Study on the Base Oil Production Scheme of the Hydroisomerization Dewaxing Unit at the Terminal Stage of Its Operation

Xiaodong Yang[1], Lili Jiang[2*], Xiaodong Sui[3], Yupei Liu[1], Xinmiao Wang[1]

1. Petrochemical Research Institue, CNPC, Daqing, 163714, China.

2. Daqing Petrochemical Engineering Co. LTD, Daqing 163714, China.

3. Daqing Refining and Chemical Company, Daqing 163411, China.

Abstract: At the terminal stage of the unit operation, in order to prolong the service life of the catalyst and reduce the cost of replacing the catalyst, a scheme suitable for producing the base oil at the terminal stage of the catalyst was studied. In the 200kt/a hydroisomerization unit of industrial refinery, the base oil of high-grade lubricating oil was produced by prerefining-hydroisomerization- supplementary refining process, using the dewaxing oil from the vacuum fourth oil as raw material, the results of industrial operation show that the temperature of hydroisomerization reaction is reduced by 8 °C, the treatment capacity is increased by 3 t/h, and the yield of heavy base oil is increased by 15.8% as compared with that of the raw material of the furfural refining oil from the vacuum fourth oil, the total yield of base oil increased by 9.3 percentage points, while the pour point of heavy base oil decreased from -16 °C to -22 °C and the cloud point from -3 °C to -8 °C. The furfural-ketone benzol dewaxing oil from the vacuum fourth oil is suitable to be used as the raw material to produce qualified base oil products at the terminal stage of hydroisomerization unit operation.

Keywords: Furfural-Ketone Benzol Dewaxing; Isomerization Dewaxing; Lube Base Oil; Viscosity Index; Cloud Point

1. Introduction

The development of the automotive machinery industry and the strengthening of people's awareness of environmental protection have put forward more stringent requirements on the performance of automotive lubricants. They have excellent viscosity-temperature performance, low-temperature fluidity, oxidation stability and low sulfur content API Ⅱ and III base oils have gradually replaced API I base oils. API II and III base oils have become the mainstream development direction. The hydroisomerization dewaxing technology produces base oils with good viscosity –temperature performance, low pour point and high yield, it has become the mainstream production technology for API II and Group III base oils.

The core of this technology is the hydroisomerization dewaxing catalyst. The most researched catalytic materials mainly include SAPO-11[1-5], ZSM-22[6-7] and ZSM-23[8-9] and ZSM-48[10] Zeolite molecular sieve. The 200kt/a hydroisomerization dewaxing unit of industrial refinery adopts a two-stage process route of prerefining-hydroisomerization dewaxing-hydrofinishing. The hydroisomerization dewaxing reaction is loaded with a mainstream hydroisomerization dewaxing catalyst with selective molecular sieve, and uses vacuum fraction Oil is used as the raw material to produce API Ⅱ and Ⅲ base oils. At the terminal stage of the device operation, in order to reasonably reduce the harsh processing conditions of the device and prolong the service life of the catalyst, to produce qualified lubricating base oils, two types of vacuum fourth-line oils, namely, vacuum fourth-line furfural refined oil (hereinafter referred to as vacuum fourth-line refined oil) and vacuum fourth-line furfural-ketone benzene dewaxing oil (hereinafter referred to as vacuum fourth-line dewaxing oil) are used as raw materials., and the research on processing schemes suitable for the production of base oil at the terminal stage of the catalyst is carried out.

2. Experimental section

2.1 Process modification

In order to control the operation of the device more accurately. The process parameters controlled, including the temperature control of hydrofining tower and hydroisomerization dewaxing tower were adjusted. Process modification mainly include the raw material feed temperature heating furnace gas flow regulating circuit of two towers and the bed temperature quench hydrogen feed flow regulating circuit of three reactors. The set values of these seven temperatures regulating circuits need to be changed. There is no change in pressure and the change in flow is within the original range. There is no need to replace the instrument and only need to reconfigure DCS. In view of the small difference between the temperature setting values, in order to ensure accurate control, it is recommended to use high-precision thermocouple for tower bed and feed.

2.2 The properties of raw materials

The vacuum fourth-line refined oil is obtained after the vacuum fourth-line oil is refined by furfural, and the vacuum fourth-line dewaxed oil is obtained after the vacuum fourth-line oil has undergone the two processes of furfural refining and ketone benzene dewaxing. The properties of the two vacuum fourth-line oil as raw materials to produce high-grade lubricating base oils are shown in Table 1.

Table 1 The properties of two types of vacuum fourth-line oil

Item		vacuum fourth-line refined oil	vacuum fourth-line dewaxing oil
Density (20℃), g/ml		0.8769	0.8709
S, μg/g		506.0	620.5
N, μg/g		302.8	384.0
Flash Point，℃		288	277
Pour Point，℃		60	48
Viscosity(100℃)，mm^2/s		11.55	12.08
Distillation	HK	437	399
Range，℃	KK	557	556

2.3 The processing conditions

Based on the two vacuum fourth-line oil in table 1 as raw materials, industrial test research was carried out in a 200kt/a hydroisomerization dewaxing unit. A suit of process adopts pre-refining, hydroisomerization dewaxing and hydrofinishing process and commercial catalysts thereof. The processing conditions are shown in table 2.

Table 2 The processing conditions

Processing conditions	vacuum fourth-line refined oil	vacuum fourth-line dewaxing oil
Pressure，MPa	12.5	12.5
Capacity, t/h	18	21

Prerefining reaction temperature, °C	371	375
hydroisomerization dewaxing reaction temperature, °C	388	380
hydrofinishing reaction temperature, °C	230	230
Feed temperature to vacuum tower, °C	350	345

3. Results and discussion

Based on vacuum fourth-line refined oil and vacuum fourth-line dewaxing oil as raw materials, the properties of the base oil products are shown in table 3.

Table 3 The properties of the base oil

The properties of products		vacuum fourth-line refined oil	vacuum fourth-line dewaxing oil
The yield of light base oil, %		26.5	20
The yield of heavy base oil, %		47.7	63.5
The total yield of base oil, %		74.2	83.5
Viscosity of heavy base oil, mm^2/s	40 °C	58.25	64.41
	100 °C	9.24	9.71
Viscosity index of heavy base oil		139	133
Freezing point of heavy base oil, °C		-16	-22
Cloud Point of heavy base oil, °C		-3	-8

It can be seen from table 3 that when the vacuum fourth-line refined oil is used as the raw material and the processing capacity is 18t/h, VHVI 10 is used as a heavy base oil product with a cloud point of -3 °C and a freezing point of -16 °C. The yield of heavy base oil is 47.7 %, and the yield of the total base oil is 74.2 %; when the processing capacity of vacuum fourth-line dewaxing oil is 22 t/h, VHVI 10 is also used as a heavy product, the cloud point is -8 °C, and the freezing point is -22 °C, The yield of heavy base oil is 63.5%, and the yield of total base oil is 83.5 %. From the above results, it can be analyzed that compared with the vacuum fourth-line refined oil, the processed vacuum fourth-line dewaxing oil has better heavy base oil yield, total base oil yield, and the freezing point and cloud point performance of the heavy base oil.

When the vacuum fourth-line dewaxing oil is used as the raw material, the viscosity index of VHVI 10 can be stabilized above 131, which meets the III+ base oil standard; the viscosity of VHVI 10 base oil at 40 °C is stable above 64 mm^2/s, which can meet the 40 °C viscosity index of 68# industrial white oil (61.2 - 74.8 mm^2/s), and meets the 40 °C viscosity index (62-74 mm^2/s) of 70# industrial white oil produced by Daqing Refining and Chemical Company. If the vacuum fourth-line refined oil is used as the raw material, the produced VHVI 10 base oil has a 40°C viscosity couldn't reach the index requirements of 68# industrial white oil and 70# industrial white oil.

According to General Lubricant Base Oil Production Standard QSY 44-2009, the cloud point index of VHVI 10 is not greater than -5 °C. At the terminal stage of the device operation, the cloud point properties of heavy base oil (VHVI 10) is no longer able to meet the index requirement of not more than -5 °C when the vacuum fourth-line refined oil is processed. And the cloud point of heavy base oil produced with the vacuum fourth-line dewaxing oil can reach -8 °C and meet the index requirement of no more than -5 °C.

Heavy products had a freezing point of -16 °C, which was just below the index requirement of ≤-16 °C when vacuum fourth-line refined oil was processed, and there is almost no flexible space for device operation. Either take measures to increase temperature or reduce processing capacity; The freezing point of heavy dewaxing oil products is -22 °C, which is far below the index requirement of -16°C when vacuum fourth-line dewaxing oil was processed, and the operation flexibility of the device operation was relatively large.

In order to further improve the comprehensive utilization rate of the device, the processing capacity was increased to 22 t/h when the vacuum fourth-line dewaxing oil was processed, the prerefining and hydrfinishing temperature remained unchanged, and the reaction temperature of the hydroisomerization reaction temperature was increased to 384 °C, The cloud point of heavy base oil (VHVI 10) raised to -4 °C, and the product's cloud point performance could no longer meet the index requirement of no more than -5 °C, and the best treatment capacity was 21 t/h.

Vacuum fourth-line refined oil is a raw material obtained after furfural refining, and the wax content of the raw material is about 48%, while vacuum fourth-line dewaxed oil is obtained through furfural refining and ketone benzene dewaxing process. Compared with vacuum fourth-line refined oil, one more step of ketone-benzene dewaxing process is added, after dewaxing, the wax content of the vacuum fourth-line dewaxing oil is reduced to 28 %. The key technology of the hydroisomerization dewaxing device is to convert the wax molecules of the raw materials into multi-branched isomers through shape-selective isomerization catalyzed by a hydroisomerization dewaxing catalyst in a hydrogen environment, thereby reducing the freezing point and cloud point of the product. Because the raw material of the vacuum fourth-line refined oil contains a relatively high proportion of wax molecules, it is difficult to process, especially at the terminal stage of the the device operation, it is difficult to produce qualified heavy base oil by processing the vacuum fourth-line refined oil. Especially, the problem of cloud point of heavy base oil is prominent. Containing 1~2% trace wax in the base oil will cause the cloud point to increase [11]; Compared with the vacuum fourth-line refined oil, the wax content of the vacuum fourth-line dewaxed oil is reduced by 42 %. Because of the low wax content, it can be used to produce qualified heavy base oil at the terminal stage of the device operation when the catalyst activity is low.

4. Conclusions

At the terminal stage of the unit operation, the cloud point of heavy base oil is about -3 °C with vacuum fourth-line refined oil as raw materials, which could not meet the requirement of -5 °C, however, the cloud point of heavy base oil is about -8 °C with vacuum fourth-line dewaxed oil, which can meet the requirement of no more than -5 °C. The pour point of heavy base oil is -16 °C with vacuum fourth-line refined oil as raw materials, which can meet the requirement of no more than -16 °C, and the pour point of heavy base oil is -22 °C with vacuum fourth-line dewaxed oil, far Less than -16 °C. Compared with vacuum fourth-line refined oil, the temperature of hydroisomerization dewaxing reaction is reduced by 8 °C, the treatment capacity is increased by 3 t/h, the yield of heavy base oil is increased by 15.8 %, and the total yield of base oil is increased by 9.3 %, the viscosity index of base oil meets API III^+ standard, and the vacuum fourth-line dewaxed oil is suitable to be raw material for producing lube base oil at the terminal stage of the unit operation.

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