Lube-Tech

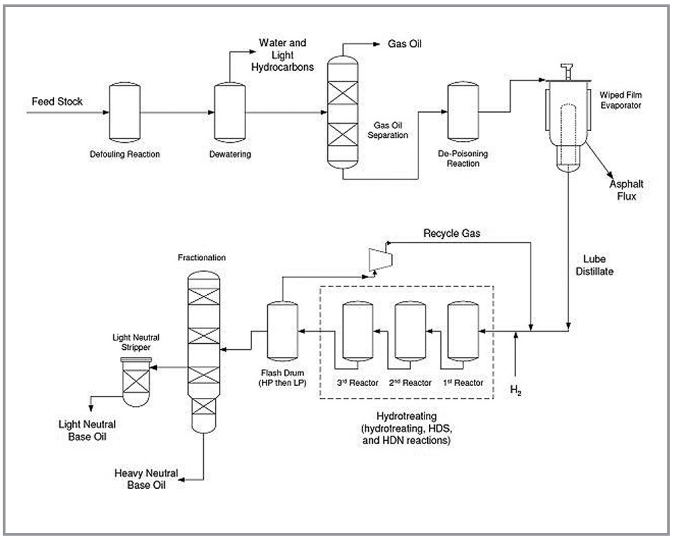
No.84 page 1

PUBLISHED BY LUBE: THE EUROPEAN LUBRICANTS INDUSTRY MAGAZINE

Used Oil Re-refining: Improvements in CEP Technology Make Economics More Attractive

Introduction

Lube base oil is one of the most valuable components in a barrel of crude oil. While many components of crude oil such as gasoline, jet and diesel fuels are 'lost' after combustion, lube base oil can be recovered and 'regenerated' to the quality equal to or better than its original virgin form by using a proper re-refining process such as Chemical Engineering Partner's (CEP) hydrotreating process. While there are other re-refining processes available such as clay treatment and solvent extraction, the lube oil produced from those processes does not meet the specifications of API Group II base oil. This is because of their inability to reduce the sulphur concentration low enough to produce the API Group II base oil. They also suffer lower yield due to the loss of product inherent to their processes. For example, the solvent extraction process achieves a high saturates concentration by selectively extracting the aromatic compounds. However, doing so also removes valuable products from the total lube oil available in the used oil. CEP's hydrotreating process, instead, converts these aromatics into saturated hydrocarbons, hence maintaining the highest yield of base oil recovery among all re-refining processes.



CEP's re-refining process, shown on the process flow diagram above, is regarded by many industry experts as the best available hydrotreating technology to recover and regenerate lube base oil. Such accomplishments could only be achieved by numerous advancements that were made since its start-up over 25 years ago.

Defouling Process

The chemical additives in the motor oil lead to two major processing challenges in re-refining. One is the fouling and corrosion of process equipment and the other is the poisoning of the hydrotreating catalysts. In order to minimise the fouling of the process equipment, CEP tested the Mohawk process developed by the Mohawk Re-Refinery in Vancouver, B.C. The Mohawk process treats the incoming feedstock to prevent fouling by neutralising the remnants of the chemical additives. Improvements and enhancements were subsequently made and reported.[1-3]

Further research led to a better understanding of the fundamentals and the resulting improvements were patented.[4]

The process was further perfected by instrumenting the correct amount of heat and dosage of chemicals to the incoming feedstock. This significantly reduced fouling of process equipment and is referred as 'Defouling Process' by CEP.

Catalyst Poisons

One of the causes that poison the catalysts is the 'entrainment' effect where the vapour carries the liquid droplets that contained the catalyst poisons during the flashing of the used oil in the wiped film evaporator. Through numerous tests and analyses, CEP has optimised the process conditions that allow the maximum lube oil recovery while minimising the entrainment of the catalyst poisons.

CEP conducted a major study on catalyst poisons in the full-scale semi-works operation to develop the 'De-Poisoning Process' to remove the hydrotreating catalyst poisons. In the 'De-Poisoning Process', the catalyst poisons are polymerised into high molecular weight compounds. The polymerised poisons are separated and removed from the lube base oil as the wiped film evaporator bottom product, asphalt flux.

The CEP design includes poison 'traps' that absorb the poisons at the entrance to the first reactor that results in increased catalyst life. The combination of these improvements along with the catalyst management program allowed the semi-works plant to achieve exceptional 11-month run in 2010 and 2011. CEP's customers have reported catalyst runs lasting more than 12 months using the catalyst management program.

Out of this work, CEP now offers its own brand of catalysts most suitable for re-refining of drain oil. In addition, CEP is also able to predict the yields and product properties for 'wild' feedstocks and determine required operating conditions to achieve pre-set goals. This is especially important in countries where virgin lube oils don't have upgraded properties similar to the USA and Europe.

The CEP process can now be built economically using pre-fabricated modules. In a recent CEP project, the 'Front End' recovery process utilised these modules to save overall construction cost. The 'Front End' process refers to the lube oil recovery process prior to the hydrotreating process. Now, the entire process including the hydrotreating process is available using appropriate process modules, saving capital cost while minimising the risk of cost overruns.

Hydrotreating

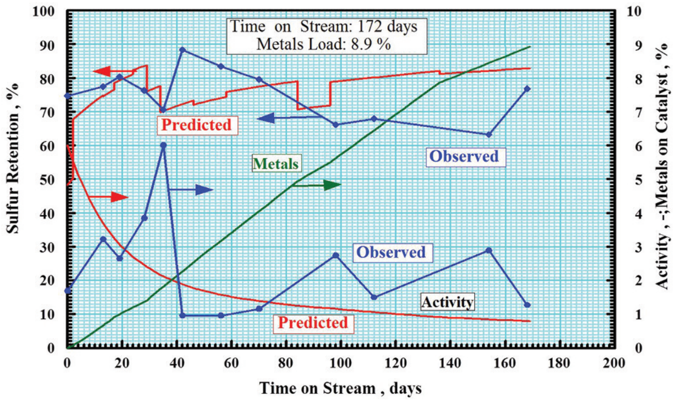
In order to achieve the best hydrotreating technology, several advancements had to be made. The challenge in the hydrotreating process of used oil is that it is very difficult to sustain operations without frequent catalyst change-outs. Some re-refineries have 'guard beds' to function as sacrificial reactors to the main catalyst reactor. These guard beds tend to last typically one to three months at a maximum before switching over to another guard bed reactor. Having extra guard bed reactors increases the capital investment as well as requiring more maintenance. In the hydrotreating step, CEP designs according to mathematical models developed by MAGNA Associates.

Entering the real data with the precise analyses of the feed and discharge of each reactor of the three-in-line allowed us to adjust the models for differences in catalyst activities and unit peculiarities. The desulphurisation/deactivation model allows operators to optimise the hydrotreating reactor temperatures in each reactor to achieve the optimum life for the three beds. This also helps balance the deactivation rate of the catalysts to achieve the same run lengths for all three reactors in series. The examples below illustrate how the predictions of the mathematical models match the operating data for the three hydrotreating reactors.

Modeling of CEP Hydrotreaters

Results of a review and analysis of Evergreen Oil's operation in 2004 are presented in Figures A, B and C. In Figure A, observed and predicted performance data are displayed for Reactor R-301. Metals loading is an indication of foulant embedded onto the catalyst, which decreases activity.

Figure A Evergreen Desulphurisation R-301

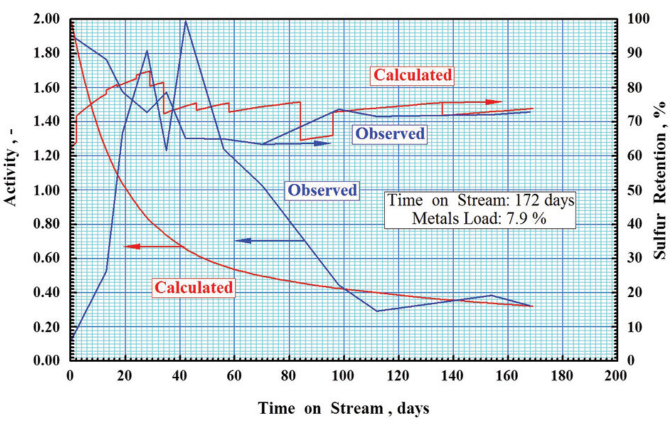


Catalyst activity comparisons are only valid for the same reactor. Catalyst activities for each reactor serve as a guideline to help predict product specifications. Agreement between commercially observed and predicted performance is generally quite good.

The metals loading of this catalyst was 8.9% after 172 days of operation. Sulphur retention (the amount of sulphur remaining in the oil) for this reactor varied between 65% and 85%.

Observed and predicted data for R-302 are shown in Figure B. The metals loading of this catalyst was 7.9% after 172 days of operation. Sulphur retention for this reactor varied between 65% and 85%. There is generally good agreement between observed and predicted.

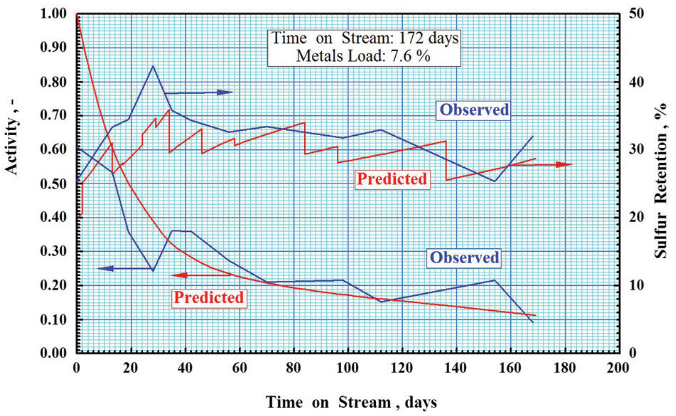
Figure B Evergreen Desulphurisation R-302



Observed and predicted data for R-303 are shown in Figure C. The metals loading of this catalyst was 7.6% after 172 days of operation. Sulphur retention for this reactor varied between 25% and 40%. A comparison with reactors R-301 and R-302 shows quite clearly the increase in desulphurisation. This is due to the higher temperature in R-303. There is generally good agreement between observed and predicted data.

Lube-Tech
PUBLISHED BY LUBE: THE EUROPEAN LUBRICANTS INDUSTRY MAGAZINE

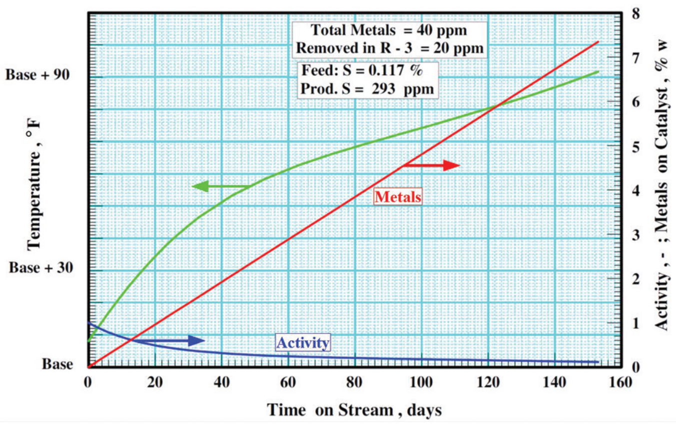
Figure C Evergreen Desulphurisation R-303



CEP Reactor Design

Having developed the mathematical model that matches the real operations, CEP uses this model to design the optimum hydrotreating reactors for any new re-refineries. The optimum process conditions and reactor sizes are determined using this model to ensure all specifications of the API Group II base oil are met. A typical example of a reactor design is presented in Figure D. This is a design graph for a last reactor. Designs for other reactors are quite similar.

Figure D Performance Reactor 3



Note that the product sulphur value is 293 ppm, less than the 300 ppm required for Group II lubricants.

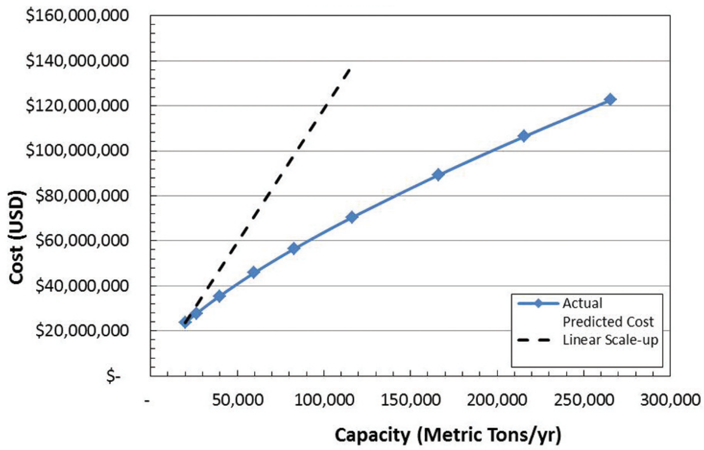
From models such as shown in Figure D, CEP can predict the optimum operating temperature for each reactor through the catalyst life cycle. In addition, metals loading as well as degree of desulfurisation are determined for the life cycle of the catalyst.

In this example, the design temperature increases from Base + 10°F (Base is the temperature used at the start of the catalyst life) at the beginning of the life cycle, to Base + 90°F at the end of the useful catalyst life. At the end of the catalyst life cycle a metals loading of about 7.5% has been calculated. The indicated sulphur retention is quite low, i.e. a high degree of desulphurisation of 75% is predicted during the whole life of the catalyst.

Economics of Re-Refining

All of the changes made above make the re-refining business more attractive in terms of profitability. As one considers to build and operate a re-refinery, one must have enough used oil feedstock available to feed the plant without interruption. CEP recommends a minimum annual capacity of 20 thousand metric tons (20,000 MTA) of feed in order to generate a reasonable profit. The graph below shows the capital cost required for various capacities for a CEP technology re-refinery.

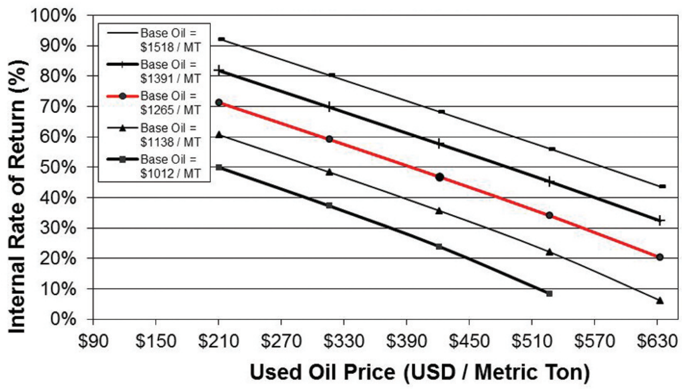
Capital Cost vs Capacity for a Grassroots Re-refinery



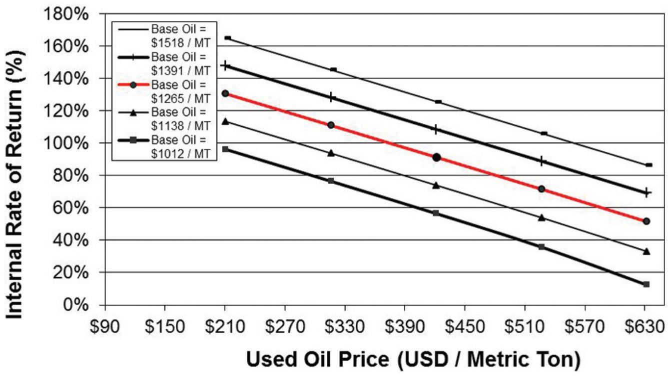
While these costs are just estimates, it is clear that the relationship between the capital cost and the capacity is not linear (as shown by the deviation from the dashed line). The higher the capacity of the plant, the less the capital cost is required per metric ton of used oil processed. It truly shows 'Bigger is Better!'

The parametric charts below show the relationship between the used oil prices and the rate of return at various base oil prices.

Grassroots 40,000 MTA Re-refinery Internal Rate of Return at Various Feed & Base Oil Prices



Grassroots 165,000 MTA Re-refinery Internal Rate of Return at Various Feed & Base Oil Prices



Again, as with the capital cost vs capacity, the rate of return is much greater for a bigger plant. The return for a 165,000 metric ton per year (MTA) plant at $422 (USD) feed and $1,265 (USD) base oil is about 90% while it is about 45% for the 40,000 MTA plant for the same used oil and the base oil prices. The labour cost is one of the major factors in the operating costs. However, the labour cost does not increase for a higher capacity plant since it takes the same number of people to operate a plant whether it is a 40,000 MTA or 165,000 MTA plant. This is unique for a small re-refinery as compared to larger virgin oil plants. That's the main reason why the rate of return for a higher capacity plant is greater. Therefore, it is recommended to maximise the capacity of the plant as long as the volume of the feedstock collection allows. However, whether it is a 40,000 MTA or 165,000 MTA plant, the rate of return for a CEP technology re-refinery is very attractive in today's market. Other factors in the operating cost include utilities such as electricity, natural gas, cooling water, hydrogen and catalysts.

In conclusion, the lube base oil derived from drain oil is a very important resource that should not be wasted by being burned as fuel. Using the best technology available such as CEP's re-refining process, it can be regenerated into the quality that is equal to or better than virgin base oil refined from crude oil. With process advancements made by CEP, the re-refining process is not only a very efficient and reliable way to recover one of the most important natural resources, but also provides a very attractive business opportunity.

References:

1. *L.M. Magnabosco, M. Falconer & K. Padmanabhan, "The Mohawk/CEP Process", Proceedings of Sixth International Conference on Used Oil, Recovery and Reuse Re-refining Rebirth. Association of Petroleum Re-refiners, San Francisco, California, May 28-31, 1991.*

2. *L.M. Magnabosco, "Progress in Mohawk/CEP Technology: Reduction in Catalyst Deactivation", Seventh International Conference on Used Oil, Recovery and Reuse. Association of Petroleum Re-refiners, Chicago, Illinois, September 27-October 1, 1992.*

3. *L. M. Magnabosco, "High Quality Lube Base Stock from Waste Lube Oil Streams via the Mohawk-CEP Process", Presented at the First International Oil, Gas and Petrochemical Congress. Isfahan, Iran, September, 1993.*

4. *L.M. Magnabosco and W.A. Rondeau, "Improved Process for the Production of Base Stock Oils from Used Oil", European Patent EP0574272, (1993).*

Joshua H. Park[a] and Louis M. Magnabosco[b]
a) Chemical Engineering Partners (CEP), 2415 Campus Drive, Suite 225, Irvine, CA 92612
b) MAGNA Associates, 22365 El Toro Road, Suite 277, Lake Forest, CA 92630

LINK
www.ceptechnology.com