INTRODUCTION

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The conversion of the synthesis gas to aliphatic hydrocarbons over metal catalysts was discovered by Franz Fischer and Hans Tropsch at the Kaiser Wilhelm Institute for Coal Research in Mullheim in 1923. They proved that CO hydrogenation over iron, cobalt or nickel catalysts at 180-250°C and atmospheric pressure results in a product mixture of linear hydrocarbons.

It took about 20 years for FT synthesis, to develop from the early experiments of invention in 1925 to a 600,000 t per annum industrial capacity in 1945 **[Frohning et al., 1977]**, the main development took place in Germany, particularly in Franz Fischer's laboratories at the Kaiser Wilhelm Institute for Coal Research at Mulheim (Ruhr) in collaboration with the Ruhrchemie Company for commercialization of FT processes. At those times strategic arguments for liquid fuel production from coal exceeded economic aspects **[Schulz, 1999]**.

The period (1945-1955) was featured by passed world war two reorientation.

- Evaluation of German FT activities by Storch, Golumbic and Anderson during the war times at the US Bureau of Mines **[Storch et al., 1951** and **Pichler et al., 1957]**.
- Development of new FT processes.
  ** Fluid bed process, Brownsville plant, US,
  ** Circulating catalyst process, Kellogg, US,
  ** Arge (Ruhrchemie-Lurgi) process with a fixed bed, multi-tubular reactor,
  ** Slurry process by Kolbel/Rheinpreuben,
  ** Building and improvement of FT plants in South Africa.

At that time large reserves of coal, increasing demands for liquid fuels and less optimistic forecasts for oil reserves stimulated the interest in FT synthesis. However, soon the discovery of big oil fields, e.g. in Saudi Arabia, Alaska, the North Sea and other areas changed the scenario.

In the 15 years period (1955-1970) before the oil embargo, the world energy scene was governed by a plenty and cheap oil supply. In consequence, only marginal interest in FT synthesis survived with a few scientifically interested groups continuing their research, the exception being the South African FT industry at Sasol, the international embargo of South Africa's apartheid regime motivated that motion to create a 150,000-bbl/day FT synfuels industry **[Schulz, 1999]**.

Energy programs in the US, Japan and Europe enforced the development of coal- based FT processes. Coal and heavy oil power plants with a first integrated gasification and gas-cleaning step were considered to simultaneously produce clean syngas for methanol and FT synthesis. The production of olefins C_2 - C_4 by FT synthesis was a target within the German energy research program **[Schulz, 1999]**.

The reserves of natural gas have increased and a significant portion of this has been assigned stranded **[Agee, 1998].** Such stranded gas from remote locations can be converted into shippable hydrocarbon liquids by means of FT synthesis. Present areas with a high potential for an early implementation of FT synthesis are the European North Sea, the US state Alaska and countries around the Arabian Gulf, particularly Qatar with its large natural gas and its shrinking petroleum reserves. In Japan and in US- in consequence of environmental demands also FT synthesis to produce clean diesel via syngas from residual heavy oils is considered as an outlet for this disliked material. The commercial FT synthesis on the basis of low price coal in South Africa has now been directed towards more valuable olefins instead of gasoline **[Steynberg, 1999]**, since the country has meanwhile access to the world oil market **[Schulz, 1999]**.

Overall Fischer-Tropsch process

Figure 1 shows a block diagram of the overall Fischer-Tropsch process configuration. The commercial process involves three main sections, namely:

synthesis gas production and purification, Fischer-Tropsch synthesis, and product grade-up. These subjects are described in more detail below.

Synthesis Gas Production

Synthesis gas can be obtained from reforming of natural gas with either steam or carbon dioxide, or by partial oxidation. The most important reactions are:

Steam reforming	$CH_4 + H_2O \longleftrightarrow CO + 3H_2$
CO_2 reforming	$CH_4 + CO_2 \longleftrightarrow 2CO + 2H_2$
Partial oxidation	$CH_4 + 1/2\,O_2 \longrightarrow CO + 2H_2$
Water gas shift reaction	$CO + H_2O \longleftrightarrow CO_2 + H_2$

Usually, a combination of synthesis gas production processes is used to obtain synthesis gas with the stoichiometric ratio of hydrogen and carbon monoxide required by the down stream synthesis process.

Fischer-Tropsch Synthesis

The Fischer-Tropsch synthesis section consists of: FT reactors, recycle and compression of unconverted synthesis gas, removal of hydrogen and carbon dioxide, reforming of methane produced and separation of the FT products.

The Fischer-Tropsch product spectrum consists of a complex multicomponent mixture of linear and branched hydrocarbons and oxygenated products. Main products are linear paraffins and α-olefins. The hydrocarbon synthesis is catalyzed by metals such as cobalt, iron, and ruthenium. Both iron and cobalt are used commercially these days at a temperature of 200 to 300 °C and at 10 to 60-bar pressure **[Jager and Espinoza, 1995 and Sie, 1998].**

Product Upgrading and Separation

Conventional refinery processes can be used for upgrading of Fischer-Tropsch liquid and wax products. A number of possible processes for FT products are: wax hydrocracking, distillate hydrotreating, catalytic reforming, naphtha hydrotreating, alkylations and isomerization [**Choi et al., 1996 and 1997**]. Fuels produced with the

FT synthesis are of a high quality due to a very low aromaticity and zero sulfur content.

The diesel fraction has a high cetane number resulting in superior combustion properties and reduced emissions. New and stringent regulations may promote replacement or blending of conventional fuels by sulfur and aromatic free FT products **[Gregor, 1990 and Fox, III, 1993]**. Also, other products besides fuels can be manufactured with Fischer-Tropsch in combination with upgrading processes, for example, ethene, propene, α-olefins, alcohols, ketones, solvents, specialty waxes, and so forth.

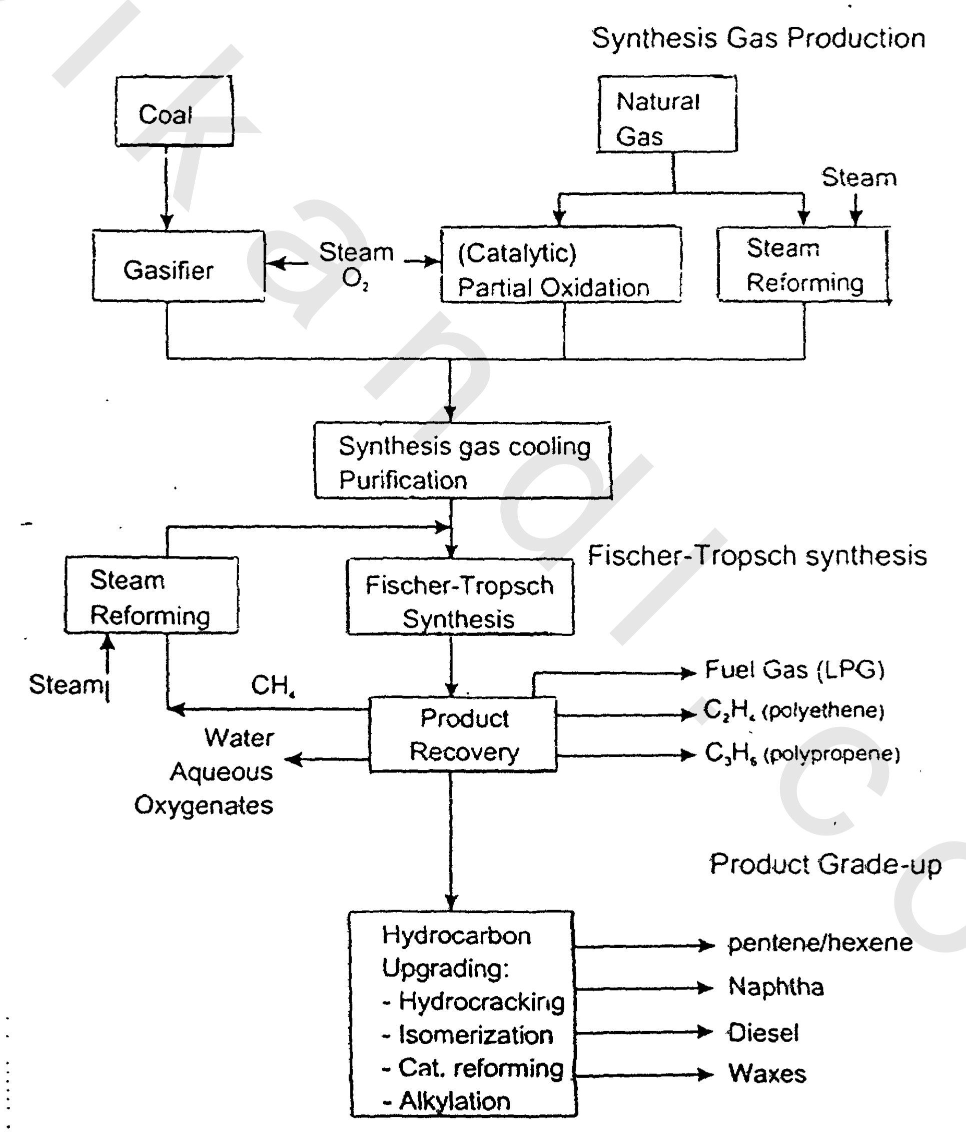

Figure 1 Overall process scheme for Fischer-Tropsch synthesis.

Several factors are converging to drive the growth in the GTL industry: **[Fleisch et al., 2002]**

(1) Desire to monetize existing stranded gas reserves;

(2) Energy companies keen to gain access to new gas resources;

(3) Market demand for cleaner fuels and new cheaper chemical feedstocks;

(4) Rapid technology development by existing and new players;

(5) Increased interest from gas rich host governments.

Egypt has witnessed recently a significant increase in natural gas reserves. Besides using natural gas as fuel, other projects e.g. production of liquefied natural gas for exportation, production of petrochemicals, and GTL are considered for adding value to natural gas. GTL produces ultra clean gasoline and middle distillates with zero sulfur and aromatics content.

Slurry bubble column reactors for Fischer-Tropsch synthesis are receiving increasing interest as the choice of any new large scale unit because of its favorable properties. Design and operation of this type of reactors requires through understanding of the complex phenomena taking place such as hydrodynamics and reaction kinetics.

The present work is an attempt to understand the design basis for the slurry bubble column reactor chose among the mathematical models and apply this model for predicting the reactor performance.

Also energy conservation in Fischer-Tropsch synthesis will be handled so as to achieve maximum energy recovery.