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Maximizing Natural Gas Utilization Using Gas to Liquid Microchannel Technology

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Abstract

Over the years, Natural gas has been a major source of Energy to the world with its supply of worlds energy expected to increase by 1.9% annually. Gas underutilization which has led to gas flaring is one of the most challenging energy and environmental problems facing the world today. Gas to Liquid Technology which has been an attractive option in converting gas to useful products because of the properties of its products. However, its size and economic viability is a major challenge in its utilization.

The major focus of this paper is on Microchannel Technology. This technology which is borrowed from the automotive industry has the potential of transforming the energy used in Gas to Liquid Technology by sustaining the temperature of the reaction thereby reducing the size of the reactor. This paper analyzed the possibility of merging Microchannel technology with Gas to Liquid Technology and concluded that it can be used to access stranded gas reserves including those containing small amount of gas initially in place (as low as 0.5 Tcf GIIP). It will also lead to effective utilization of associated and non-associated gas produced in remote locations.

Keywords: *Natural Gas Utilization, Gas to Liquid, Microchannel Technology.*

1. Introduction

Natural gas is a naturally occurring fossil fuel which is a mixture of saturated hydrocarbons with some non-hydrocarbon components. It consists of mainly methane as saturated hydrocarbon with about 80% of the natural gas composition. Some of these gases exists in separate phases in gas reservoirs while others exist in association with crude oil. Hence, we have associated and non-associated gas. Most oil and gas reserves are isolated (located at a distance far from processing location). This distance makes the transportation of excess gas gotten from these locations costly therefore making most of these gases to be flared. Because natural gas is valuable, it would be better for companies to capture it rather than flare it thus a dynamic approach is needed in order to maximize the utilization of Natural Gas produced from isolated wells.

2. Gas to Liquid Technology

Gas to liquids (GTL) is a refinery process used to convert natural gas or other gaseous hydrocarbons into longer-chain hydrocarbons such as gasoline or diesel fuel. Methane-rich gases are converted into liquid synthetic fuels either via direct conversion or via syngas as an intermediate, using the Fischer Tropsch or Mobil processes.
There are three stages involved in gas to liquid technology. They are:

- Syngas Generation
- Fischer - Tropsh synthesis and
- Product upgrade

It starts with synthetic gas production i.e., the conversion of natural gas to carbon monoxide and hydrogen using a reformer or gasifier (This technology is similar to that used in making methanol and ammonia). The synthetic gas is fed to a Fischer Tropsch reactor which converts it into straight chain paraffinic waxes that are hydrocracked to make variety of products ranging from diesel, naphtha, lube oil, base stocks down to gases. After this process, the product is then upgraded so as to yield clean Sulphur free diesel fuel and naphtha.

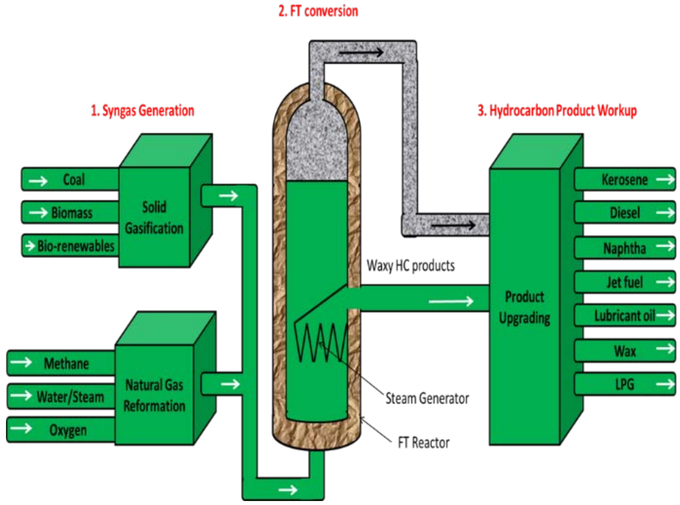

Figure 1: Schematic of a Gas to Liquid process

3. Gas to Liquid Chemistry

Tropsh method is a multi-step energy consuming process that takes molecules of natural gas apart predominantly methane and reassembles them into long chain molecules. The first step requires input of oxygen separated from air. The oxygen is blown into a reactor to strip hydrogen atoms from methane. The products are synthetic hydrogen and carbon-monoxide which is called synthetic gas. The second step uses a catalyst to recombine the hydrogen and carbon-monoxide into liquid hydrocarbons. In the last step, the liquid hydrocarbons are fed into a cracking unit where they are converted into products that can be used immediately or blended with others. The major product is diesel otherwise known as gas oil.
A schematic of gas to liquid chemistry is shown below

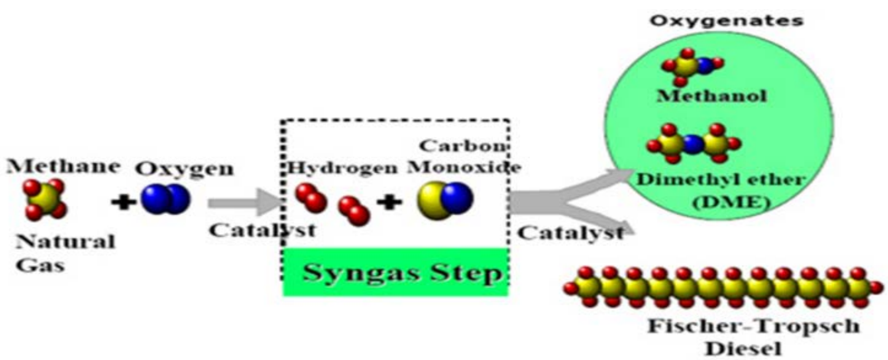

Figure 2: Schematic of gas to liquid chemistry.

4. Challenges of Gas to Liquid Technology

There are two major challenges facing the conventional gas to liquid technology. They are:

- High capital cost and
- Low profit margin

Most companies have experienced about 50% – 400% increase in estimated capital cost when setting up a GTL plant. With capital costs this high, a GTL plant will need 25 or more years of high oil prices and low natural gas prices in order to be a competitive source of processing Natural gas Apanel et al (2005).
This dependence on high oil prices and low natural gas prices makes GTL technology highly undependable rendering it unfit for tackling the challenges associated with natural gas production especially in remote locations.

5. Microchannel Technology

Microchannel process technology is a process used in improving endothermic and exothermic reactions by sustaining the temperature of the reaction. Systems based on microchannel process technology have the potential to transform the energy used in chemical processing industries by greatly reducing the size of chemical reactor hardware. This technology has many parallels with the microelectronics that revolutionized the computer industry because it can shrink processing hardware while improving performance. The concept of producing synthetic fuels in compact unit's hinges on the ability to economically scale-down reaction hardware while maintaining sufficient capacity. By greatly reducing the size and cost of chemical processing hardware, microchannel process technology holds the potential to enable cost effective production of synthetic fuels in smaller scale facilities.
The Microchannel coil design is based on technology from the automotive industry. It is constructed of parallel flow aluminum tubes that are mechanically brazed to enhanced aluminum fins, resulting in better heat transfer and a smaller, lighter, corrosion resistant coil.

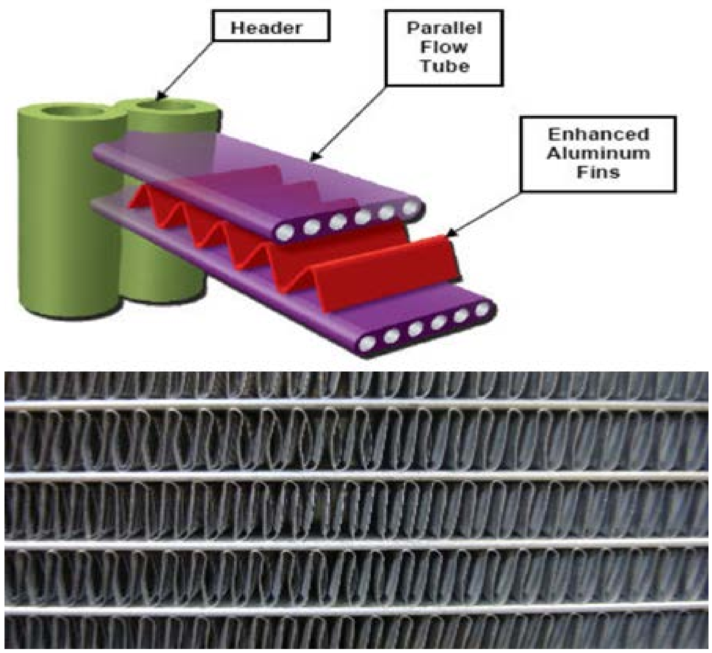

Figure 3: Schematic diagram of Microchannel Design coil

Microchannel process technology, has been proven to be advantageous at laboratory and pilot scales, and is now being scaled up to produce commercially significant quantities of chemicals and energy products. It can be applied in many applications ranging from hydrogen generation and biofuel production to chemical synthesis. Jude et al (2007)
Some of the advantages of microchannel technology are:

i. It increases domestic fuel production and efficient use of energy in the chemical industry.
ii. It permits the fabrication of low-cost microchannel devices that can dramatically improve the economics and efficiency of a range of unit operations, including reactors, heat exchangers, distillation, mixing and separations
iii. Since it will update industrial processes with more efficient alternatives, it will stop any form of dependence on foreign energy resources, unnecessary emissions of greenhouse gases and a less competitive domestic chemical industry.

Chemical reactor units based on microchannel technology are characterized by parallel arrays of microchannels, with typical dimensions in the 0.1 to 5.0 mm range. Processes are accelerated 10 to 1,000-fold by reducing heat and mass transfer distances, thus decreasing transfer resistance between process fluids and channel walls. Reactor volumes can be reduced 10-fold or more compared with conventional reaction unit hardware. These smaller reactors significantly reduce the cost of processing equipment, limit by pproduusctsformeffiicieancdy.im

6. Gas to Liquid Microchannel Technology

This is the addition of Microchannel technology to Gas to liquid reactors thereby increasing the efficiency, effectiveness and profitability of Gas to liquid technology. This tends to reduce the capital cost of GTL technology thereby making it a more competitive method of converting gas produced in remote locations.
A schematic representation of reactor size is shown below

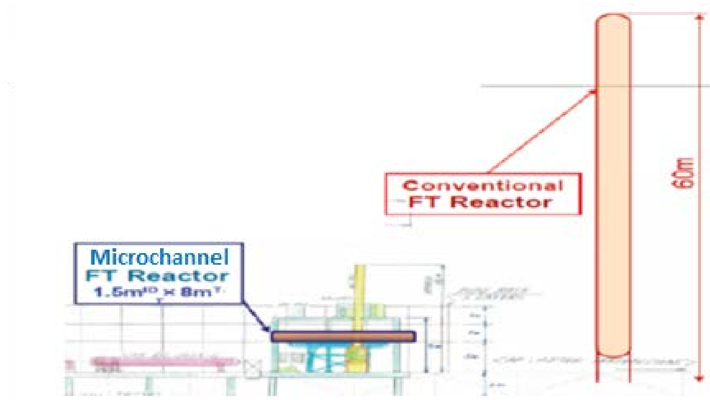

Figure 4: Size comparison of Microchannel reactor assembly and Conventional FT reactor (Steve LeViness et al - 2011)

In order to fulfil the commercial potential of this project, microchannel reactor must be cost effectively manufactured at larger scales. The challenges associated with this are rooted in the manner in which microchannel devices are scaled up by "numbering up" to form microchannel arrays. Numbering up means that capacity is increased simply by adding (i.e., arraying) parallel microchannels. The proposed development program will solve the problem of cost effectively manufacturing microchannel arrays and reactors by developing a suite of low cost, high precision manufacturing techniques.

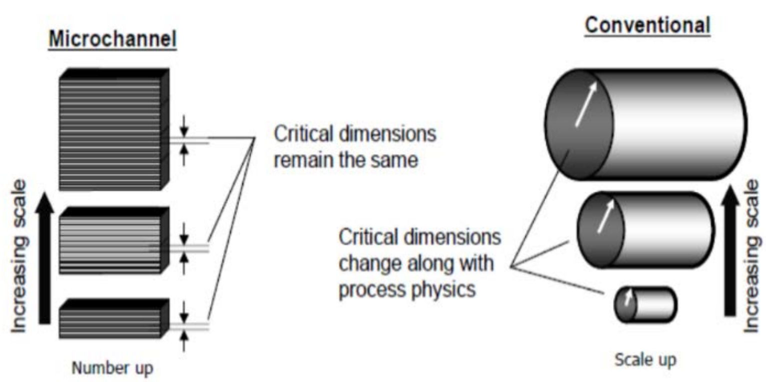

Figure 5: Numbering-up system and scale-up system in microchannel technology

The numbering up approach introduces its own challenges as each of the thousands of microchannels in a reactor must be sufficiently uniform to ensure even flow distribution and reactor performance. Depending on the material employed, many microchannel fabrication techniques can be used to create small, uniform passages. However, most large -scale applications require the use of ferrous alloys or similar materials. One methodology that is being pursued for commercial - scale microchannel reactors is known as microchannel lamination, or micro-lamination. This technique is thought to provide cost effectiveness, design flexibility to accommodate a complex suite of chemical unit operations in a single component, and the tolerances required to make sufficiently uniform internal passages.
Another concern for Gas to Liquid Microchannel Technology is the plugging or fouling of the thousands of small channels inside each microchannel device. While this is an understandable concern, experiments show that two interrelated strategies mitigate the risk of microchannel plugging:

1) High wall shear, and
2) Good flow distribution.

Long duration microchannel vaporizer experiments were run with and without good flow distribution. For the devices with good flow distribution, no pressure drop increases were observed in runs ranging from 1,000 to 9,000 hours at both ambient and high pressure (20.3 bar) conditions. The lack of pressure drop increases held true even when the feed water was intentionally doped with high levels of dissolved solids. This absence of fouling within individual microchannels was verified by post operational autopsies and attributed to high wall shear. Some fouling was noted in the headers and footers, but they were sufficiently large as not to affect pressure drop or heat transfer performance

7. Use of Gas to Liquid Microchannel Technology for Stranded Gas

Due to the fact that there is high transportation cost for associated gases coproduced with oil in remote locations, there is need to convert the gas into liquid fuels so as to make its transportation easier. Gas to Liquid technology is a perfect solution for this but GTL plants usually require very large reserves. According to some statistics, only about 6% of the world's gas fields are large enough to sustain a 10,000+ bpd GTL plant (Adegoke et al – 2005). Reducing the production rate to 2,000 bpd makes approximately 40% of gas fields viable sources of gas that can be converted to liquid as illustrated below.

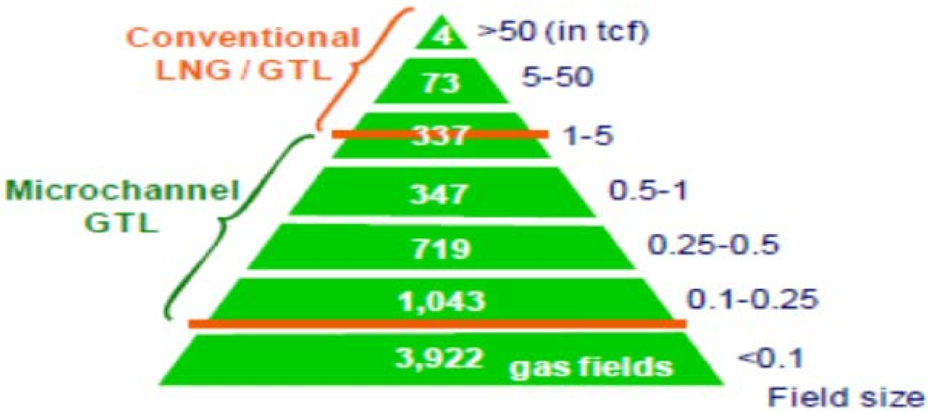

Figure 6: Reservoir volumes and the best method used in recovering gas from the field

Also, because Microchannel FT permits economic production at smaller scale (Due to the fact that it reduces the size of chemical reactor). The reduction in size makes it possible to use the reactor in remote offshore locations as conceptualized below

Figure 7: Conceptual design of Microchannel FT plant in an offshore facility

8. Advantages of Microchannel Technology over Conventional Fischer-Tropsch Process

Due to improved volumetric and catalytic productivity, microchannel FT has the following advantages over Conventional Fischer-Tropsch Process

1) Microchannel GTL technology has the potential of transforming the energy used in chemical processing industries by greatly reducing the size of chemical reactor hardware.
2) Microchannel FT enables lower capital and operating costs compared to conventional FT reactor systems.
3) GTL microchannel technology is an appropriate option in natural gas exploitation as it enables development of natural gas resources from small gas reserves (0.5 – 5 TCF) to large gas reserves (5 TCF and above). This means that it will significantly reduce the flaring of associated natural gas.
4) Fuels produced from GTL are more energy efficient, clean and Sulphur free compared to the conventional fuel. This means that it produces a lower amount of dangerous gases (e.g. Sulphur) which makes it environmentally friendly.
5) GTL technology can act as an alternative gas utilization process which will conquer the increasing demand of fuel in the future as it will reduce gas flaring, fuel scarcity gas reinjection and storage costs etc.

9. Conclusion/Recommendations

The following recommendations need to be put into consideration to maximize Gas to Liquid Microchannel Technology for Stranded Gas

1) In order to unlock the full potential of GTL microchannel technology, it's by product such as steam and hydrogen can be utilized for commercial power generation. The generation of power with GTL by products creates a strategic diversification for commercial power supply, monetizes waste heat to improve cost and improves the overall profitability of GTL plants.
2) There should be efficient and continuous research and development on GTL conversion especially on the simplification of the processes so as to reduce capital cost.
3) Efforts should be made to integrate more computerized control systems in order to facilitate the operation.
4) Efforts should be made to ensure the training programs for future GTL projects. This will ensure the smooth operations of the plant.
5) Government should create policies and environment that will favour investment in GTL projects.

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