Analysis of Current Situation and Trend of Modern Coal Chemical Technology

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Abstract: The rapid development of modern coal chemical enterprises and progress in the technical research and application demonstrate the great potential of the industry. For example, they have been strong performers in manufacturing substitute natural gas, coal-to-liquids and coal-based chemicals, boosting demands for its products. The scale of medium and large enterprises indicates a satisfied overall situation with promising future. The paper discussed the technical development of the modern coal chemical industry in general and the future of the industry.

1. Introduction
Modern coal chemical industry is based on the traditional coal chemical technology with a high demand for cleaning, utilization and efficient transformation of coal. It is a new industry featuring high efficiency, high yield and high quality. As early as in the "12th Five-year" period, China has proposed adjustment of external oil dependency and new standards on natural gas price and chemical cost, hoping to upgrade the diversified development paths of raw material industry by utilizing modern coal chemical technology. Meanwhile, conditions for industrialization were clarified to ensure effective transformation and upgrading of the coal chemical industry. Furthermore, it was also proposed that modern coal chemical technology should be eco-oriented, reflecting multiple considerations concerning all fields and areas.

2. Current development of modern coal chemical technologies in China
China's modern coal chemical industry is on the track of rapid development on a large scale. However, there are prominent problems along the way, including weak competitiveness of low oil price, increasing pressure of environmental protection and severe constraint of water resources, which seriously hinder the development of the industry and subject itself to criticism from the public. In the context of the new economic normal, new topics and new technological positioning have emerged centering on the development of modern coal chemical industry, offering guidance for the sustainable development of the nation's modern coal chemical industry.

(1) Development of coal-to-liquids technology industry
During the 12th Five-year Plan period, China has built a complete coal-to-liquids chemical technology system, including direct and indirect liquefaction of coal as well as medium-low temperature hydrogenation of tar. Rich experiences have been accumulated in the construction, design and operation of large-scale CTL projects, and there has been significant improvement of technical level of domestic equipment. Under such circumstances, the scale of direct coal liquefaction industry has reached more than one million tons, making it an influential industry integrating fancy technologies, thus solving the problem of high concentration sewage treatment while meeting and the
national standards of gas, liquid and solid waste discharge. Based on current technology utilization, oil products from direct coal liquefaction are very popular in the market, which are difficult to produce through traditional procedures. These oil products, with independent intellectual property rights, have taken a lead in the world. For example, domestic companies including Inner Mongolia Yitai Group, China Shenhua and Shanxi Jincheng Anthracite Mining Group have successfully established the indirect coal liquefaction system, integrating gasification, purification, air separation, fischer-tropsch synthesis and product processing technologies. The system, featuring rational design, high yield and high quality, ensures long-term stable and safe operation under full load.

(2) Current development of substitute natural gas

Compared with CTL, SNG is still in the early stage of development in China, with several SNG trials putting into practice. The trial results indicated that the SNG has been mature in each individual technology despite technical challenges, including inconsistency between gasification and coal quality in the gasification procedure when lignite is pressurized on the fixed crushed coal bed, gasifier wastewater treatment of fixed bed gasifier as well as difficulties in by-products utilization, etc. Generally, the SNG technology of China is still in the process of upgrading, and there is still plenty of space for optimization in terms of large-scale installations, high conversion efficiency, and emission reductions [1].

(3) Current development of coal-based chemical industry

Coal-based chemical industry is going through rapid development, with seven CTO (Coal to Olefin) trail projects in place, including four DMTO, two MTP and one DMTO-II, all of which have basically upgraded the core CTO technology based on local needs. In addition, school-enterprise cooperation further promoted R&D of such technologies. For example, the well-known Fluidized-bed Methanol to Aromatics (FMTA) adopts ZSM-5 as the catalyst system while the continuous reaction and regeneration system of fluidized bed is adopted in the aromatics structural chemical reactor. In addition, aromatics-based liquid products integrating trimethylbenzene, xylene and benzene could reach a purity of more than 95%. Taking Shaanxi Huadian Yuheng Coal Power Company as an example. The company manufactured the world's first 10,000-ton FMTA full-process industrialized test device, which met various standards with greater quality and efficiency, especially in terms of reducing energy consumption and pollutant emission, though there is still room for improvement [2].

3. Technical requirements for the development of China's modern coal chemical industry

Based on current situation, the coal chemical industry of China features large capacity of production and front-tier technologies, which will be analyzed from the following three main aspects.

(1) Accelerated development of new products and technologies

Domestic enterprises have never stopped the pursuit of new products and technologies, making reckless efforts to achieve this at present stage. After the introduction of numerous technologies from abroad, China is gathering momentum for innovation, as reflected in development of core technologies and engineering projects. However, there are still problems in the practical application of these technologies, such as inconsistency between procedures, device failures and defects in design, which have also become the bottleneck for the development and application of new products and technologies in coal chemical enterprises [3].

On the other hand, stability, energy consumption and economic rationality remain a challenge for large domestic equipment, which is far behind that of developed countries. For example, direct and indirect liquefaction requires huge investment with more complex process, especially in non-processing equipment while some equipment and devices still have relatively rich capacity. Finally, supporting conditions of key equipment, materials and automatic control are not in place, not fully fulfilling the demands for technical innovation.

(2) Constant fall in water and energy consumption

In terms of water and energy consumption, the domestic enterprises keep searching for ways to minimize resources used for production, because the two resources are heavily consumed in traditional procedures. For example, CTL needs as much as 6.0 t/t of water while SNG takes up to 1.0 t/1000m³,
and FMTO 28.0 t/t, a common phenomenon in northeast, northwest, and western China. Shortage of water resources in these regions prevents the development of coal chemical industry. Therefore, the overall development of innovation and conservation technologies for water and energy need to be improved. At present, it seems that the modern coal chemical engineering projects have been completed, with clear procedures and strong capability for energy conservation. For example, the oil consumption of direct million-ton coal liquefaction in Shenhua has decreased from 62.2MJ/t in 2014 to 48.1MJ/t in 2018, and the integrated energy consumption has decreased from 172.1MJ/t in the beginning to 160.0MJ/t. Combined with this key technology, its processing system has been further developed and improved [4].

(3) **Enhanced treatment and disposal of waste water and salt residue**

Wastewater produced by coal chemical projects is relatively complex in composition, so the water treatment generally takes long time. But at present, there is no domestic project preventing leakage of wastewater in the long run. In terms of high-salt wastewater, no enterprise has been able to separate and obtain relatively pure sodium sulfate and sodium chloride, with unclear destination of sewage discharge and more hazardous wastes with mixed salt content. After stabilizing and fixation treatment, landfill is also required, which is costly and demands a vast area of land. At present, the solution to this problem in China is not clear, requiring further improved experimental data verification. In particular, the research and development of environmental protection technology needs to be further strengthened along with integration and optimization of proprietary environmental protection technologies to fundamentally reduce the total emission and solve problems related to environmental protection [5].

4. **Future development of China's modern coal chemical industry**

At present, the development of modern coal chemical technology industry in China still needs to focus on three aspects: CTL, SNG and coal-based chemicals. New technologies should be developed in combination with coal chemical technologies for large-scale engineering projects from the following four aspects.

(1) **Draw experiences from advanced CTL technologies from abroad**

First of all, China's modern coal chemical industry needs to learn more from developed countries. For example, in the direct liquefaction of coal in CTL, the NEDOL technology of Japan could be a model to learn from, which is more suitable to produce bituminous coal combined with circulating solvent hydrogenation to improve production efficiency. The catalyst, made by replaceable natural pyrite and synthetic iron compounds, is environmentally friendly.

In addition, China also learned from IGOR+ solid-liquid separation technology from Germany, which adopted decompression distillation and red mud as the catalyst for coal chemical production. Then the HTI technology in the United States, a three-phase bubbling-bed reactor with full-back mixing of external circulation, uses highly dispersive nano-scale Fe as the catalyst for solid-liquid separation of critical solvent extraction.

While taking advantage of foreign technologies, Shenhua is working hard to upgrade its own procedures of direct coal liquefaction, where ultrafine hydrated iron oxide catalyst is used in the two-stage series full reverse-mixing suspended window reactor couple with super-fine hydrated ferric oxide as the catalyst. And this is the only successful technology in the world, meeting every requirement for optimization. The development of CTO has promoted the rapid progress of China's coal industry, whose products are widely used in the research and development of military low-freezing diesel, aviation kerosene and various rocket kerosene scarce products. For example, the wastewater treatment technology is still in the pilot stage, with the innovation process pressing ahead. As the core technology, it has dismantled the bottleneck hampering cyclist technology home and abroad, and successfully established a system of its own modern coal chemical technologies. By developing fischer-tropsch synthesis of alpha-olefin and synthetic wax, it has bridged technical gaps, paving way for further researches and development of innovative chemical technologies in China [6].
(2) Trend and development of SNG technology

SNG, as a mixture of renewable and unrenewable energy, has a promising future because of its technical features. In the early stage of domestic methanation industry, the R&D of new technologies is gathering momentum, with large-scale domestic projects of methanation catalyst in place at a scale of 5000m³/d in trial projects, which offers an ideal solution to excessive energy consumption in the traditional cycle methane chemical process. At a scale over 1000m³/h, it could fulfill the needs of the industry. Generally, SNG technology is still in the stage of experimental development, heavily reliant on independent development and introduction of key technologies. Taking indirect SNG as an example. Currently, the topso methanation technology, which is made up of 5 reactors and introduced from abroad, uses oxidized nickel-based catalyst. Also, it takes additional steam to ensure that the CH4 content can reach 99.17% and above. The Dalian Institute of Chemical Compounds in China discovered the non-cyclic methanation technology that adopts methanation catalyst, featuring hydrothermal stability under high temperature, strong resistance to carbon accumulation and good performance in catalyst activity and selectivity. After adopting the new non-cycle technology, its capacity of hydrogen-carbon ratio grading regulation has been upgraded. Meanwhile, the institute has independently developed a new high-temperature methane catalyst and methanation reactor, with the CH4 content reaching more than 95%. Moreover, in terms of direct SNG, China has also introduced the catalytic gasification technology of giant energy blue gas from Exxon of the United States, and the hydrogenation and gasification technology of coal from ARCH gas bed of Japan, etc. The products, highly active with strong capacity of high carbonization and deoxidization, can be directly hydrogenated to produce methane with high production efficiency [7].

(3) Optimizing the FMTO technology

During the 13th Five-year Plan period, China's coal chemical industry has developed the integrated C4 technology and DMTO-III based on the DMTO-II process, a new generation of FMTO processing technology. However, the R&D of downstream FMTO products in China are still in the initial stage of development. For example, in the process of α-olefin preparation, Yanshan Petrochemical has an olefin production capacity of more than 50,000 t/a, but it still cannot meet the current market demand. In the future, large-scale production of olefin copolymer and high-density polyethylene will be the key, requiring more efforts to be made in independent development and introduction of technologies, especially in the direct manufacture of aromatic hydrocarbons from syngas to improve thermal balance in the reaction process of methanol to aromatic hydrocarbons when applying direct syngas-based production of aromatics as well as the performance of xylene as a catalyst. At present, there have been in-depth researches on ethylene glycol in FMTO technology by domestic scholars. It has been a future trend to prepare ethylene glycol with oxalate and carry on large-scale production. [8].

5. Conclusion

Modern coal chemical enterprises have introduced various technologies from abroad along with independently researches in order to ensure further development of CTL, SNG, FMTO and MTO technologies. However, there are still a few technologies in domestic coal chemical enterprises that are still in the primary stage of R&D. Therefore, the modern coal chemical enterprises of China still has a long way to go, and the development and application of new products and technologies still need to be accelerated.

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