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A Historical Analysis of the Coal Liquefaction Technology Development in China

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Abstract

During 10th 5-year plan (2001-05) China succeeded to develop the coal liquefaction technology and completed the construction of a large-scale commercial plant of 1million tons per year in Ordos, Inner Mongolia in 2008. This is the first commercial large-scale coal liquefaction plant by the direct liquefaction method in the world. Historically technology to produce oil from coal, namely coal liquefaction technology was developed before and during WW II for the first time by Germany and then by Japan. Both Germany and Japan were poor in oil resources but rich in coal resources. Both countries needed oil for the war and tried to produce oil from coal. As a result, both counties produced a small quantity of oil but the production cost was very high. After WW II the oil price stayed for a long time in a low level. Neither Germany nor Japan continued the technical development of coal liquefaction technology. In China, however, the situation is different.

Pre-war Japan constructed coal liquefaction plants not only in Japan but also in Manchukuo. Manchukuo was prewar Japanese puppet state in Manchuria. Japan got the Manchurian interests from Russia by the Treaty of Portsmouth in 1905 through the victory of Russo?Japanese War. Pre-war Japan feared that the newly born USSR might come back to Manchuria. Therefore Japan/Manchukuo decided to construct an independent self-sufficient economy in Manchuria for the possible war with USSR. Thus Japan/Manchukuo constructed 5 coal liquefaction plants in Manchukuo.

The coal liquefaction technology was inherited to the new China and the coal liquefaction technology development in China is originated from the pre-war R&D works in Manchukuo. The coal liquefaction technology development was restarted in China soon after beginning of the new open-door policy through the cooperation of China and Japan. In this paper the technological development of coal liquefaction in China is analyzed historically from the Manchukuo days up to now.

Keywords: Coal Liquefaction, China, Manchukuo, Direct Liquefaction, NEDO, Energy Policy, Hydrogenation Technology, Ordos Plant, Environmental Issues, Historical Analysis.

Introduction

During 10th 5-year plan (2001-05) China succeeded to develop the coal liquefaction technology and completed the construction of a large-scale commercial plant of 1million tons per year in Ordos, Inner Mongolia in 2008. This is the first commercial large-scale coal liquefaction plant by the direct liquefaction method

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Pre-war Japan constructed coal liquefaction plants not only in Japan but also in Manchukuo. Manchukuo was prewar Japanese puppet state in Manchuria. Japan got the Manchurian interests from Russia by the Treaty of Portsmouth in 1905 through the victory of Russo-Japanese War. Pre-war Japan feared that the newly born USSR might come back to Manchuria. Therefore Japan/Manchukuo decided to construct an independent self-sufficient economy in Manchuria for the possible war with USSR. Thus Japan/Manchukuo constructed 5 coal liquefaction plants in Manchukuo. The coal liquefaction technology was inherited to the new China and the coal liquefaction technology development in China is originated from the pre-war R&D works in Manchukuo. The coal liquefaction technology development was restarted in China soon after beginning of the new open-door policy through the cooperation of China and Japan. In this paper the technological development of coal liquefaction in China is analyzed historically from the Manchukuo days up to now.

Coal Liquefaction Plants of Manchukuo Inherited by the New China

Japan's oil resource has been very poor and pre-war Japan sought to produce oil from coal not only in Japan but also in Manchukuo. Five coal liquefaction plants were constructed in the days of Mnchukuo, namely in Fushun, Jilin, Mukden, Sipingjie and Jinzhou. There are three methods in the coal liquefaction technology. They are direct liquefaction method, indirect coal liquefaction method and low temperature dry distillation method. Direct liquefaction method is to change coal to oil by adding hydrogen under the high temperature (400-450°C) and high pressure (200-300 atmospheric pressure) conditions with the help of catalyst.

Indirect liquefaction method is to change coal to oil by changing first to the mixed gas of hydrogen and carbon monooxide then change the gas to oil with the help of catalyst. Low temperature dry distillation method is technically easy but field of use of the produced oil is quite limited. Therefore R&D work of Japan was devoted mostly to direct liquefaction method, since the energy efficiency of direct liquefaction method is better than indirect method but it is more difficult technologically.

In the new China which was established in 1949 Fushun plant became the technical center of hydrogenation and the oil refinery plant, Jilin plant was converted to methanol plant, Mukden plant was converted to chemical plants including agricultural chemicals, Sipingjie plant was converted to chemical plants including carbide and PVC and Jinzhou plant was utilized as the coal liquefaction plant by the indirect method.

Table 1: briefly shows the technologies of the five plants and how the new China inherited and made use of them.

Table 1 Coal liquefactiion plants Manchukuo inherited by the new China

Location	Process	Inherited as
Fushun, Liaoning Province	D	oil refinery plant and technical center of hydrogenation
Jilin, Jilin Province	D	converted to methanol plant
Mukuden, Liaoning Province	D	converted to chemical plants including agricultural chemicals
Sipingjie, Jilin Province	LTDD	converted to chemical plants including carbide and PVC
Jinzhou, Liaoning Province	I	coal liquefaction plant by the indirect method

Remark: D, I and LTDD in Process colum mean direct liquefaction method, indirect liquefaction method and low temperature dry distillation method respectively.

Source: Mine (2009), *Manchuguo's Industry Inherited by the New China*, Ochanomizushobo

Among the above five plants Fushun plant was the one the pre-war Japan spent national resources mostly to develop the technology. Hydrogen adding, namely hydrogenation is the key process of the direct liquefaction technology and this hydrogen adding technology of Fushun plant was inherited to the new China. This is because Daqing oil is very heavy and because the property of Daqing oil is quite similar to the property of coal. Daqing oil had been the major oil of China covering more than half of the national demand at that time, and hydrogen adding technology of Fushun contributed a lot to the processing of the heavy Daqing oil. Thus, Fushun became the technical center of China's hydrogen adding technology. China continued to develop the hydrogen adding technology even in the days of Mao Zedong for the processing of the heavy Daqing oil.

Jinzhou plant was the only plant used as the coal liquefaction plant by the new government of China. When Daqing oil field was discovered, however, Jinzhou plant was also converted to the chemical plants including phenol, carbide, PVC etc. This is because the production cost of oil from Jinzhou plant was very high. As a result, coal liquefaction technology was not developed in the days of the planning economy.

A Proposal to China by Manchukuo Engineers

In 1978 China adopted the new policy of economic reform and open door. In 1979 the central government of China dispatched a delegation headed by Wang Xinsan to Japan requesting the technical cooperation for the modernization of Chhna. Wang Xinsan was the man responsible during 1949-1952 for the reconstruction of Fushun industrial complex, the central industrial regions of Manchukuo. Owing to the successful reconstruction

of Fushun industrial complex he was promoted to the central government. He had co-worked intimately with "Ryuyo" engineers for the economic reconstruction of the new China and he highly evaluated the technical development ability of "Ryuyo" engineers.

Wang Xinsan met "Ryuyo" engineers with whom worked together for the economic reconstruction of Fushun during 1949-1952 and he asked them to cooperate once again for China's new policy of economic reform and open-door policy. "Ryuyo" engineers agreed to accept the request of Wang Xinsan and visited China with the proposal for the modernization of China. Coal liquefaction is one of the projects proposed to China with a special emphasis. China accepted this proposal and asked Japanese government to cooperate with China in developing coal liquefaction technology. Japanese government agreed to cooperate with China to develop the technology, assigning NEDO (New Energy Development Organization) for cooperation.

Technical Cooperation by NEDO

May 1980 Minister Sasaki of MITI (Ministry of Industry and Trade) of Japan visited China and agreed to cooperate with China on the joint study of developing the coal liquefaction technology. Because of the oil crises at that time Japan draw up a plan called Sunshine Project in 1974 and newly organized NEDO in 1980 for solution of energy problem of Japan. R&D work of the coal liquefaction was restarted by NEDO and NEDO was assigned to the joint coal liquefaction technology development collaboration with China.

NEDO and CCRI (China Coal Research Institute) signed in November 1981 the agreement on the joint research of the coal liquefaction technology development. In 1983 NEDO donated 0.1 t/d laboratory plant in Beijing Coal Science Institute of CCRI. NEDO and CCRI had a joint study of performances of 27 kinds of coal using the 0.1 t/d laboratory plant of Beijing Coal Science Institute and cumulatively total 43 Chinese engineers were invited to Japan and cumulatively total 15 Japanese engineers visited China to help the operation of 0.1 t/d laboratory plant of Beijing Coal Science Institute.

In November 1998 NEDO was requested by Shenhua to collaborate Shenhua's coal liquefaction business development. A joint feasibility study of coal liquefaction business using Shenhua coal was signed between NEDO and Shenhua in 1999 and Shenhua coal was examined using NEDO's new 1 t/d process development unit plant in Kimitsu, Japan. In March 2000 NEDO submitted feasibility study report to Shenhua.

At the same time Shenhua requested HTI (Hydrocarbon Technology Institute) of the United States, besides NEDO, to cooperate with Shenhua's coal liquefaction business development. HTI agreed with Shenhua's request and submitted also in 2000 a feasibility study report based on the financial support by DOE (Department of Energy) of the United States.

In the 10th 5-year plan (2001-05) China decided to construct a coal liquefaction plant. Three feasibility studies were conducted including Shenhua. Two others were Xianfeng coal of Yunnan Province with cooperation of Ruhr Khole of Germany and Yilan coal of Heilongjiang Province with cooperation of JICA (Japan International Cooperation Agency) and NEDO of Japan. Finally, Shenhua project was selected among the three. China does not mention to Japan's cooperation of this kind because of pre-war Japan's invasion into China. However, a reference book of China describes the situation as follows :

The fundamental research work of coal liquefaction technology in China was conducted during 6th 5-year plan (1981-85) and 7th 5-year plan (1986-90) and China succeeded in achieving PDU (Process Development Unit) through the 20 years collaboration with the foreign firm. The books published in China do not describe the technical assistance and/or cooperation done by Japan due to the pre-war Japan's invasion to China. It seems that China may consider such assistance and/or cooperation done by Japan as a part of the postwar reparations. Cooperation by NEDO was done surely for 20 years (1980-2000). Therefore, it is quite reasonable to regard "the foreign firm" written in the reference book of China as NEDO of Japan. China succeeded to increase capacity of 1 ton per day NEDO process to 6 tons per day without the help of NEDO. Then China also succeeded in the pilot plant of 150 tons per day by herself. Then Shenhua started to construct a new coal liquefaction plant with the capacity of 1milliion tons per year in Ordos, Inner Mongolia in 2005.

Successful Construction of the Large-scale Commercial Plant

It is very lucky that I have visited May 2019 this coal liquefaction plant in Ordos together with Dr. R. Ashida of Kyoto University, owing to the kind arrangement by Mitsui Chemicals Beijing Office. Ordos plant is principally disclosed to foreigners. But China seemed to have propagated a good Japan-China relation since Sino-US conflict has been intensified, according to Mitsui Chemicals Beijing Office. Dr. R. Ashida is an excellent scientist highly evaluated as the excellent researcher of the direct method coal liquefaction both in Japan and in the United states. Mitsui Chemicals Beijing Office succeeded to arrange "Japan- China round table conference" on the direct method coal liquefaction technology in Ordos .

(Photos 1)

Round Table Discussion at the Meeting Room of Ordos

Remark: Author (Right side the third from the front), Dr. Ashida (Right side the second from the front) and General Manager Mr. Wang (Left side the third from the front)
Source:https://mp.weixin.qq.com/s?__biz=MzUyNjQ4OTcyNA==&mid=2247486603&idx=1&sn=e3015c5ff104de79209c0d5d3f508c1c&chksm=fa0f4d98cd78c48e1c61b79da9a73434285f8304baf866220e4b4b4c3c22ffe6d43b3c10b892&mpshare=1&scene=1&srcid=&exportkey=AZ0RgR9y%2B5f81%2BrMBGZQNRs%3D&pass_ticket=0WbLNk66tk9B%2FxEWqCUVU9i9FkaBpl%2B1HDp1ZjOWS2p3ILgUeCEVIbMJTrW4Ah7M&wx_header=0#rd

(Photos 2)

Display of Waste Water Samples in the Factory

Remark: Author (Front side the third from the right), Dr. Ashida (front side the second from the right) and General Manager Mr. Wang (Front side the third from the left)

Source:https://mp.weixin.qq.com/s?__biz=MzUyNjQ4OTcyNA==&mid=2247486603&idx=1&sn=e3015c5ff104de79209c0d5d3f508c1c&chksm=fa0f4d98cd78c48e1c61b79da9a73434285f8304baf866220e4b4b4c3c22ffe6d43b3c10b892&mpshare=1&scene=1&srcid=&exportkey=AZ0RgR9y%2B5f81%2BrMBGZQNRs%3D&pass_ticket=0WbLNk66tk9B%2FxEWqCUVU9i9FkaBpl%2B1HDp1ZjOWS2p3ILgUeCEVIbMJTrW4Ah7M&wx_header=0#rd

According to General Manager Mr. Wang of Ordos plant, construction started in 2005 and mechanical completion was December 2008. After 3 years of the technical improvement the new plant has been operating well up to now. After the discussion meeting in the room (Photo 1) Mr. Wang kindly showed us around the factory but photography prohibited. He told that the quality of waste water was very bad at the beginning time of trial run. But the waste water problem was settled through additional investments supported by the central government. Currently the waste water is changed into the pure water and reused for the boiler. The waste water is drinkable now (Photo 2).

The Rise of an Environmental Issue

The direct liquefaction method has been considered to be the best technology for a long time because of the energy efficiency of the process. Both pre-war Germany and Japan constructed coal liquefaction plants using direct liquefaction method but the production cost was very high and production amount was very small. Since the oil price had long been at low level after the war, coal liquefaction had not been economically feasible. We can say that China was the only nation that continued for 30 years the data accumulation of hydrogen adding, the key technology of direct liquefaction method, because of the necessity of processing the heavy Daqing oil.

Owing to the new policy of economic reform and open-door policy, China newly started the coal liquefaction technology development by direct method and spent national resources for the technology development for another 30 years. Finally, China succeeded in the commercial production of oil from coal partly due to the high oil price.

A new problem arises, however, despite the success of the 30 years technical development of the direct liquefaction method. It is environmental problem. Coal contains a lot of impurities other than hydrogen, oxygen and carbon. Waste water contains these impurities and large-scale production by the direct liquefaction method results in the enormous tonnage of waste water full of impurities. Environmental regulation in China has been severe year by year and the cost of removing the impurities from the waste water has become increased a lot. On the other hand, oil production by the indirect liquefaction method does not accompany the waste water full of impurities because impurities were removed easily during the process of gasification. Therefore, all of the succeeding coal liquefaction plants adoped indirect method.

Table 2: shows such coal liquefaction projects in 2014. Among the projects of Table 2 several plants already started commercial operation including Yulin of Shanxi Province and Shenhua Ninxia of Shanxi province.

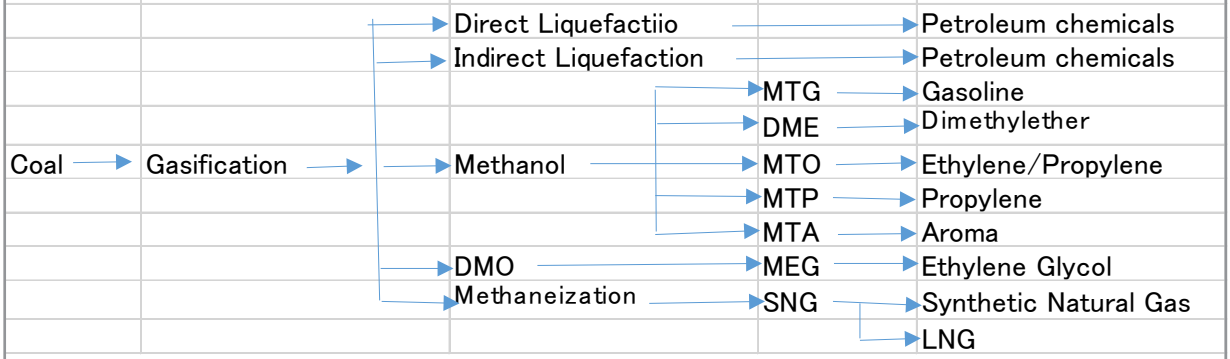
Table 2 Coal liquefaction projects of China by indirect method in 2014

company	location	capacity (1,000t/y)
Shenhua Ninmei	Ninxia	4,000
Yulin	Shanxi	1,000
Dalu	Neimenggu	2,000
Yufu	Guizhou	2,000
Yili	Xinjiang	1,000
Luan	Shanxi	1,000
Jingneng	Neimenggu	500
Hanjinqi	Neimenggu	1,000
Ganquanbao	Xinjiang	2,000

Source: Information Center of China Chemical Industry (2016), "Coal chemicals", *China Chemical Industry Yearbook*

Table 3: shows the recent development of new coal chemicals in China. The remarkable achievement is to produce various kinds of petrochemicals, including olefines, aroma, etc. from methanol. Nowadays many MTO, MTP, MTA, MEG plants are in operation mainly in the inland district of China, producing mostly TPA and MEG for the polyester fiber.

Table 3 New coal chemicals in China



Source: JPEC (2014), "Reviving coal liquefaction projects of China due to deregilation", *JPEC Report 2014*, No. 9

It seems that China's success in the technical development owes much to the petrochemical technology which has been developed after WW II. Both Germany and Japan were late comers in petrochemicals and petrochemical companies of Germany and Japan did not have an interest in coal liquefaction. Development of the world petrochemical industry after WW II has been brought mostly by US companies, and US companies including HTI and Mobil were said to have contributed a lot to the development of coal liquefaction technologies in China.

In summary China newly started to develop coal liquefaction technology with the help of Japan in early 1980's, and continued to catch up during 1980's and 1990's obtaining collaboration of Germany and USA besides Japan. China has succeeded in catching up the pre-war technical level of Japan and Germany during 1980's and 1990's and finally surpassed Japan, Germany and USA in 21st century.

References

1. Ashida, R. (2012). Examination of coking behavior of coking coal and binder through characterization utilizing high temperature solvent fractionation. Journal of the Japan Institute of Energy, 91(1), 48-55.
2. Ashida, R. (2017). Production of metallurgical coke utilizing low-rank coals upgraded by solvent treatment. ISIJ International, 57(1), 37-40.
3. Wasaka, S. (2002). Study on coal liquefaction characteristics of Chinese coals. Fuel, 81, 1551-1557.
4. Wasaka, S. (2003). The influence of hydrodynamics on the NEDOL coal liquefaction reaction. Energy & Fuels, 17, 412-418.
5. Mine, T. (2019). A historical analysis of the coal liquefaction technology development in China. Paper presented at the 12th International Conference on the History of Chemistry (ICHC12), Maastricht, The Netherlands.