

A method for hydroprocessing feedstocks containing vacuum gas oil

The present invention is directed to a method of hydroprocessing feedstocks containing reduced pressure oil (vacuum gas oil) using a hydroprocessing catalyst, more in particular to a hydroprocessing method aimed at combining mild hydrocracking with hydrodesulphurisation.

Units for hydroprocessing feedstocks containing vacuum gas oils have been used for various hydrotreating operations such as hydrodesulphurisation, hydrodenitrogenation, and hydrogenation. These hydrotreating operations are generally controlled by raising the temperature during the reaction so as to keep the sulphur content of the product oil at a predetermined value.

On the other hand, hydroprocessing units are increasingly used for effecting mild hydrocracking (MHC) to increase conversion into kerosene and light oils having a high added value. This is generally effected by increasing the temperature at the start or at the end of the operation until a conversion into light oils of about 15-50% is obtained. More in particular, after presulphiding the hydroprocessing catalyst, an MHC operation may be carried out by raising the temperature in a stepwise or continuous fashion to a predetermined temperature in a comparatively short period of time, concretely 1 week to 1 month or so, and keeping the operation at that temperature until the end of the run. An MHC operation may also be carried out by gradually raising the temperature to compensate the degradation of the desulphurisation activity of the catalyst. The temperature at the end of the run is in many cases the highest possible temperature the hydroprocessing unit can handle.

In mild hydrocracking, the yield of the kerosene/light oil fraction increases with increasing operating temperature, and hence, high temperature hydroprocessing is economically advantageous. However, at higher temperatures, larger volumes of coke (carbon produced by overheating

petroleum fractions) are deposited on the hydroprocessing catalyst, and as a result thereof the activity of the catalyst, especially the desulphurisation activity, rapidly declines. In particular, when the temperature is raised in the initial stage of an MHC operation, the increase in catalyst activity will lead to the deposition of a large volume of coke.

Therefore, if the temperature regimen of a mild hydrocracking operation is not selected properly, the catalyst activity will deteriorate too much in the initial stage of the run, and the sulphur standard (sulphur content of the product oil in accordance with the JIS Standard) cannot be satisfied. To cope with this problem, the feed rate has to be decreased. However, this leads to a decrease in the amount of product produced, and thus is economically disadvantageous.

In short, it had been very difficult heretofore to keep the desulphurisation activity in balance with the desire to increase the production of kerosene/light oil fraction by way of increasing the temperature.

The task of the present invention is to provide a method for hydroprocessing feeds containing vacuum gas oil which enables the yield of the kerosene/light oil fraction to be increased while preventing the rapid degradation of the desulphurisation activity of a hydroprocessing catalyst, especially in the initial stage of the run of the hydroprocessing operation. The present inventors found that the rapid degradation of desulphurisation activity may be prevented while maintaining hydrocracking conversion by adjusting the temperature in the initial stage of the operation in accordance with a specific regimen.

The present invention is therefore directed to a method for effecting hydroprocessing of a vacuum gas oil containing hydrocarbon feed in which the feed is contacted with a hydroprocessing catalyst under hydroprocessing conditions, wherein during the heating up period, which is a period starting with achieving a product sulphur content below 0.5 wt.% up to 1/3 of the total

operating period, the heating up is performed in a stepwise fashion with a step width of 2-7°C and a heating rate of 5-15°C per 30 day period.

The invention prevents deterioration in the hydrodesulphurisation activity of a hydroprocessing catalyst in mild hydrocracking operation, and therewith makes it possible to obtain a hydroprocessing operation which effects simultaneous hydrodesulphurisation and mild hydrocracking with a good hydrodesulphurisation activity, an increased yield in light oils, and often an extension of the operation cycle length.

In a preferred embodiment of the process according to the invention the total temperature rise during the heating up period is 40°C or less. In another preferred embodiment of the process according to the invention, the sulphur content of the product oil produced in the heating up period is 0.04 wt.% or more. In another preferred embodiment of the process according to the invention, the desulphurisation rate in the heating up period is 98.5% or less.

The feedstock to be used in the process according to the invention is a feedstock containing vacuum gas oil. If so desired, it may contain less than 50%, preferably less than 30% of other hydrocarbon fractions, including light gas oils (LGO), heavy gas oils, cracked (decomposed) oils from cokers and fluid catalytic crackers, residual oils thereof, and deasphalted oils. The feedstock preferably has a sulphur content of 0.9-3.0 wt.%, a nitrogen content of 400-1600 wppm, a metals content, calculated as the total of nickel and vanadium, of 0-2 wppm, a density at 15°C of 0.88-0.94 g/ml, a viscosity at 50°C of 10-40 cSt, an initial boiling point (IBP) of 240-290°C, determined in accordance with ASTM D1160, and a final boiling point (FBP) of 470-590°C, determined in accordance with ASTM D1160.

The catalyst to be used in the hydroprocessing method of this invention is a conventional hydroprocessing catalyst, and commercially available hydrodesulphurisation catalysts, hydrodenitrification catalysts, hydrocracking catalysts,

mild hydrocracking catalysts may be used. Suitable commercial catalysts are, e.g., available from Nippon Ketjen Co. Ltd., and include KF 1022, KF 843, KF 846, KF 901H, KF 902, KC 2301, KC, 2601, etc.

Suitable catalysts generally comprise hydrogenation metal components on a carrier. The hydrogenation metal components generally comprise a Group VI metal component, typically molybdenum or tungsten, and a Group VIII metal component, typically nickel and/or cobalt. The carrier may comprise alumina, silica, silica-alumina, boria, magnesia, zinc oxide, zirconia, titania, zeolites, clay minerals, and mixtures thereof. Optionally, the catalyst may comprise additional components like phosphoric acid or halogens. The use of catalysts comprising molybdenum and nickel and/or cobalt on an amorphous acidic carrier, e.g., a carrier comprising silica-alumina, silica-alumina-boria, silica-alumina-titania, or fluorine-doped alumina may be preferred.

Before use in the process according to the invention, the catalyst is subjected to a sulphidation step, which can be done in a conventional manner. Sulphidation can be carried out in the gaseous or the liquid phase, generally by contacting the catalyst with a sulphur-containing compound such as elementary sulphur, hydrogen sulphide, dimethyldisulphide (DMDS), or polysulphides. The sulphidation can generally be carried out *in situ*, that is, in the hydroprocessing unit and/or *ex situ*, that is, in a separate reactor prior to the sulphided catalyst composition being loaded into the hydroprocessing unit. It may be preferred in the present invention to effect *in situ* presulphiding in the liquid phase. This can be done using feedstocks like LGO or VGO, or LGO or VGO to which a sulphur containing compounds like DMDS or tertiary nonylpolysulphide (TNPS) has been added. Such *in situ* presulphiding is generally carried out at a temperature of 150-350°C. If an *ex situ* presulphided catalyst is used, it will generally be necessary to activate the catalyst with hydrogen before use.

After completion of the presulphiding or activation, the feedstock to be used in the process according to the invention is brought into the reactor, and the reaction conditions are adapted to obtain a sulphur content of the product oil of

0.5wt.% or less, preferably 0.3wt.% or less. This is generally done by raising the reactor temperature during a period of about 1-10 days up to a value of 340-380°C.

When the sulphur content of the product reaches a value of less than 0.5 wt.%, preferably less than 0.3 wt.%, the heating up period of the process according to the invention starts. As indicated above, in the process according to the invention, during the heating up period the reaction temperature is raised in a stepwise fashion. More specifically, the temperature is raised with 2-7°C in a period of 2 minutes to 10 days to effect a heating step. Then, the temperature is maintained at that value for a period of 2-15 days, followed by the next temperature raising step.

This step-wise method is in contrast with the method in which the temperature is continuously and gradually raised without being maintained at a certain value. If such a method is adopted, an uncontrollable reaction threatens to occur because the catalyst is overheated, and further, the operational fluctuation of the hydroprocessing unit becomes large, and it becomes difficult to regulate the properties of the products produced. Therefore, such a temperature raising method is unsuitable for commercial hydroprocessing operation.

A run of a hydroprocessing unit usually starts with loading the reactor with a catalyst, generally followed by presulphiding and/or activation, depending on whether or not the catalyst was already presulphided *ex situ*. Next, the feedstock flow is started, to perform the hydroprocessing reaction (actual operation) for about 6-48 months. When due to deterioration of the catalyst activity it has become impossible to produce product conforming to a predetermined standard or after a predetermined operation period, the operation is stopped and the deactivated catalyst is removed. In the present specification, the term "total operating period" refers to the period starting with the start of feeding the feedstock to the catalyst layer in the reactor and ends with the start of the temperature drop for stopping the unit. When conventional hydroprocessing conditions and a conventional catalyst are used, the total

operating period is generally between 180 and 1440 days. It is preferred for the heating up period, which is a period starting with achieving a sulphur content below 0.5 wt.% up to 1/3 of the total operating period, to be 30 days or more, especially 60 days or more. The exact length of the heating up period will depend on the needs of the refinery. If a long-term operation is desired, the heating up period is long. If more hydrocracking activity is desired, the heating up period is selected shorter. The reason why the heating up period ends at a maximum of 1/3 of the total operating period is economical.

The stepwise temperature rise is done in steps with a step width of 2-7°C, preferably 2-5°C. If the step width is lower than 2°C, the period during which the reaction temperature is low increases, which results in a decrease in the yield of kerosene and light oil. If the step width is above 7°C, the desulphurisation activity of the catalyst rapidly deteriorates, and it becomes difficult to produce products with a predetermined sulphur content.

The heating rate during the heating up period should be 5-15°C per 30 day period. If the heating rate is below 5°C per 30 day period, the cracking rate is low, thus lowering the yield of kerosene/light oil. If it is higher than 15°C per 30 day period, the desulphurisation activity of the catalyst deteriorates rapidly, and it becomes difficult to produce products with a determined sulphur content. The heating rate per 30 day period refers to the total temperature increase during each period consisting of 30 days. For example, in the event that a temperature rise of 5°C is done twice between day 31 and day 60, the heating rate is $2 \times 5^\circ\text{C} = 10^\circ\text{C}$ per 30 day period for that period. In the present specification, the wording "5-15°C per 30 day period" means that within each 30 day period within the heating up period the temperature should be increased with 5-15°C. This will be elucidated below:

An embodiment wherein during a heating up period of 90 days the heating rate is 10°C between day 1 and day 30, 10°C between day 31 and day 60, and 10°C between day 61 and day 90 is inside the scope of the present invention, since in each 30 day period the heating rate 5-15°C.

An embodiment wherein during a heating up period of 90 days the heating rate is 2°C between day 1 and day 30, 18°C between day 31 and day 60, and 10°C between day 61 and day 90 is outside the scope of the present invention, since in the first and second 30 day period the heating rate is outside the 5-15°C per 30 day period range, even though the total temperature increase during the heating up period is the same as in the embodiment discussed above.

In view of equipment run control, it is preferred for the total temperature rise during the heating up period to be kept at 40°C or less, especially 35°C or less.

To prevent deactivation by coke formation due to an uncontrolled reaction of the catalyst in heating up period, it is preferred to select the temperature regimen such that the sulphur content of the oil produced during the heating up period does not become lower than 0.04wt.%, preferably 0.05wt.%, or that the desulphurisation rate does not exceed 98.5%, preferably 98.1%. If this state is kept during the heating up period, sudden coke formation can be prevented. In consequence, the deterioration of both the desulphurisation activity and the cracking activity can be prevented, and the life of the catalyst can be extended to allow the running period of the hydroprocessing unit to be extended. The product sulphur content during the heating up period and the rest of the hydroprocessing operation will be kept below the value at which the heating up period started, that is, below 0.5 wt.%, preferably below 0.3 wt.%.

The hydroprocessing conditions in this invention are not especially limited, and conventional hydroprocessing conditions can be adopted. For example, the hydrogen partial pressure is 2 to 20MPa, more preferably 4 to 11 MPa; the liquid hourly space velocity is 0.1 to 10 h⁻¹, more preferably 0.4 to 2 h⁻¹; the hydrogen/feedstock ratio is 50 to 1500 Nm³/kl, more preferably 200 to 1000 Nm³/kl (kiloliter at 15°C); and the reaction temperature is 300 to 450°C, more preferably 340 to 430°C.

Example 1

A small isothermal flow type tester was packed with 100ml of a commercially available catalyst comprising CoO and MoO₃ on an alumina-boria-silica carrier (MoO₃ 15wt.%, CoO 3wt.%), and presulphided with a light gas oil (LGO) containing 2.5wt.% of dimethyldisulphide (DMDS).

Then, the catalyst was contacted at 320°C with a feedstock having the properties given in Table 1, and the temperature was raised to 370°C in 3 days, to obtain a product oil with a sulphur content of 0.2wt.% or less. This step is further indicated as the pre-treatment step. The other conditions applied during the pre-treatment step and the hydroprocessing step are given in Table 2.

Table 1: Feedstock properties

Sulphur content (wt.%)	2.68
Nitrogen content (wtppm)	990
Carbon content (wt.%)	84.9
Hydrogen content (wt.%)	12.0
Density at 15°C (g/ml)	0.9181
Kinematic viscosity at 50°C (cSt)	26
Residual carbon (wt.%)	0.35
C6+ 160°C fraction (wt.%)*	0.4
160°C - 360°C fraction (wt.%)*	17.6
360°C + fraction (wt.%)*	82.0

*By gas chromatography according to ASTM D 2887.

Table 2: Hydroprocessing conditions

Hydrogen partial pressure (MPa)	5
Hydrogen/feedstock ratio (Nm ³ /kl)	500
Liquid hourly space velocity (h ⁻¹)	1.7

Starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 5°C per step and a heating rate of 10°C per 30 day period (2 steps per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 410°C to 420°C. After 360

days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-1.

The sulphur content of the product oils and the cracking rate of the fraction boiling above 360°C (360°C+ fraction) were determined at day 120 and day 360. The results are given in table 4. The cumulative yield ratio of light oil (fraction boiling below 360°C) to feedstock from day 1 to day 360 was 31.6 vol%. This value was standardised to 100 in Table 4. The sulphur content was determined using a fluorescent X ray sulphur analyzer ("SLFA 900" (trade name) produced by Horiba). The cracking rate of the 360°C+ fraction was obtained by gas chromatography according to ASTM D 2887.

Example 2

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 5°C per step and a heating rate of 5°C per 30 day period (1 step per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 390°C to 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-1.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Example 3

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 2.5°C per step and a heating rate of 10°C per 30 day period (4 steps per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 410°C to 420°C.

After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-1.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Example 4

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 7°C per step and a heating rate of 7°C per 30 day period (1 step per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 398°C to 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-1.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Example 5

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 5°C per step and a heating rate of 15°C per 30 day period (3 steps per 30 day period) until day 60. Starting at day 61, the temperature was raised in a stepwise manner with a step width of 5°C per step and a heating rate of 5°C per 30 day period (1 step per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 410°C to 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-1.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Comparative Example 1

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 8°C per step and a heating rate of 16°C per 30 day period (2 steps per 30 day period) until day 60. Starting at day 61, the temperature was raised in a stepwise manner with a step width of 4°C per step and a heating rate of 4°C per 30 day period (1 step per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 398°C to 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-2.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Comparative Example 2

The temperature was raised as described for Comparative Example 1, but since at day 240 the sulphur content of the product oil was more than 0.3wt.%, the oil feed rate was lowered to about 1.35 h⁻¹ to keep the sulphur content of the product at 0.3wt.%.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4. The cumulative yield ratio of light oil (fraction boiling below 360°C) to feedstock from day 1 to day 360 was 31 vol%. This translates to a relative value of 98 as compared with Example 1.

Comparative Example 3

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 5°C per step and a heating rate of 20°C per 30 day period (4 steps per 30 day period) until day 60. Starting at day 61, the temperature was raised in a stepwise manner with a step width of 1°C per step

and a heating rate of 2°C per 30 day period (1 steps per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 414°C to 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-2.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Comparative Example 4

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 8°C per step and a heating rate of 16°C per 30 day period (2 steps per 30 day period) until day 90. Starting at day 91, the temperature was raised in a stepwise manner with a step width of 2°C per step and a heating rate of 2°C per 30 day period (1 step per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was maintained at 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-2.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

Comparative Example 5

Presulphiding and pretreatment were carried out as described for Example 1. Then, starting at 370°C on day 1, the temperature was raised in a stepwise manner with a step width of 1°C per step and a heating rate of 3°C per 30 day period (3 steps per 30 day period) until day 120. During the subsequent 240 days, the operating temperature was gradually raised from 382°C to 420°C. After 360 days of total operation, the process was stopped. The detailed temperature regimen is given in Table 3-2.

The sulphur content of the product oils and the cracking rate of the 360°C+ fraction at day 120 and day 360 are given in Table 4.

From the results of Table 4, it can be seen that the method of this invention results in improved activity in desulphurisation in combination with hydrocracking as compared to the comparative examples. More in particular, in Comparative Example 1, the step width of 8°C and the heating rate of 16°C per 30 day period during the first 60 days of operation were too high, which resulted in a decrease in hydrodesulfurisation activity. In Comparative Example 2, the decrease in oil feed rate necessary to keep the sulphur content of the oil below 0.3 wt.% resulted in a decrease in product yield and a decrease in hydrodesulphurisation activity. In Comparative Example 3, the use of a heating rate of 20°C per 30 day period during the first 60 days resulted in a decrease in hydrodesulphurisation rate. In Comparative Example 4, the use of a step width of 8°C and a heating rate of 16°C per 30 day period during the first 90 days of operation resulted in a decrease in hydrodesulphurisation activity after 360 days. In Comparative Example 5 the use of a step width of 1°C and a heating rate of 3°C per 30 day period resulted in a good hydrodesulphurisation activity but a decrease in hydrocracking activity after 120 days.

Table 3-1: Temperature regimen for Examples 1-5

	Start-up period (days)				Operation period (days)		
	1-30	31-60	61-90	91-120	121-150	151-180	181-360
Example 1	2 * 5°C 10°C/30 days end T = 380°C	2 * 5°C 10°C/30 days end T is 390°C	2 * 5°C 10°C/30 days end T is 400°C	2 * 5°C 10°C/30 days end T is 410°C	4 * 1°C end T is 414°C	3 * 1°C end T is 417°C	3 * 1°C end T is 420°C
Example 2	1 * 5°C 5°C/30 days end T = 375°C	1 * 5°C 5°C/30 days end T is 380°C	1 * 5°C 5°C/30 days end T is 385°C	1 * 5°C 5°C/30 days end T is 390°C	10 * 1°C end T is 400°C	10 * 1°C end T is 410°C	10 * 1°C end T is 420°C
Example 3	4 * 2.5°C 10°C/30 days end T = 380°C	4 * 2.5°C 10°C/30 days end T is 390°C	4 * 2.5°C 10°C/30 days end T is 400°C	4 * 2.5°C 10°C/30 days end T is 410°C	4 * 1°C end T is 414°C	3 * 1°C end T is 417°C	3 * 1°C end T is 420°C
Example 4	1 * 7°C 7°C/30 days end T = 377°C	1 * 7°C 7°C/30 days end T is 384°C	1 * 7°C 7°C/30 days end T is 391°C	1 * 7°C 7°C/30 days end T is 398°C	9 * 1°C end T is 407°C	7 * 1°C end T is 414°C	6 * 1°C end T is 420°C
Example 5	3 * 5°C 15°C/30 days end T = 385°C	3 * 5°C 15°C/30 days end T is 400°C	1 * 5°C 5°C/30 days end T is 405°C	1 * 5°C 5°C/30 days end T is 410°C	4 * 1°C end T is 414°C	3 * 1°C end T is 417°C	3 * 1°C end T is 420°C

Table 3-2: Temperature regimen for Comparative Examples 1-5

	Start-up period (days)				Operation period (days)		
	1-30	31-60	61-90	91-120	121-150	151-180	181-360
Comp. Ex. 1	2 * 8°C 16°C/30 days end T = 386°C	2 * 8°C 16°C/30 days end T is 402°C	1 * 4°C 4°C/30 days end T is 406°C	1 * 4°C 4°C/30 days end T is 410°C	4 * 1°C end T is 414°C	3 * 1°C end T is 417°C	3 * 1°C end T is 420°C
Comp. Ex. 2	2 * 8°C 16°C/30 days end T = 386°C	2 * 8°C 16°C/30 days end T is 402°C	1 * 4°C 4°C/30 days end T is 406°C	1 * 4°C 4°C/30 days end T is 410°C	4 * 1°C end T is 414°C	3 * 1°C end T is 417°C	3 * 1°C end T is 420°C
Comp. Ex. 3	4 * 5°C 20°C/30 days end T = 390°C	4 * 5°C 20°C/30 days end T is 410°C	2 * 1°C 2°C/30 days end T is 412°C	2 * 1°C 2°C/30 days end T is 414°C	2 * 1°C end T is 416°C	2 * 1°C end T is 418°C	2 * 1°C end T is 420°C
Comp. Ex. 4	2 * 8°C 16°C/30 days end T = 386°C	2 * 8°C 16°C/30 days end T is 402°C	2 * 8°C 16°C/30 days end T = 418°C	1 * 2°C 2°C/30 days end T is 420°C	- end T is 420°C	- end T is 420°C	- end T is 420°C
Comp. Ex. 5	3 * 1°C 3°C/30 days end T = 373°C	3 * 1°C 3°C/30 days end T is 376°C	3 * 1°C 3°C/30 days end T is 379°C	3 * 1°C 3°C/30 days end T is 382°C	13 * 1°C end T is 395°C	13 * 1°C end T is 408°C	12 * 1°C end T is 420°C

Table 4: Results

	step width (°C) during start-up (days)	Heating rate (°C/30 days) during start-up (days)	Sulphur content of product oil (wt.%)		Cracking rate (wt.%)		Standardised cumulative yield ratio of light oil
			at day 120	at day 360	at day 120	at day 360	
Example 1	5°C (1-120)	10 (1-120)	0.06	0.30	24.1	33.0	100
Example 2	5°C (1-120)	5 (1-120)	0.08	0.28	18.1	33.2	
Example 3	2.5°C (1-120)	10 (1-120)	0.05	0.29	24.2	33.1	
Example 4	7°C (1-120)	7 (1-120)	0.07	0.29	22.5	33.1	
Example 5	5°C (1-120)	15 (1-60) 5 (61-120)	0.07	0.31	24.0	32.9	
Comp. Ex. 1	8°C (1-120)	16 (1-60) 4 (61-120)	0.11	0.40	23.6	32.3	
Comp. Ex. 2	8°C (1-120)	16 (1-60) 4 (61-120)	0.11	0.30	23.7	31.9	98
Comp. Ex. 3	5°C (1-120)	20 (1-90) 2 (91-120)	0.13	0.42	23.5	32.1	
Comp. Ex. 4	8°C (1-90) 2°C (91-120)	16 (1-90) 2 (91-120)	0.03	0.45	32.0	31.0	
Comp. Ex. 5	1°C (1-120)	3 (0-120)	0.08	0.28	14.1	33.2	



Claims

1. A hydroprocessing method of vacuum gas oil containing hydrocarbon feeds, in which the feed is contacted with a hydroprocessing catalyst under hydroprocessing conditions, wherein during the heating up period, which is a period starting with achieving a sulphur content below 0.5 wt.% and up to 1/3 of the total operating period, the heating up is performed in a stepwise fashion with a step width of 2-7°C and a heating rate of 5-15°C per 30 day period.
2. The hydroprocessing method of claim 1 wherein the total temperature rise during the heating up period is 40°C or less.
3. The hydroprocessing method of claim 1 or 2 wherein the sulphur content in the product oil in the heating up period is 0.04 wt.% or more.
4. The hydroprocessing method of any one of claims 1-3 wherein the desulphurisation rate in the heating up period is 98.5% or less.
5. The hydroprocessing method of any one of the preceding claims wherein the heating up period is at least 30 days.