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Methanol to Gasoline

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Report Abstract
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INTRODUCTION

As the memory of the oil price upsurge in the second half of 2008 is still relatively fresh, we have witnessed the oil price take another upswing in the first half of 2011. The growing civil unrest throughout the Middle East and North Africa has led to a reduction in oil supplies and has pushed oil prices well above $100 per barrel ($853 per ton) in the international market.

Gasoline is one of the most important refined products due to its use as fuel in internal combustion engines. It usually consists of hydrocarbons with 4 to 12 carbon atoms in each molecule. Global demand for gasoline was estimated to reach above 22 million barrels per day (2.6 million tons per day) by the end of 2011, most of which was produced from refineries using crude oil as raw material. However, suffering from the soaring feedstock price, traditional crude oil-based gasoline production is facing a profit margin squeeze. Spurred by the challenging market environment, the industry is motivated to switch to alternative energy resources for gasoline production, and the methanol to gasoline (MTG) process provides a possible solution.

The ideal methanol production would be the direct oxidation of methane to methanol via a one-step reaction. However, commercially-viable catalysts that can selectively activate methane to methanol, with an acceptable methane conversion and a reasonably high methanol selectivity, have yet to be established. Today's practical methanol production technology employs a two-step process, by first generating synthesis gas (mixture of carbon monoxide and hydrogen) from natural gas (mainly methane) or other hydrocarbon feedstocks, such as naphtha, heavy oils, and coal. The synthesis gas generated in the first step is then converted to methanol in the second step.

Neat methanol, (i.e., 100 percent methanol, can be used directly as automotive fuel in dedicated methanol-fuelled vehicles, with the required engine modifications). A comparison between the properties of methanol and gasoline is provided in Section 2.

One of the major advantages of using neat methanol is that it has a higher octane number compared to gasoline and can be run at a higher compression ratio without causing detonation. However, there are several drawbacks that restrict the large scale application of methanol as a replacement of gasoline at current stage. These are discussed in the report

In order to take advantage of the benefits of methanol while avoiding its drawbacks, blending methanol with gasoline has been proposed and tested. Low concentration blending (e.g., M15 to 15 volume percent methanol fuel blend) only requires minor modifications to the spark-ignition gasoline engines; whereas higher concentration blending (e.g., M85 to 85 volume percent methanol fuel blend) can be used only when engines are properly refit.

In this approach, fuel efficiency and environmental benefits are slightly sacrificed in exchange for a solution to the cold-starting issue. The use of methanol-gasoline blends solved many of neat methanol’s problems in the internal combustion engine, yet other problems arise, especially in low methanol blends. This issue is discussed further in the report.

The report also reviews strategic, technical, and commercial considerations of methanol gasoline versus gasoline from methanol.

TECHNOLOGY

Methanol to gasoline (MTG) chemistry was first discovered by Mobil scientists in the 1970s. The reaction sequence can be summarized as follows:

$$2CH_3OH \longrightarrow CH_3OCH_3 + H_2O \qquad (1)$$

$$CH_3OCH_3 \longrightarrow C_2\text{-}C_5 \text{ Alkenes} \qquad (2)$$

$$C_2\text{-}C_5 \text{ Alkenes} \longrightarrow \text{Higher Alkenes + Aromatic + Alkanes + Cyclic Alkanes} \qquad (3)$$

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Approximately 75 percent of the methanol is partially dehydrated to an equilibrium mixture of dimethyl ether (DME), methanol and water. This reaction is rapid, reversible and exothermic. Then, DME is further dehydrated over ZSM-5 zeolite catalyst to generate light alkenes (C_2-C_5 range), which will undergo oligomerization and cyclization to give final products (i.e., higher alkenes, cyclic alkanes, alkanes, and aromatics).

Mobil has carried out extensive studies to develop the MTG process. Heat removal is the principal problem in the MTG process, and in the fixed-bed process, it is managed by splitting the conversion into two parts.

Mobil also conducted process development studies on the fluid-bed version of the MTG process. A demonstration plant adopting a fluid-bed version of the MTG process was built in Wesseling in West Germany, near Cologne. The plant, with a designed capacity of 100 barrels of gasoline per day, started up in December 1982 and operated until 1984. Results obtained from the pilot plant indicate that all designed goals were met or exceeded. Although no commercial plants employing a fluid-bed MTG process have been built, the technology is ready for commercialization.

Lurgi, under a cooperation agreement with Mobil Oil Corporation, has developed its own version of the Mobil MTG process. Lurgi-Mobil MTG process is similar to the fluid-bed MTG process in that the conversion of methanol to gasoline range hydrocarbons is accomplished in one reactor. However, instead of using a fluid-bed, Lurgi-Mobil MTG process adopted fixed-bed technology.

The report discusses:

- The original Mobil MTG fixed bed process
- The Urbk-Uhde-Mobil MTG fluid bed process
- Lurgi-Mobil MTG process in a multi-tubular fixed bed reactor

Recent technology developments are discussed, including:

- Second generation ExxonMobil process
- One-Step MTG Process
- Topsoe Integrated Gasoline Synthesis (TIGAS) process

An overview of the status of MTG commercialization and operations, as well as the outlook for MTG technologies is included.

PROCESS ECONOMICS

The report includes cost estimates for producing gasoline using coal-based methanol as feedstock. Detailed cost tables for the following are included:

- Cost of producing syngas from coal (China and USGC location bases)
- Cost of producing methanol from syngas (China and USGC location bases)
- Cost of producing gasoline from methanol (China and USGC location bases)

A sensitivity analyses to assess the impact of variation in the coal price and plant scale on gasoline cost of production are included.

The report includes cost estimates for producing gasoline using natural gas-based methanol as feedstock. Detailed cost tables for the following are included:

- Cost of producing methanol from natural gas (China and USGC location bases)
- Cost of producing gasoline from methanol (China and USGC location bases)

A sensitivity analyses to assess the impact of variation in the natural gas price and plant scale on gasoline cost of production are included.

- The report includes a detailed cost estimate for producing gasoline using purchased methanol as feedstock (China and USGC location bases)

A sensitivity analyses to assess the impact of variation in the methanol price and plant scale on gasoline cost of production are included.

The detailed cost tables given in this report include a breakdown of the cost of production in terms of raw materials, utilities consumed (electrical energy, cooling water, fuel etc.), direct and allocated fixed costs, by unit consumption and per metric ton and annually, as well as contribution of depreciation to arrive at a cost estimate. Capital costs are broken down according to inside battery limits (ISBL), outside battery limits (OSBL), other project costs, and working capital.

COMMERCIAL MARKET REVIEW

The report includes market analysis as follows:

- Global gasoline demand data is given and discussed
- Current and planned global refining capacity is discussed
- Global refined petroleum product supply (i.e., LPG, naphtha, gasoline, kerosene/jet fuel, diesel/gas oil, residual fuel) data is given and discussed
- Global net trade is discussed
- In addition, supply, demand and trade data is given and discussed according to key regions, i.e., North America, South America, Western Europe, Eastern Europe, Africa, the Middle East, and Asia

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