Processing heavier crudes to meet future needs

Improved modeling improves designs

Fast Forward
- Crude oil is a non-renewable decreasing resource, making it important to better exploit heavy oils or oil sands.
- Coupling a pipeline simulator with a reservoir simulator can accurately model the entire steam-assisted gravity drainage (SAGD) process.
- User partnerships are effective to create improved petroleum characterization procedures for heavy oils.

By Joseph McMullen, Brittany Doyle, and David Bluck

Countless factors will drive the future of the global refining industry, including the state of the worldwide economy; availability, accessibility, and quality of raw material; and legislation surrounding industry practices. For this reason, it is difficult to determine what exactly is in store for this important industry. However, assessing these contributing factors can help predict the direction the market might take.

Crude oil is a non-renewable resource. Once it is used, it cannot be regenerated, and its overall supply is continuously decreasing. In particular, the supply of higher-quality sweet, light oils, which, with their low sulfur content and low density, have historically been the easiest to extract, refine, and process, is rapidly diminishing. This has created the need for new technical resources and capabilities that help obtain and refine lower quality, heavier sour oils that are more difficult to access.

For that reason, the industry’s attention has shifted from downstream processing to upstream exploration and extraction. Few methods are currently available for extracting heavy oils and bituminous oil sands from deep within the earth. Yet, this will become a crucial practice as the supply of accessible light, sweet oils continues to wane. Having the knowledge to obtain these heavy oils or oil sands must be coupled with the technology to refine this lower-quality feedstock.

Heavy crude access, processing

Crude oil from the Western Canadian Sedimentary Basin will soon be a viable crude source. Transporting that crude through southbound pipelines will result in new feedstock for refineries in the U.S. But that means U.S. refineries will need new capabilities to refine these crudes. Currently, only a few U.S. refineries, primarily on the western coast, have that capability. Because of their proximity to Canada and their processing ability, these refineries could see an increase in throughput compared to their less flexible counterparts.
However, pulling the oil out of the ground is still a problem. Since this crude is more viscous, it must be loosened before it can flow upward. Enter steam assisted gravity drainage (SAGD) technology. In the SAGD process, steam is injected into the reservoir to heat the heavier, more viscous crude, allowing it to be removed through a second pipe. Historically, this has been an expensive process, but recent advances in technology and the increased price of crude means SAGD has become a real, economically viable alternative to oil production.

Modeling technologies have been a great help in implementing SAGD. Coupling a pipeline simulator with a reservoir simulator can accurately model the entire SAGD process, leading to enhanced efficiency in the design and operation of the process, but all of that hinges on the ability to accurately simulate heavier crudes, which many experts believe is the future of the industry. Unfortunately, however, the majority of commercial simulators utilize methods developed for conventional light, sweet crudes.

Invensys Operations Management recognized this back in 2007 when it started a heavy-oils consortium that engages customers to develop new simulation methodologies that accurately model heavier crudes. The empirical data from the consortium is fundamental to building accurate models for heavy oil production. Consortium members include Shell, ConocoPhillips, Suncor, Syncrude, Petrobras, Chevron, TOTAL, Petrocanada, PDVSA, KBR, Toyo Engineering, Fluor, BP, StatOil, and ENI. Processing these heavier oils can tax equipment that is not designed appropriately. Therefore, it is important the crude oil is characterized correctly from the beginning of the design process. To address this, Invensys has developed heavy oil methods, using its SimSci-Esscor technologies that are able to accurately characterize heavier oils.
Characterization, modeling of heavy oils

In November 2007, through customer partnerships, processing data was used to create a new petroleum characterization procedure for heavy oils. This heavy-oils characterization method is intended to extrapolate critical properties and molecular weight of petroleum components with normal boiling points beyond 1000 degrees Kelvin.

Since it was implemented, the correlation has twice been modified and improved as more data became available from consortium members. Using kinematic velocity, Figure 1 shows how the new correlation compared to measured data for heavy crude.

To see how the increased accuracy would affect the design of process equipment, the example above illustrates the affects of kinematic viscosity on the design of a heat exchanger (Figure 2). The streams entering the heat exchanger are both heavy oils. Therefore, a comparison could be made on the predicted kinematic viscosity and how that would affect exchanger sizing during the design phase.
In Figure 3, it is easy to see the differences between the kinematic viscosity values predicted by API 11A4.2 and the heavy oil correlation. For the crude stream, the API 11A4.2 over predicts the viscosity, wherein the kinematic viscosity is under predicted for the Vac Resid stream.

In both cases, the heavy-oil correlation-predicted values are much closer to the measured values than the API A4.2 method. This illustration shows the heavy-oils method much more accurately predicts the kinematic viscosity. However, the important factor is how well the heat exchanger is designed, as well as how the equipment design is affected by the kinematic viscosity.

Figure 4 depicts how kinematic viscosity affects the design of the heat exchanger. Notice if the API Procedure 11 A4.2 is used, then the duty would be oversized by more than 200%. The heavy-oil method also over predicts the duty, but by a much smaller margin. The heat transfer value is over predicted by almost 300% with API 11A4.2, while the heavy-oil method over predicts by less than 200%. These calculations could lead the design to be unnecessarily large, which would increase capital and operating costs. The ramifications of the under-predicted pressure drop could lead to not having the proper pumps in place to drive the fluid through the exchanger. These flaws in the design of this exchanger are cause for concern and support the need for accurate heavy-oil modeling.
<table>
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<tr>
<th>Temperature °F</th>
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<th>Vac Resid Kinematic Viscosity, cSt</th>
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Measured, predicted kinematic viscosities (Figure 3)
Modeling additional properties

Invensys designers have also developed a methodology for modeling heavy oils that can be detailed for liquid viscosity and liquid thermal conductivity. This helps to more accurately predict the properties of heavy oils, which leads to enhanced accuracy in process design and operation.

Additionally, because mercury is a common pollutant in heavy crude oil that is increasingly regulated, Invensys has also introduced an updated methodology for predicting mercury solubility in hydrocarbons. The new methodology enables proper accounting for mercury within raw materials, products, and waste, as well as mercury mitigation.

As the Invensys-sponsored heavy-oils consortium continues to provide more data and valuable guidance, more accurate thermodynamic methods will be developed that anticipate growing and changing industry needs to help oil processors optimize their operations in real time. This will drive the continued development of software.
modeling tools and provide value to engineers by helping them address design and operational problems now and in the future.

ABOUT THE AUTHORS

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