# REVIEW ON DIFFERENT TECHNOLOGIES FOR COAL LIQUEFACTION

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**Abstract -** *Our modern world depends upon transportation and electricity. We can't imagine our lives without both. Transportation and electricity mainly depends on crude oil. But as the demand of crude oil is increasing, prices of oil are also increasing and there is shortage of crude oil. So it has created an interest in alternative fuels. CTL (coal-to-liquid) is the technology which will reduce dependence on crude oil as we will able to produce fuel from coal. In this paper we will be discussing about various technologies from which we can make fuels from coal. The various technologies used are Pyrolysis, Direct Coal Liquefaction, Indirect Coal Liquefaction, Bio-Liquefaction. CTL is not a feasible solution for the shortage of crude oil but it will be a minor contribution to overcome the shortage of crude oil and will help in dropping down the prices of crude oil.*

***Key Words*: Pyrolysis, Direct Coal Liquefaction, Indirect Coal Liquefaction, Bio- Liquefaction**

## 1. INTRODUCTION

The oil price has risen dramatically over the last few years. Alternative liquid hydrocarbon fuels can be obtained from various feed-stocks, ranging from solids to gases. Coal-to-Liquids (CTL) is a technology based on the liquefaction of coal using three basic approaches; Pyrolysis, direct coal liquefaction (DCL) and indirect coal liquefaction (ICL). Gas-to-Liquids (GTL) and Biomass-to-Liquids (BTL) are related options, based on feedstock other than coal. Generally, synthetic fuel properties can be made almost identical to conventional petroleum fuels [1].

## 2. HISTORY

CTL is an old technique, developed at the beginning of the 20th century and has recently attracted attention once more. Historically, it helped to fuel the German military during two world wars. CTL-technologies have steadily improved since the Second World War. Technical development has resulted in a variety of systems capable of handling a wide array of coal types. However, only a very small number of commercial enterprises based on generating liquid fuels from coal have been undertaken, most of them based on ICL-technology. The most successful is the South African company Sasol, originally created as a way to protect the country's balance of payment against the increasing dependence on foreign oil. A new DCL plant has recently become operational in China, possibly marking the beginning of a new era [1].

## 3. PYROLYSIS

The oldest method for obtaining liquids from coal is high temperature pyrolysis. Typically, coal is heated to around 950° C in a closed container. The heat causes decomposition and the volatile matter is driven away, increasing carbon content. This is similar to the coke-making process and accompanying tar-like liquid is mostly a side product. The process results in very low liquid yields and upgrading costs are relatively high. Coal tar is not traditionally used as a fuel in the transportation sector. However, it is used worldwide for manufacturing roofing, waterproofing and insulation products and as a raw material for various dyes, drugs and paints. Mild temperature pyrolysis uses temperatures of 450-650 °C. Much of the volatile matter is driven off and other compounds are formed through thermal decomposition. Liquid yields are higher than for high temperature pyrolysis, but reach a maximum at 20% . The main product is char, semi-coke and coke (all smokeless solid fuels). This technique has mostly been used to upgrade low-rank coals, by increasing calorific value and reducing sulphur content [1].

The Karrick process is a low temperature carbonization process that also yields liquids. The main product is, however, semi-coke. The tar liquids produced require further refining before they can be used as a transportation fuel.

In summary, pyrolysis provides low liquid yields and has inherently low efficiency. Furthermore, the resulting liquids require further treatment before they can be used in existing vehicles. A demonstration plant for coal upgrading was built in the USA and was operational between 1992 and 1997. However, there is little possibility that this process will yield economically viable volumes of liquid fuel. Consequently, further investigation and analysis of coal Pyrolysis is not undertaken.

## 4. DIRECT COAL LIQUEFACTION

This process is built around the Bergius-process, where the basic process dissolves coal at high temperature and pressure. Addition of hydrogen and a catalyst causes "*hydro-cracking*", rupturing long carbon chains into shorter, liquid parts. The added hydrogen also improves the H/C-ratio of the product. Liquid yields can be in excess of 70% of the dry weight coal, with overall thermal efficiencies of 60-70% .The resulting liquids are of much higher quality, compared to pyrolysis, and can be used unblended in power generation or other chemical processes as a synthetic crude oil (syncrude). However, further treatment is needed before they are usable as a transport fuel and refining stages are needed in the full process chain. Refining can be done directly at the CTL-facility or by sending the synthetic crude oil to a conventional refinery. A mix of many gasoline-like and diesel-like products, as well as propane, butane and other products can be recovered from the refined syncrude. Some smaller pilot-plants and testing facilities have provided positive results. In 2002, the Shenhua Group Corporation, the largest state-owned mining company in China, was tasked with designing and constructing the world's first DCL commercial plant in Inner Mongolia Autonomous Region, which recently became operational [2].

## 5. INDIRECT COAL LIQUEFACTION

This approach involves a complete breakdown of coal into other compounds by gasification. Resulting syngas is modified to obtain the required balance of hydrogen and carbon monoxide. Later, the syngas is cleaned, removing sulphur and other impurities capable of disturbing further reactions. Finally, the syngas is reacted over a catalyst to provide the desired product using FT-reactions.

Alteration of catalysts and reaction conditions can create a wide array of different products. For instance, methanol is one possible product that can be produced directly or further converted into high quality gasoline via the Mobil process in additional stages. In general, there are two types of FT-synthesis, a high temperature version primarily yielding a gasoline-like fuel and a low temperature version, mainly providing a diesel-like fuel. More details on FT-synthesis via ICL-technology have been discussed by others [1].

Sasol in South Africa owns the only commercial-scale ICL plants currently in operation with well established and proven technology and together with a lot of operational experience. In total, Sasol has over 50 years of experience of

ICL and has produced over 1.5 billion barrels of synthetic oil during its existence. A number of different ICL-technologies have been developed by Sasol, the oldest ones date from the 1950s and was used to late 1980s. Today, advanced technologies from the 1990s are utilized, including the Sasol Advanced Synthol High Temperature FT-synthesis and the Sasol Slurry Phase Distillate Low Temperature FT-synthesis.

## 6. BIO-LIQUEFACTION

Coal is the main energy resource of China, which accounts for 91% of Chinese annual energy consumption and 70% of Chinese total fossil energy reserves .For a long time, coal will still keep dominating Chinese energy market .Among different coal types, lignite is an important fossil energy resource in China. By the end of 1995, proved recoverable reverses of Chinese lignite was 130 billion tons, accounting for more than 13% of total coal reserve in China, and 190 billion tons according to the third nationwide coal prediction [4]. However, compared with bituminous and high rank coal, lignite has some disadvantages, such as high ash content (~21.9%), high water content (~35%), high sulfur content (for example, it is over 4.5% in Hainan lignite, China), low heating value (for example, it is only 19.39 MJ/kg of Enogene), degradation under windy conditions, and spontaneous combustion.

Thus, lignite application is difficult and limited .So far, lignite is mainly utilized by combustion to produce electricity or by pyrolysis to generate combustion gas. Those processes, however, not only require high input energy but also produce air pollutants such as sulfide and nitrogen oxides. Therefore, it is necessary to develop a new technology to utilize lignite economically and environmentally.

Bio-liquefaction of lignite to liquid fuel/chemicals is a potential technology, where lignite is liquefied by microorganism at ambient conditions without generation of air pollutants. In the 1980s, German researcher Fakoussa reported that microorganism showed the ability of liquefying lignite at room temperatures. Later, more microorganisms with this ability were found and confirmed world widely by other researchers. Literatures showed that both bacterial and fungal were able to liquefy lignite. Bacteria include Bacillus cereus. Fungal include Streptomyces badius, Polyporus versicolor and Trichoderma atroviride. But, in our previous research, above microorganism could not liquefy Chinese lignite, so our research group isolated another microorganism, fungus AH, from decaying wood from Fushun Mine in China to liquefy Chinese lignite [7].

## 7. COMPARISON OF DCL & ICL

The main candidates for future CTL-technology are DCL and ICL. In essence, DCL strives to make coal liquefaction and refining as similar to ordinary crude oil processing as possible by creating a synthetic crude oil. By sidestepping the complete breakdown of coal, some efficiency can be gained and the required amount of liquefaction equipment is reduced. Coal includes a large number of different substances in various amounts, several unwanted or even toxic. Some substances can poison catalysts or be passed on to the resulting synthetic crude oil. Ever-changing environmental regulations may force adjustment in the DCL process, requiring it to meet new regulatory mandates, just as crude oil processing has to be overhauled when new environmental protocols are introduced [1].

In comparison, ICL uses a "*designer fuel strategy*". A set of criteria for the desired fuel are set up and pursued, using products that can be made in FT synthesis. Many of the various processes will yield hydrocarbon fuels superior to conventional oil derived-products. Eliminating inherent noxious materials in coals is not just an option; it is a must to protect the synthesis reactor catalysts. Far from all ICL-derived products are better than their petroleum-derived counterparts when it comes to energy content or other characteristics. However, all ICL fuels are inherently clean and virtually free from nitrogen, sulphur and aromatics, generally giving lower emissions when combusted [7].

Comprehensive comparison between DCL and ICL has been performed by other studies. In general, it is not easy to compare them directly, as DCL yields unrefined syncrude while ICL usually results in final products. ICL has a long history of commercial performance, while DCL has not. Consequently, the economic behavior of a DCL-facility has only been estimated while ICL-analyses can rely on actual experience.

**Table -1:** Typical properties of DCL and ICL final products.

| | DCL | ICL |
|---|---|---|
| Distillable product mix | 65% diesel, 35% naphtha | 80% diesel, 20% naphtha |
| Diesel Cetane Number | 42-47 | 70-75 |
| Diesel sulphur Content | <5 ppm | <1 ppm |
| Diesel Aromatics | 4.8% | <4% |
| Diesel specific Gravity | 0.865 | 0.780 |
| Naphtha octane number (RON) | >100 | 45-75 |
| Naphtha sulphur Content | <0.5 ppm | Nil |
| Naphtha Aromatics | 5% | 2% |
| Naphtha specific gravity | 0.764 | 0.673 |

## 8. CONCLUSIONS

ICL seems to be the more likely option for future CTL-projects, based on its higher flexibility, better environmental capabilities and stronger supporting experience and infrastructure. Furthermore, the fuel properties seem to benefit ICL compared to DCL, especially if end-use efficiencies are considered instead of just process efficiencies. Estimated costs between the two system types seem similar and do not favor either approach. However, more meticulous economic studies are required for a comprehensive discussion but the lack of commercial DCL experience is problematic.

In our compilation and analysis, we find that the coal consumption is a major factor for CTL feasibility. Significant CTL production requires equally significant coal production and resources. We anticipate that only a few countries or regions can realistically develop a large scale CTL industry. Effectively, CTL will be limited to the dominating coal reserve holders that can divert shares of their production to liquefaction.

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