Refining the science of refining

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What progress has been made to improve the efficiency of refining, and what major challenges remain?
Crude oil, a natural resource, requires refining before it can be used. During the refining process crude oils undergo structural changes and contaminants must be removed such as sulphur, nitrogen, oxygen, water, metals and inorganic salts. Hence, refining adds value by converting crude oil into a range of refined products, including transport fuels such as ultra low-sulphur gasoline and diesel fuels.

Modern refineries have pools of refined products with physical characteristics such as density, volatility and boiling range; chemical properties relating to sulphur and aromatics content; and fuel performance characteristics such as the octane rating or smoke point. The finished product requires multi-component blending.

Refiners' major challenges are to satisfy market demand and supply. This can involve using refinery processes with catalyst technologies and heavier feedstocks to make the right products that are both environmentally clean and in demand. The cyclical demand between gasoline and diesel can swing from one direction to the other, depending on various factors including process availability, capacity, costs and pricing.

How is the refining sector adapting to use more diversified feedstock, including unconventional oil shale and oil sands?
The main challenge for technology is to optimise heavy oil production with cost-effective and environmentally sound methods. Unconventional oil resources have major issues. The recovery factor remains very low, at about 15-20 per cent with high extraction costs, so it becomes difficult to operate economically. Shale oil and oil sand production is more expensive than conventional crude oil, and its energy intensity has a negative impact on the environment. However, I believe much of the crude oil supply rebalance will come from these two resources. Reliable technological treatment of diversified feedstocks (heavy or extra heavy) is very difficult, because a method that works in one situation may fail utterly in a different one. Hence, it is essential that the properties of these resources should be fully understood at molecular level before selecting a production scheme. The major problem with heavy oil feedstock is the complexity of the feedstock and the analysis of its components.

Using diversified feedstock in downstream refining requires more intense operating conditions and higher cost for the processing to produce gasoline and distillate fuels. Thus, the chemical composition of an unconventional crude oil heavily affects the downstream sector. Technologies such as blending, direct up-grading as well as thermal processes need to be further developed in order to be cost-effective.

What can be done to improve the reliability of refineries, to minimise corrosion and to shorten turnaround times in maintenance and upgrading?
Petroleum refining is a high-hazard industry, as refineries are vulnerable to a variety of corrosion phenomena. Corrosion can cause leaks of hydrocarbons, sometimes leading to serious accidents. In order to mitigate the corrosion risk, refineries should implement a sound risk management strategy considering the corrosivity of feedstock and the processing conditions. Material selection for refinery equipment and piping should consider the characteristics of feedstock in terms of corrosive sulphur compounds, salt content, and acid content. Implementation of an effective risk-based inspection strategy, based on the identified corrosion loops and anticipated material degradation mechanisms, is also essential. The corrosion risk management strategy should involve advanced corrosion monitoring and non-destructive testing techniques. Occurrences of corrosion need to be properly recorded and investigated to identify root causes.

How is the refining sector coping with the challenges of tighter environmental regulation to reduce emissions and health hazards?
Refineries are making it a priority to respond to tighter environmental specifications. Refining processes are changing, with newer or improved ones such as isomerisation and alkylation process, replacing liquid catalysts with solid (zeolite or super acids) based catalyst technologies.

The profitability of refining can fluctuate very sharply – does this have an impact on the level of research as well as investment in refining?
The complex, sophisticated refineries can handle a very wide range of crude oils and blends to deliver the highest value of products demanded by the market. However, high- value products are the shared output of basic research as well as of technological refinements. Refining margins are the difference in value between the products produced by a refinery and the value of the crude oil used to produce them. Thus, the role of maximising the product slate using innovative technology (research) definitely influences refinery investment as well as integration of refineries with other petrochemical complexes to add value.