^2.s^{-1}$)/CST	4.17	-	ASTM D445
Viscosity Index	108	≥60	ASTM D2270
Flash point (°C)	195	≥165	ASTM D93
Pour point (°C)	-16	≤-9	ASTM D97
Moisture content (%)	Not detectable	-	ASTM D95
Acid number/(mg KOH/g)	0.01	≤0.05	ASTM D974
Carbon residue /%	-	-	ASTM D189

[0076] Table 1. The comparison of the specifications of the base oil 2 from the 2nd stage of molecular distillation column **DZ102** with that of MVI 250

[0077]

Item	Product from 2nd stage	MVI 250	Testing Method
Appearance	Yellowish, transparent	Transparent	Visual
Smell	Insignificant	-	Smell
Viscosity (40°C)/($mm^2.s^{-1}$)/CST	43.64	42 - 55	ASTM D445
Viscosity (100°C)/($mm^2.s^{-1}$)/CST	6.5	-	ASTM D445
Viscosity Index	98	≥60	ASTM D2270
Flash point (°C)	224	≥190	ASTM D93
Pour point (°C)	-14	≤-9	ASTM D97
Moisture content (%)	Not detectable	-	ASTM D95
Acid number/(mg KOH/g)	0.01	≤0.05	ASTM D974
Carbon residue /%	-	-	ASTM D189

[0078] Table 1. The comparison of the specifications of the base oil 3 from the 3rd stage of molecular distillation column **DZ103** with that of MVI 350

[0079]

Item	Product from 3rd stage	MVI 350	Testing Method
Appearance	Yellowish, transparent	Transparent	Visual
Smell	Insignificant	-	Smell
Viscosity (40°C)/($mm^2.s^{-1}$)/CST	70.66	65 - 75	ASTM D445
Viscosity (100°C)/($mm^2.s^{-1}$)/CST	8.42	-	ASTM D445
Viscosity Index	89	≥60	ASTM D2270
Flash point (°C)	246	≥200	ASTM D93
Pour point (°C)	-11	≤-5	ASTM D97
Moisture content (%)	Not detectable	-	ASTM D95
Acid number/(mg KOH/g)	0.02	≤0.05	ASTM D974
Carbon residue /%	0.01	≤0.02	ASTM D189

[0080] Example 2

[0081] The regeneration of spent lubrication oil of the present invention could be operated with a system employing only two stages of molecular distillations in a similar

configuration as shown in FIG 2. Thus, the description will be made in connection with FIG 2, where only the differences from Example 1 are highlighted below.

[0082] The 1st stage molecular distillation column **DZ101** was operated at the temperature of about 210°C, and the vacuum of about 80Pa, where the distillation range was from about 370 - 440°C, and the product recovery rate was about 51%. The flash point and viscosity specifications of the product are in compliance with MVI 200 base oil specifications.

[0083] The 2nd stage molecular distillation column **DZ102** was operated at temperature of about 320°C, and the vacuum of about 3 Pa, where the distillation range as from about 440 – 540 °C, and the product recovery rate was about 39%. The viscosity and flash point specifications of the product are in compliance with MVI 250 base oil specifications.

[0084] The residue from the 2nd stage of molecular distillation **DZ102** was discharged. The quantity of residue was about 8.2%.

[0085] The application of the molecular distillation to spent lubrication oil recycling has the advantages of high distillation efficiency, high quality fractionated base oil of multiple grades, low operating temperature, high vacuum and being environmental-friendly. The process also avoids the problems caused by cracking, polymerization, carbonization and choking that are commonly encountered in normal distillations and other existing spent lubrication oil recycling technologies. In addition, molecular distillation which is utilized in the disclosed process does not produce any secondary pollution such as acid residue, waste acid or waste water.

[0086] While the foregoing has presented descriptions of certain preferred embodiments of the present invention, it is to be understood that these descriptions are presented by way of example only and are not intended to limit the scope of the present invention. It is expected that others skilled in the art will perceive variations which, while differing from the foregoing, do not depart from the spirit and scope of the invention as herein described and claimed.

CLAIMS

What is claimed is:

1. A process of recovering base oil from lubrication oil that contains contaminants therein, the process comprises the steps of:
(i) extracting a light diesel fraction from the lubrication oil; and
(ii) distilling the lubricating oil under vacuum conditions after said extracting step (i) to obtain a base oil that is substantially free of said contaminants.

2. The process as claimed in claim 1, wherein the distilling step (ii) comprises molecular distillation.

3. The process as claimed in claim 2, wherein said molecular distillation comprises multi-stage molecular distillation.

4. The process as claimed in claim 3, wherein said multi-stage molecular distillation is performed from two to five stages.

5. The process as claimed in any one of claims 3 or 4, wherein the temperature in each stage is increased sequentially.

6. The process as claimed in any one of claims 3 to 5, wherein the pressure in each stage is decreased sequentially.

7. The process as claimed in any one of the preceding claims, wherein the extracting step (i) comprises removing of non-light diesel from the light diesel fraction to obtain a substantially pure light diesel fuel.

8. The process as claimed in any one of the preceding claims, further comprising the step of removing at least part of said contaminants from the lubrication oil before said extracting step (i).

9. The process as claimed in claim 8, wherein said removing step comprises at least one of sedimentation, precipitation, centrifugation, dehydration, deodorization and chemical treatment.

10. The process as claimed in any one of the preceding claims, wherein at least 85% by weight of said base oil is recovered.

11. The process as claimed in any one of the preceding claims, wherein said light diesel fraction comprises petrol.

12. A system for recovering base oil from lubrication oil that contains contaminants therein, the system comprises:

an extractor for extracting a light diesel fraction from the lubrication oil; and

a distiller for distilling the lubricating oil, after said light diesel fraction has been extracted therefrom, under vacuum conditions to obtain a base oil that is substantially free of said contaminants.

13. The system as claimed in claim 12, wherein the distiller is in fluid communication with said extractor.

14. The system as claimed in claim 12, wherein the distiller comprises a plurality of molecular distillation units.

15. The system as claimed in claim 14, wherein said distiller comprises two to five molecular distillation units.

16. The system as claimed in any one of claims 12 to 15, further comprising a dehydrator for removing water from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor.

17. The system as claimed in any one of claims 12 to 16, further comprising a filter for removing solid contaminants from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor.

18. The system as claimed in any one of claims 12 to 17, further comprising a precipitator for precipitating contaminants from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor.

19. The system as claimed in any one of claims 12 to 18, further comprising a centrifugator for centrifuging solid contaminants from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor.

20. The system as claimed in any one of claims 12 to 19, further comprising a deodorizer for removing odor from the lubrication oil that contains contaminants therein, before said lubrication oil is being fed into the extractor.

21. The system as claimed in any one of claims 12 to 20, further comprising means for generating vacuum conditions in said distillation unit.

22. The system as claimed in any one of claims 12 to 21, further comprising a condenser disposed within said distillation unit for condensing the base oil which is substantially free of said contaminants.