

## 1: New Approaches to Reaction Engineering for Direct Coal Liquefaction | Faculty of Engineering

*Processes for direct coal liquefaction by solvent extraction are considered along with the structure and properties of coal and the mechanism of coal liquefaction, heteroatom removal during.*

This plant operated from to In this process, coal is mixed with a recycle solvent and iron catalyst. After preheating and pressurizing, H<sub>2</sub> is added. In this process, coal is mixed with a recycled solvent and a synthetic iron-based catalyst; after preheating, H<sub>2</sub> is added. The produced oil has low quality and requires intensive upgrading. First tests were implemented at the end of A second and longer test campaign was started in October The oil produced had properties that were unique when compared to other coal oils; it was lighter and had far fewer heteroatom impurities. The process was scaled-up to the 6 ton per day level, but not proven commercially. Indirect conversion processes[ edit ] See also: In the first stage, coal is converted into syngas a purified mixture of CO and H<sub>2</sub> gas. In the second stage, the syngas is converted into light hydrocarbons using one of three main processes: Fischerâ€™Tropsch synthesis, methanol synthesis with subsequent conversion to gasoline or petrochemicals , and methanation. Fischerâ€™Tropsch is the oldest of the ICL processes. In methanol synthesis processes syngas is converted to methanol , which is subsequently polymerized into alkanes over a zeolite catalyst. Based on this methanol synthesis, China has also developed a strong coal-to-chemicals industry, with outputs such as olefins , MEG , DME and aromatics. Methanation reaction converts syngas to substitute natural gas SNG. Environmental impact of the coal industry Typically coal liquefaction processes are associated with significant CO<sub>2</sub> emissions from the gasification process or as well as from generation of necessary process heat and electricity inputs to the liquefaction reactors, [9] thus releasing greenhouse gases that can contribute to anthropogenic global warming. Especially if coal liquefaction is conducted without any carbon capture and storage technologies. CO<sub>2</sub> emission control at Erdos CTL , an Inner Mongolian plant with a carbon capture and storage demonstration project, involves injecting CO<sub>2</sub> into the saline aquifer of Erdos Basin, at a rate of , tonnes per year. But with their higher carbon footprint, fuels from coal liquefaction face the significant challenge of reducing life-cycle GHG emissions to competitive levels, which demands continued research and development of liquefaction technology to increase efficiency and reduce emissions. Since , the U. Department of Energy and the Department of Defense have been collaborating on supporting new research and development in the area of coal liquefaction to produce military-specification liquid fuels, with an emphasis on jet fuel, which would be both cost-effective and in accordance with EISA Section Every year, a researcher or developer in coal conversion is rewarded by the industry in receiving the World Carbon To X Award. The Award recipient is Mr. The Award recipient is Dr. Coal liquefaction plants and projects[ edit ] World Non-U. Coal to Liquid Fuels Projects [18] [29] Project.

*Direct coal liquefaction has been studied and practiced since the s. It was used in Germany during World War II to produce synthetic fuels when there was no oil allowed into the country. Since.*

Direct coal liquefaction has been studied and practiced since the s. It was used in Germany during World War II to produce synthetic fuels when there was no oil allowed into the country. Since then, it has been studied in the United States and many different technologies have been investigated. Since the US is rich in coal resources, this is one way to be energy independent. Most of the development activity occurred in the s and numerous technologies were studied, the most notable of these being H-Coal, Exxon Donor Solvent, Solvent Refined Coal, and Two Stage Liquefaction. A Brief History of Coal Liquefaction Interest in coal liquefaction has seen several high and low periods over the last 60 years. Direct coal liquefaction starts just prior to World War II by Germany, continues through the s and s with the research by the U. Bureau of Mines, and then hit an extensive pace following the Arab oil embargo of . Since the early s, interest has waned due to the decrease in crude oil prices, but the invasion of Kuwait by Iraq in caused the world to reevaluate their position and think about a national energy policy which will provide incentives to develop U. The largest source of liquid hydrocarbons is crude oil and the United States has found and used up the cheap domestic crude that it once had. When demand exceeds supply, or a political or military action in one of the oil producing countries happens, the price of crude oil will increase. This stimulates alternative fuel options to produce liquid hydrocarbons from domestic energy resources such as coal. Coal liquefaction would be an attractive option for the United States due to the vast coal reserves. As a key component of the national energy strategy, the Shenhua direct CTL project is based in coal-rich Inner Mongolia This trial run made China the only country in the world to have achieved key technologies for 1 million-ton-scale direct CTL production. The trial ended after hours, but Shenhua made improvements so it could conduct a 1,hour trial the following month. However, in June , China announced that the commercial plant had been put on hold due to concerns of economics and greenhouse gas emissions [ 1 ]. Before discussing direct coal liquefaction, it is important to briefly acknowledge the role of indirect coal liquefaction, consisting of coal gasification to synthesis gas hydrogen and carbon monoxide with subsequent conversion to liquid fuels via Fischer-Tropsch synthesis. Sasol runs an indirect coal liquefaction facility in South Africa and produces , barrels per day [ 2 ]. Robinson and Tatterson updated the economics of co-production of diesel fuel and electricity via integrated gasification combined cycle IGCC and identified a number of situations which produce a very attractive return on investment, particularly when the byproduct carbon dioxide is captured and sold for enhanced oil recovery [ 3 , 4 ]. However there have been dramatic improvements in the technology since that have not been widely appreciated. The solvent provides a convenient transportation medium for the coal and enhances heat and mass transfer during chemical reaction. In many processes, the solvent shuttles hydrogen from the gas phase to the coal and is called a donor solvent. The elevated temperature cracks the coal molecules by thermally rupturing carbon-carbon linkages and increases the rate of reaction. High pressure keeps the solvent and products in the liquid phase, prevents coke build-up on the reactor walls and catalyst surface, and promotes hydrogenation by maintaining a high partial pressure of hydrogen. Catalysts are normally used to increase the rates of the desirable reactions which include cracking, hydrogenation, and removal of oxygen, nitrogen, and sulfur. Coal consists of complex macromolecules without repeating monomer units that are built primarily of carbon and hydrogen but also consist of significant amounts of oxygen, nitrogen, and sulfur. The constituent units tend to be mostly substituted aromatics or hydroaromatics and the degree of condensation increases as the coal matures. Coal has a hydrogen-to-carbon ratio which is significantly less than petroleum; converting coal into liquids requires either the addition of substantial amounts of hydrogen or the removal of excess carbon. The coal time line for the 20th century [ 6 ] helps to trace the major events that have occurred in our recent history. Direct coal liquefaction technology developed from work on hydrogenating coal tar by Bergius in Germany in the s [ 7 ]. The first German brown coal was hydrogenated in . In the s, several plants were built in Germany, and one in Billingham, England. Both hydrogenation reactors operated with catalyst and

pressures of 5,â€”10, psig. German capacity increased to the point that during World War II, eight additional plants were built in Germany. In , the installed capacity was over , BSD in 15 plants processing about 50, tons of dry coal per day. All of these efforts were technically successful, but could not compete economically with inexpensive petroleum from the Middle East in the early s. Second generation technology came along in the late s and early s. EDS did use a catalytic stage to hydrotreat part of the recycle solvent in a second reactor but no catalyst was used in the coal liquefaction unit. HRI and was derived from their H-Oil process for petroleum resid upgrading. The basis of the process was a novel catalytic reactor in which the catalyst was ebullated in the liquid phase, similar to the more familiar gas-phase fluidized bed processes used in the petroleum industry. The advantage of this type reactor is that the reactor contents are well mixed helping to alleviate the excessive heat release associated with coal liquefaction plus the ability to add and withdraw catalyst from the reactor while it is operating so that the catalyst activity is maintained at a relatively high and constant level. Department of Energy DOE and a consortium of industrial sponsors built a ton per day pilot plant at Catlettsburg, Kentucky which ran from June to January The plant was a technical success and confirmed yields by smaller scale equipment and a wide variety of mechanical equipment was tested including ebullation pumps, pressure letdown and block valves, and hydroclones to concentrate the solids-containing product. Although the process was not economic, two developments promised further cost reductions. The first was a new catalyst developed by Amoco researchers with a unique bimodal pore size distribution resulting in less catalyst deactivation, and most importantly higher liquid yields. The second improvement came from Chevron Research, a two stage liquefaction scheme which lowered hydrogen consumption by tailoring reaction conditions in each stage to favor the reactions of coal dissolution, hydrogenation of the donor solvent. It was a two stage Solvent Refined Coal process and achieved some major success with the incorporation of a catalytic reactor to hydrogenate the donor solvent and critical solvent deashing, developed by Kerr-McGee. Process Overview of Coal Liquefaction Direct coal liquefaction refers to the direct reaction of coal with hydrogen to form liquids. The hydrogen reacts with oxygen, sulfur, and nitrogen in coal to remove them as water, hydrogen sulfide, and ammonia. Consequently the conversion of coal to petroleum-like products requires direct hydrogen addition and this adds considerable expense to the product. The ideal technology for direct coal liquefaction for gasoline production would: Second-generation liquefaction processes now under development are descendants of the classic Bergius technology. Most involve, more or less, catalyzed interactions between molecular hydrogen and coal-oil slurries of elevated pressure and temperature. Coal liquefaction process summary.

### 3: Energies | Free Full-Text | Reaction Engineering of Direct Coal Liquefaction | HTML

*Processes for direct coal liquefaction by solvent extraction / Y.C. Fu and Y.T. Shah Structure and properties of coal and the mechanism of coal liquefaction / J.A. Gray and Y.T. Shah Heteroatom removal during liquefaction / Y.T. Shah and S. Krishnamurthy Kinetic models for donor solvent coal.*

### 4: Reaction Engineering of Direct Coal Liquefaction - pdf descargar

*Since DCL and FTS are all exothermic reactions and the reaction heat released corresponds to about 20% of the heat of combustion of the product, reaction temperature control and optimal used of the reaction heat are the major challenges in chemical reaction engineering to all coal liquefaction processes.*

### 5: Reaction Engineering of Direct Coal Liquefaction

*Direct coal liquefaction technology developed from work on hydrogenating coal tar by Bergius in Germany in the s. A major improvement was the development of sulfur-resistant hydrogenation catalyst by Pier in BASF's laboratories in Ludwigshaven, Germany in*

## 6: EconPapers: Reaction Engineering of Direct Coal Liquefaction

*Abstract Processes for direct coal liquefaction by solvent extraction are considered along with the structure and properties of coal and the mechanism of coal liquefaction, heteroatom removal during liquefaction, kinetic models for donor-solvent coal liquefaction, the design of coal liquefaction reactors, and the refining of coal liquids.*

## 7: Coal liquefaction - Wikipedia

*Oct 29, Reaction Engineering of Direct Coal Liquefaction Ken K Robinson Mega Carbon Company, 5N Jens Jensen Lane, St Charles, IL ,nbspOct 29, Direct coal liquefaction has been studied and practiced since the s It was used in Germany during World War II to produce synthetic fuelsnbsp Reaction Engineering of Direct Coal.*

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*Direct coal liquefaction refers to the direct reaction of coal with hydrogen to form liquids. The hydrogen reacts with oxygen, sulfur, and nitrogen in coal to remove them as water, hydrogen sulfide, and.*

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