

MANUFACTURE OF HYDROCRACKED LOW POUR POINT LUBRICATING OILS

This invention relates to a process for the manufacture of lubricating oils, in particular, an energy-efficient process for manufacturing hydrocracked lube oils of good stability and low pour point.

Refining suitable petroleum crude oils to obtain a variety of lubricating oils which function effectively in diverse environments has become a highly developed and complex art. Although the broad principles involved in refining are qualitatively understood, the art is encumbered by quantitative uncertainties which require considerable resort to empiricism in practical refining. Underlying these quantitative uncertainties is the complexity of the molecular constitution of lubricating oils. Because lubricating oils for the most part are based on petroleum fractions boiling above about 232°C (450°F), the molecular weight of the hydrocarbon constituents is high and these constituents display almost all conceivable structures and structure types. This complexity and its consequences are referred to in "Petroleum Refinery Engineering", by W. L. Nelson, McGraw Hill Book Company, Inc., New York, N.Y., 1958 (Fourth Edition).

In general, the basic concept in lubricant refining is that a suitable crude oil, as shown by experience or by assay, contains a quantity of lubricant stock having a predetermined set of properties such as, for example, appropriate viscosity, oxidation stability, and maintenance of fluidity at low temperatures. The process of refining to isolate that lubricant stock consists of a set of unit operations to remove the unwanted components. The most important of these unit operations include distillation, solvent refining, and dewaxing, which basically are physical separation processes in the sense that if all the separated fractions were recombined, one would reconstitute the crude oil.

Unfortunately, crude oils suitable for the manufacture of lubes are becoming less available due to exhaustion of reserves and the reliability of a steady, adequate supply from a known source is a matter of concern due to political instability.

The desirability of upgrading a crude fraction normally considered unsuitable for lubricant manufacture to one from which good yields of lubes can be obtained has long been recognized. The so-called

"hydrocracking process", sometimes referred to in the art as "severe hydrotreating", has been proposed to accomplish such upgrading. In this process, a suitable fraction of a poor grade crude such as a California crude is catalytically reacted with hydrogen under pressure. The process is complex in that some of the oil is reduced in molecular weight and made unsuitable for lubes but concurrently a substantial fraction of the polynuclear aromatics is hydrogenated and cracked to form naphthenes and paraffins. Process conditions and choice of catalyst are selected to provide an optimal conversion of the polynuclear aromatic content of the stock since this component degrades the viscosity index and stability of the stock. Also, in the hydrocracking process, paraffins can be isomerized, imparting good viscosity index (V.I.) characteristics to the final lube product. For purposes of this invention, the term "hydrocracking" will be employed for the foregoing process step and to distinguish this step from the "hydrotreating" step to be described below, the purpose of the latter being to stabilize the lube base stock produced by hydrocracking. For purposes of this invention, the hydrocracking and hydrotreating steps may be distinguished also by the amount of hydrogen consumed, the hydrocracking step typically consuming about 178-356 NI/l (1000-2000 SCF/bbl)(standard cubic feet per barrel of feed) while the hydrotreating step consumes only about 18-36 NI/l (100-200 SCF/bbl).

The hydrocracking process for increasing the availability of lube oils has an attractive feature that is not immediately apparent. Generally, the composition and properties of hydrocracked stocks are not particularly affected by the source and nature of the crude, i.e. they tend to be much more alike than lube fractions prepared from different crudes by conventional means. Thus, the process promises to free the refiner from dependence on a particular crude with all of the advantages that this freedom implies.

Hydrocracked lube stocks, however, tend to be unstable in the presence of air when exposed to sunlight. On such exposure, a sludge is formed, sometimes very rapidly and in fairly substantial amount. This tendency in a lubricating oil is unacceptable. Additionally, some hydrocracked lube oils tend to darken or to form a haze.

Several methods have been proposed to correct the above-described instability. U.S. Patent No. 4,031,016 to Berger et al. proposes to add certain antioxidants to the hydrocracked oil. A second proposed approach is to hydrotreat the hydrocracked material. Variants of this approach are described in U.S. Patent No. 3,666,657 which utilizes a sulfided mixture of an iron group metal and a Group VI metal for the hydrotreating stage; U.S. Patent No. 3,530,061 which utilizes a hydrotreating catalyst having one or more elements from Group IIB, VIB and VIII at hydrogen pressure up to about 791 kPa (100 psig); and U.S. Patent No. 4,162,962 which teaches to hydrotreat the hydrocracked material at a temperature in the 200° to 300°C range with a catalyst of prescribed pore size. U.S. Patent No. 3,530,061 to Orkin et al. utilizes a non-cracking support for the hydrotreating stage. U.S. Patent No. 3,852,207 to Strangeland et al. teaches to hydrotreat with a noble metal hydrogenation component supported on an oxide. The patents cited above are believed representative of the state of the art.

Hydrocracked lubricating oils generally have an unacceptably high pour point and require dewaxing. Solvent dewaxing is a well-known and effective process but expensive. More recently, catalytic methods for dewaxing have been proposed. U.S. Reissue Patent No. 28,398 to Chen et al. describes a catalytic dewaxing process wherein a particular crystalline zeolite is used. To obtain lubricants and specialty oils with outstanding resistance to oxidation, it is often necessary to hydrotreat the oil after catalytic dewaxing, as illustrated by U.S. Patent No. 4,137,148 to Gillespie et al. The foregoing patents are indicative of the state of the dewaxing art.

It is inferentially evident from the foregoing background material that the manufacture of modern high quality lubricants in general requires that the crude be treated in a sequence of fairly complex and costly steps. It is further evident that there is a need for processes which can efficiently provide such lubricants from interchangeable and readily available low grade crudes.

This invention provides an energy-efficient process for manufacturing a stabilized and dewaxed hydrocracked lubricating oil stock from a hydrocarbon feedstock boiling above about 343°C (650°F), such as vacuum gas oils and resids substantially free of asphaltenes. The

process comprises passing the feed sequentially through a hydrocracking zone, a catalytic dewaxing zone provided with a dewaxing catalyst exemplified by ZSM-5 and a hydrotreating zone at high pressure conditions in each of these zones such that hydrogen recycle is effected with minimal recompression.

The effluent hydrogen from the hydrocracking zone is separated from the hydrocracked material and is treated to remove at least a substantial portion, i.e. at least 50%, of the H_2S and of the ammonia produced in the hydrocracking zone, as more fully described below, and the purified hydrogen is recycled to the hydrocracker. Simultaneously, fresh hydrogen substantially free of hydrogen sulfide and ammonia is introduced into the catalytic dewaxer and passed on a once-through basis together with the separated hydrocracked material through the catalytic dewaxer and then through the hydrotreater section, after which excess hydrogen is separated and combined with the recycle hydrogen for passage to the hydrocracker. The amount of fresh hydrogen introduced into the catalytic dewaxer section is about equal to, or less than, the amount consumed in the process of this invention, as more fully described hereinbelow.

The process provided by this invention with the catalytic dewaxing step following the hydrocracking step and preceding the stabilizing step requires only one stabilizing step to produce stable, dewaxed hydrocracked lubricant base stock. And, since only makeup hydrogen, which is already clean, is introduced to the catalytic dewaxing section as herein described, catalytic dewaxing efficiency is sustained without the necessity of a very high degree of purity of recycle hydrogen passed to the hydrocracker. In fact, if a sulfided catalyst is employed in the hydrocracking zone, its effectiveness is maintained better when some hydrogen sulfide is present in the recycle hydrogen, as is known to those skilled in the art.

In a preferred embodiment of this invention the hydrogen recirculation to the hydrocracker is maintained with a pressure difference not greater than about 5272 kPa (750 psig) between the inlet and outlet of a single compressor, which may be a multi-stage compressor.

The process of this invention will now be illustrated by reference to Figure 1 of the drawing.

The feed, which may be any hydrocarbon feedstock boiling above about 343°C (650°F), such as a heavy neutral oil or a deasphalted residuum, is introduced via line 1 together with hydrogen via line 2 to hydrocracker section 3. Hydrocracker section 3 includes a catalytic hydrocracking zone at conditions effective to convert in a single pass at least 20% of the feed to materials boiling below the initial boiling point of the feed.

A wide variety of hydrocracking catalysts is contemplated as suitable for use in the process of this invention. Such catalysts in general possess an acid function and a hydrogenation function, exemplified by a porous acidic oxide such as a silica alumina or silica zirconia associated with a nickel-tungsten or palladium or platinum, or cobalt-molybdenum or nickel-molybdenum component. In general, a Group VIII metal or a combination of a Group VI and a Group VIII metal, as the oxides or sulfides thereof, deposited on silica alumina or silica zirconia, may serve as hydrocracking catalyst. The hydrocracking itself may be conducted in two or more stages, with pretreatment of the raw feed as part of the first stage.

The effluent from the hydrocracker 3 including excess hydrogen will be contaminated with free hydrogen sulfide and in some cases with ammonia since the hydrocracking step, in addition to saturating aromatic compounds, also is accompanied by desulfurization and denitrogenation. This effluent is passed via line 4 to a high pressure gas-liquid separator (G/L Sep) 5 wherein the hydrocracked material is separated from contaminated hydrogen. The contaminated hydrogen is passed from separator 5 via line 6 to a high pressure sorption section 7 wherein a substantial fraction of the hydrogen sulfide and of the ammonia are removed via line 8.

The hydrogen from sorption unit 7 is passed via line 9 to a high pressure separator section 10 wherein it is separated from light hydrocarbons which are removed via line 11.

The hydrocracked material separated in separator section 5 is passed via line 12 to catalytic dewaxing section 13 along with makeup hydrogen introduced via line 14. It is important to note for purposes of this invention that the only hydrogen supplied to the catalytic dewaxer section 13 is fresh hydrogen having a hydrogen sulfide partial pressure

of less than about 34.5 kPa (5 psia) and less than 100 ppm of ammonia. The amount of hydrogen supplied via line 14 may be up to about the amount consumed in the process. Thus, all of the makeup hydrogen may be supplied via line 14. Alternatively, if it is desired to supply to the catalytic dewaxer 13 less than the makeup requirement of the system, the remainder may be supplied to the hydrocracker via line 15, or at any other point in the system.

Various zeolitic dewaxing catalyst, with or without hydrogenation component, may be used in dewaxing section 13. For example, the mordenite catalyst in the hydrogen form and containing a Group VI or Group VIII metal, as described in U.S. Patent No. 4,100,056 to Reynolds, is suitable. Also useful, and in fact preferred, is ZSM-5 associated with a hydrogenation component as more fully described in U.S. Reissue Patent No. 28,398. Another preferred zeolite is ZSM-11 associated with a hydrogenation component such as nickel or palladium. ZSM-11 is more fully described in U.S. Patent No. 3,709,979. The preferred dewaxing catalyst comprises ZSM-5 or ZSM-11.

The effluent from the catalytic dewaxer, including excess hydrogen, is passed via line 16 to hydrotreater unit 17. Catalytic hydrotreater 17 contains a hydrotreating catalyst in a hydrotreating zone at stabilizing conditions. The effluent from the hydrotreater unit is passed via line 18 to a high pressure separation section 10 wherein it is treated to separate light hydrocarbons, which are removed together with a hydrogen bleed via line 11. Also separated is the hydrocarbon mixture comprising a stabilized and dewaxed hydrocracked lubricating oil stock, which is recovered via line 19. The hydrocarbon mixture containing the lubricating oil stock is passed via line 19 to another unit for recovery of the lubricating oil stock, which other unit is not part of this invention. The makeup and recycle hydrogen separated in section 10 is passed via line 20 to compressor 21 to raise its pressure and then passed via line 22 and line 2 to the hydrocracker 3.

In the preferred mode of operation, the pressure in line 20, which is downstream from pump 21, and the pressure in line 22, which is upstream of pump 21, do not differ by more than about 5272 kPa (750 psig).

The embodiment shown in Figure 1 of the process of this invention illustrates this invention, which provides for processing a hydrocarbon oil by the sequence of steps comprising hydrocracking,

catalytic dewaxing and stabilization, in that order, with only fresh hydrogen provided to the catalytic dewaxer. It is known that hydrocracking by itself results in an unstable oil, and catalytic dewaxing in some instances also contributes to instability. By disposing the catalytic dewaxing step between the hydrocracking and stabilization step in the manner described in this invention, a very efficient process results with the production of a stabilized and dewaxed hydrocracked lubricating oil stock.

It will be recognized by those skilled in the art that various separation steps conducted at high pressure may be advantageously incorporated in the process flow diagram of Figure 1. For example, a high pressure separation unit may be located in line 12 or line 16, for example, to remove a low molecular weight fraction of hydrocarbon not suitable for inclusion in the final lubricant base stock, thereby reducing the hydrocarbon load to subsequent sections.

The reaction conditions for the catalytic process steps herein described are summarized in Table I. The broad ranges specified in Table I are not essential for the performance of the invention but are suggested as suitable conditions within which the refiner may wish to operate, depending upon the nature of the feed and of the specific catalysts chosen for the individual steps of the operation. Under most circumstances, operation within the preferred ranges will result in conserving energy.

TABLE I

	<u>Hydrocracking</u>	<u>Dewaxing</u>	<u>Hydrotreating</u>
Pressure, broad, kPa	6996-20786	same	same
Pressure, broad, psig	1000-3000	same	same
Pressure, preferred, kPa	10443-17338	same	same
Pressure, preferred, psig	1500-2500	same	same
Temperature, broad, °F	500-900	450-900	350-700
Temperature, broad, °C	260-482	232-482	176-371
Temperature, preferred, °F	650-800	525-800	400-600
Temperature, preferred, °C	343-427	274-426	204-316
LHSV, * broad	0.1-5.0	0.2-20	0.1-10
LHSV, preferred	0.5-2.0	0.5-5	0.2-3.0
H ₂ gas, NL/l, broad	178-3560	89-3560	89-3560
H ₂ gas, SCF/bbl, broad	1000-20,000	500-20,000	500-20,000
H ₂ gas, NL/l, preferred	356-1780	89-534	89-534
H ₂ gas, SCF/bbl, preferred	2000-10,000	500-3000	500-3000

* LHSV = liquid hourly space velocity, i.e. volumes of feed per volume of catalyst per hour.

CLAIMS

1. Process for producing a dewaxed lubricating oil base stock from a hydrocarbon feedstock boiling above 343°C (650°F), which comprises hydrocracking the feedstock in a hydrocracker section at hydrocracking conditions effective to convert at least 20 volume percent of the feedstock to materials boiling below the initial boiling point of the feedstock and including a pressure of from 6996 to 20786 kPa (1000 to 3000 psig), passing the hydrocracker effluent to a high pressure gas-liquid separator whereby the hydrocracked material is separated from contaminated hydrogen gas containing hydrogen sulfide and ammonia formed during the hydrocracking step, passing the hydrocracked material and fresh makeup hydrogen to a catalytic dewaxing section wherein the hydrocracked material is catalytically dewaxed in a high pressure dewaxing zone, passing the effluent from the catalytic dewaxing section comprising dewaxed hydrocracked material and hydrogen gas to a high pressure hydrotreating zone operated at conditions effective to stabilize the lube base stock in the hydrocracked material, passing the hydrotreater effluent to a high pressure separator section, recovering makeup hydrogen gas and hydrocarbons comprising the dewaxed, stable lubricating oil base stock, passing the contaminated hydrogen gas to a high pressure sorption section wherein a substantial fraction of the hydrogen sulfide and ammonia are removed, thereby forming recycle hydrogen and passing the recycle hydrogen and the makeup hydrogen recovered from the high pressure separator section to the hydrocracker section.

2. The process of Claim 1 wherein the dewaxing catalyst comprises ZSM-5 or ZSM-11.

3. The process of Claim 1 or 2 wherein the catalytic dewaxing is conducted at a pressure of from 6996 to 20786 kPa (1000 to 3000 psig), a temperature of from 274°C (525°F) to 426°C (800°F), and a L.H.S.V. of from 0.2 to 20.



4. The process of any one of Claims 1 to 3 wherein the pressure of the recycle hydrogen is increased by not more than 5272 kPa (750 psig) prior to passage to the hydrocracker section.

5. The process of any one of Claims 1 to 4 wherein the dewaxing catalyst comprises mordenite associated with a hydrogenation component.

6. The process of any one of Claims 1 to 5 wherein the amount of the fresh makeup hydrogen passed to the catalytic dewaxing section is about equal to the amount of hydrogen consumed in the complete process.

The text of the specification has been reproduced by photocopying the applicants original typescript. It may contain a few amendments which are difficult to read. The original typescript containing these amendments may be inspected on the premises of the Patent Office

