



Review article

Recent development in converting coal to clean fuels in China



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HIGHLIGHTS

- CTL/SNG projects in China are integrated to improve the energy efficiency and process economics.
- Dry feed entrained flow gasification are major choice for large scale gasification.
- It is proposed to combine the SNG and FTS processes by using moving bed gasification.
- New syngas conversion technologies are emphasized for efficient conversion catalyst.

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ABSTRACT

To achieve energy security in an environmentally benign way, China has to convert a significant fraction of its abundant coal resource to clean fuels (liquid fuels or synthetic natural gas, SNG) to meet the fast increasing demand on transportation fuel and municipal gas. Following the successful operation of the 4000 bbl/d Yitai and Luan coal-to-liquids plants using the medium temperature Fischer Tropsch synthesis (MTFT) process technology from Synfuels China, tremendous progresses have been made in upscaling the Fischer–Tropsch synthesis (FTS) process in China. Past experiences gained from the efforts in this field have shown that further exploration in the coal conversion field requires significant technological improvement on gasification, synthesis, and utilities related to integrating more efficient and environmentally friendly processes on the basis of current status of applications.

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1. Introduction

Global energy structure transformation has been taking place in industries, especially in areas with limited conventional oil and gas resources. These changes along with the fast increasing demands for motor fuels and town gas have greatly impacted on the energy sector inside China [1]. Due to lack of sufficient gas or oil reserves, coal accounts for about 92.6% of the gross reserves of exploitable fossil energy resources in China [2]. The dramatic increase in energy demand has decreased the current oil self-sufficiency level to about 41.9% by the end of 2013. Within the next ten to fifteen years, the Chinese oil demands and supply capacity is predicated to approach a level of 750–800 million tons annually. The domestic production of the crude will hardly exceed 200 million tons per year, leaving the gap of about 550–600 million tons to be imported, which is equivalent to an alarming oil self-sufficiency level of only 25–28%. This is in agreement with an IEA forecast which points to China's primary oil demand of 15.3 million barrels per day (about 700 million tons/a equivalent), and import dependency of 77% [3]. Traditionally, energy products are supplied by processing crude oil and natural gas. However, domestic production of oil and natural gas is very limited because of a lack of reserves, and in the past years, an “energy diplomatic politics” has been formed for China during its economy boosting era. However, eventually it is the trade balance as a decisive factor pushing China to convert coal into energy products such as clean liquid fuels (CTL) and synthetic natural gas (SNG), which can partially reduce the ever increasing cost in importing these resources [4,5].

Coal to liquid has been a long story for China since the war time in 1940s, which has been a debating topic for every stage formulating the country's energy strategy [1,6]. Progresses from early efforts were limited mainly resulting from the upheavals in economics along with crude oil price fluctuations. The high oil price since the end of 1990s has prompted the latest efforts in coal to liquid development in the country: the route via gasification and Fischer–Tropsch synthesis has been technically well developed and many related processes have been tested. This article will conduct a general review of these developments in this direction and the future developments of these fields will be discussed on the basis of the technological as well as industrial demands for the future.

2. Syngas production and gasification technologies

2.1. Syngas production from coal

Syngas production is the key to high plant availability and economic success for CTL/SNG projects. The gasification complex for syngas production, gas conditioning and cleaning usually costs about two thirds of the total direct capital investment of a CTL plant. The gasification complex typically consists of units like coal preparation, air separation (ASU), gasification, water gas shift

converter (WGS) and gas purification (Rectisol and sulfur recovery) (Fig. 1), which is a sophisticated plant and costly investment. Depending on the regional difference in coal feedstock across China, the gasification technology selection criteria has to take the following parameters into consideration for evaluating the performance of any industrial gasification process: (1) the energy conversion efficiency; (2) carbon efficiency; (3) thermal efficiency; (4) cold gas efficiency. Additionally, performance parameters such as raw gas composition, capacity, operation pressure, coal and oxygen consumption should also be compared. Details on gasification chemistry, gasifier concepts, applications and research trends can be referred to excellent reviews by Gräbner and Meyer [7] Higman and Tam [8,9], Bell et al. [10] and Tang [11].

During the past twenty years, international as well as local gasifier vendors are competing for licensing their technology in China market, while local vendors have been investing heavily on inventing and improving their technology to suit the specific requirement of gasifying a variety of coal. As shown in Table 1, major vendors of gasification technologies imported into China are Shell [3,12,13], Siemens GSP [14–16], General Electric Energy (formerly GE-Texaco) [17] and Lurgi [11,18]. Along the progress of coal gasifier installation and commissioning in chemical, metallurgical and town gas production industry and based on the knowledge and operation experiences learned, several indigenous gasifier concepts have been conceived and scaled up to commercial scales. A summary of the performance comparison is given in Table 1, which lists operation performances of Chinese gasification technologies including East China University of Science and Technology's Opposed multi-nozzle (ECUST-OMB) [19,20] and the Hangtian Gasifier (HT-L) [20,21].

For coal and other solid fuel as feed, coal gasification process operating typically at the temperature range from 900 °C to 1600 °C can be selected according to the properties of the feed. Currently, there are several types of coal gasification technologies that can be selected using solid fuel as a feedstock. Lurgi gasification has been used to gasify tens of millions tons of high ash coal annually in the world largest CTL facilities of Sasol, a well-known South Africa company running CTL business since 1950s [22]. Recently, three CTL plants have been established based on the MTFT (Medium Temperature Slurry Fischer–Tropsch Process) technology developed by Synfuels China [1,6]. The CTL plants have used different types of gasification technologies, i.e., multi-slurry gasification in Inner Mongolia Yitai plant, pressurized fixed bed gasification in Shanxi Luan plant, and Shell dry powder gasification in Inner Mongolia Shenhua plant.

The major concerns of syngas production units for the successful industrial Fischer–Tropsch processes are:

- (1) Maximized conversion efficiency in terms of specific fuel feeds by taking care of the syngas production units themselves and considering the integration of the whole plant from the preparation of the feed to the final products.

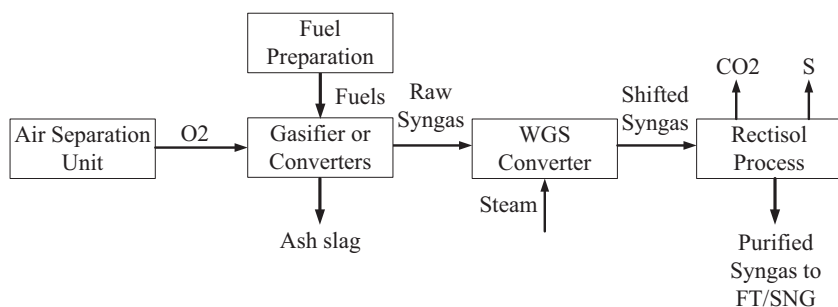


Fig. 1. Typical syngas production complex.

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