

THE DEVELOPMENT OF COAL-BASED ALCOHOL AND ETHER FUEL IN CHINA*

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Abstract: The contradiction between resources and economic development will be the toughest challenge facing in China. As China is rich in coal and lacking in oil and gas, it is very urgent to find a new carrier produced from coal to substitute the petroleum consumption. In this paper, the production and usage of coal-based alcohol and ether fuel are discussed, and the practical application of methanol as the engine fuel in Shanxi province is introduced. Based on the analysis, it is indicated that in the first 30 years of 21st century, alcohol and ether made from coal are most probably the alternative fuel that China needs. Employed the new technology, coal-based alcohol and ether production process can also be the friends with the environment. For an example, a novel coal polygeneration system that combination of gasification and coking process to multi-produce the electric power, alcohol and ether fuel, coke etc. will realize both multi-production and CO₂ emission reduce. Finally, the paper suggests that China should consider coal-based alcohol and ether alternative fuel as soon as possible, and the regions rich in coal should develop methanol fuel based on their unique conditions.

Keywords: coal-based, alcohol and ether fuel, alternative fuel

1. Status of oil consumption in China

Since 2000, the automotive industry of China has developed very quickly. There are about 20 million automobiles in 2002 and predicted the number will reach to 100 million in 2020. In 1993, China became a net import oil country. The latest statistic data show that the increase of production of petroleum and national gas in China has been slowed down. Petroleum annual production in China in the coming years will be 200 million tons and will not increase greatly, at the same time the amount of import and consumption of oil increased dramatically. In 2003, the net imported crude oil was 82.99 million tons^[1], increasing 34.4 %, which was 36.1 % of the total consumption of crude oil. (See Fig-1) The net imported oil product was 140.4 million tons, increasing 49.3%. It is predicted^[2] that the requirement of petroleum in China will reach 450-610 million tons by 2020, while the domestic yield of petroleum will be also only 180-200 million tons. The oil dependence on oversea will go to 55-60 %. Therefore, if the system of the nation energy supply was so depended on import oil, that will not only costs too much but also dangerous and insecure. Now, in China it is very urgent to develop the alternative fuel to meet the national economic development.

Coal is the main primary energy in China. The total energy consumption in 2003 was 1,678 million tons of standard coal, 67.1% of which is the consumption of coal and coal product, 22.7% is the consumption of oil and 2.8% is the consumption of natural gas^[3]. Among the mainly fossil energy resources, the coal geologic reserve in China is 1440 billion tons; the proved resource is 600 billion tons. It is 15% of the total globe proved reserves^[4]. Coal can be supplied at least 80 years if the production is at 2.5 billion tons per year. Natural gas production in 2004 is 40.7 billion Nm³; but also need import LPG to meet the domestic

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requirement. Although China planning to import natural gas from Russia, the fraction of natural gas in total energy mix will not increase greatly in the future.

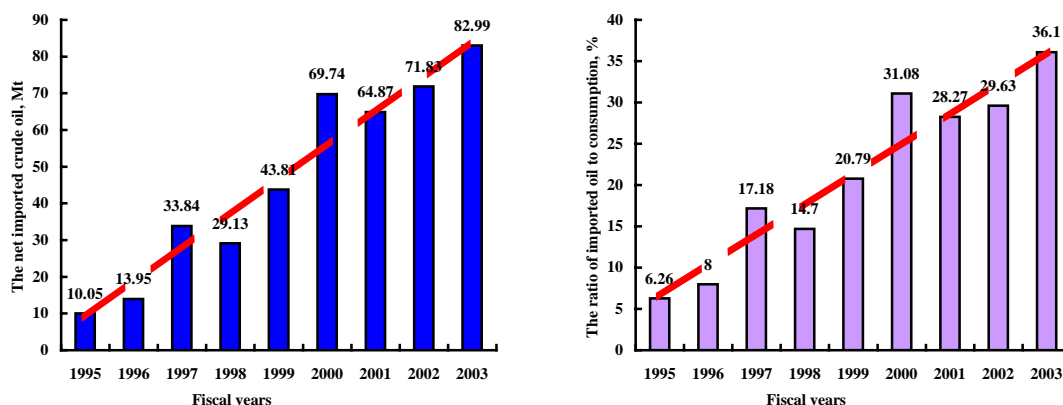


Fig-1 the chronological import of oil and its ratio in consumption

Therefore, China is scarce of natural gas and petroleum, but relative abundant in coal. The coal reserve is the reliable energy resource and can be guaranteed to be used for a middle and long period. Considering the reality, China will have to use coal as the main primary energy for quite a long term. In addition, the development of alternative fuel is depending on the domestic coal reserve.

2. Coal-based alcohol and ether fuel --- the feasible alternative fuel

Most of the developed countries have made many efforts to make cheap and clean alternative automotive fuels. In China, methanol and ethanol has been used as clean alternative automotive fuels since 1980s. Ethanol that is regard as renewable fuel has been generalized and practiced in 7 provinces and cities. However, the manufactures of ethanol need larges of foodstuff. Considering of that Chinese population is more than 1.3 billions, it is difficult to use the foodstuff made fuels.

Methanol is an alcohol fuel. Its physical and chemical characteristics result in several inherent advantages as an automotive fuel. Some methanol benefits include lower emissions, high performance, and lower risk of flammability than gasoline. In addition, methanol can be easily manufactured from coal and biomass that is very suitable to Chinese situation.

However, there are mature and feasible technologies in China for coal derived methanol and dimethyl ether. Now, the production of methanol in China nearly 5 millions tons per year, and dimethyl ether is 40,000 tons [5]. All most of these productions have been used for chemical industry. The part of used for fuels is little.

The consumption of gasoline in China is nearly 100 millions tons every year. If used M100 (essentially 100% pure methanol) as the alternative fuel, they will consume about 240 millions coal. Actually, these amounts of coal consumption can easily support for China. Considering the realities of the limited resource in China, it is difficult to use natural gas and liquefied petroleum gas as automobile fuel largely. Coal-based alcohol and ether fuel is the one and only feasible way to produce alternative fuel.

There are three basic ways that liquid can be produced from coal, 1, remove carbon; 2, fragment and reform; 3, add hydrogen the processes centered around these chemistries are pyrolysis, direct liquefaction and indirect liquefaction.

Direct liquefaction is the thermally induced decomposition of coal in the presence of a solvent that serves to transfer hydrogen under high temperature and high pressure.

Indirect liquefaction is a process of catalytic synthesis of hydrocarbons using syngas under temperature and pressure. To form one C-C bond produce one molecular of water so that the energy and elements of coal is not utilized efficiently.

Conversion of coal to alcohol and ether fuels is a similar process to indirect liquefaction, but this process is the most efficient converting pathway, in which the most energy and elements in coal have been transferred to the products. It is also a mature technology, many industrial experiences have been made and many types of equipment have been set in different scale in the most area of China.

The former two pathways are to transfer coal to hydrocarbons fuel similar to petroleum products. The initial strategy is limited by the petroleum route. However, the third pathway gets rid of the petroleum route completely, and it is the new efficient coal based energy route. Table-1 indicates the comparison of above three pathways in both technical and economic respects.

Table-1 the technological and Economic comparison of three pathways^[6]

Item	Direct liquefaction	Indirect liquefaction	Conversion of coal to alcohol and ether fuels
Flexibility	Low It is required young coal such as lignite, soft coal, etc.	High No special properties are needed.	High No special properties are needed.
Gasification	No 440°C-450 °C	Yes 250 °C -350 °C	Yes 200 °C -300 °C
Operating condition	15MPa-30MPa Rigor	3.0MPa-5.0MPa Mild	3.0MPa-10MPa Mild
Catalyst	One-off use, largely used and difficult to recovery.	Used little, a long life and easy to recovery	Used little, high activity, a long life and easy to recovery
Product's composition	Mixture of carbon-hydrogen compounds. A little S, N etc. elements contained. Difficult to separation	Mixture of carbon-hydrogen compounds. No S, N etc. elements contained. Difficult to separation	Main component was methanol or dimethyl ether. No S, N etc. element contained. Easy to separate as pure chemical.
Products	Many kinds of products. Except gasoline and diesel, other carbon-hydrogen products also produced.	Many kinds of products. Except gasoline and diesel, other carbon-hydrogen products also produced.	Methanol or dimethyl ester fuel products with very simple composition
Yield	Low	Low	Very high
Heat effect	High	Low	Normal
Element utility	Only using C and H elements. Taking off O element	Only using C and H elements. Taking off O element	Fully using C, H and O elements, the top of the element utility
Environment evaluation in the process	Using a large amount of catalyst, producing waste solid.	Normal	Clean process
Commercial application	Direct hydrogenation of coal to liquid oil was used in commerce in Germany during 1920s-1940s. New technology was studied and tested in a pilot plant since 1970s. But no commercial plant was set up by now except 2500kt/a plant is building in China	It was commercialized since 1950s by Sasol, South Africa. Recently the company wants to change the stock material from coal to nature gas. A plant with more than 10kt/a productivity was building up in China.	Methanol synthesis industry has been developed quickly since 1920s. The productivity of methanol in the world reach to 40 Mt/a and the largest equipment has a produce ability of 2Mt/a. In China, the ability to produce methanol reach to 4.5Mt/a.
Consumption t-output/t-coal	4-4.5	4.5-5.5	Methanol fuel: 1.5-1.7 Dimethyl ether fuel: 2-2.5
Investment (1Mt/a)/1MRMB	ShenHua's budge: 65	Sasol: 100	30-40
Cost RMB/ton	~ 1457 (\$ 24/barrel)	3000	Methanol fuel: 700-900 Dimethyl ether fuel: 1500-2000
Economic Scale Mt/a	>2	>1	Flexible
Application	Similar to the usage of gasoline and diesel oil used now	Similar to the usage of gasoline and diesel oil used now	The low content methanol gasoline is similar to the usage of gasoline. High content methanol gasoline or pure methanol fuel is required to set new oil distribution system and modify the automobile's engine.
The using experience in China	No	No	Commercial running for over 10 years in Shanxi and other province.

Obviously, the coal-based alcohol and ether fuel will be the best substitute of the petroleum products (gasoline, diesel oil), the development of coal based alcohol and ether fuel have already become into true from the point of view of the energy substitution strategy. Moreover, the fact cannot be neglected that China has become the number one to produce and export coke in the world. In 2004 the coke output has amounted to 220 million tons, the consumption of relative coal was approximately 530 million tons, which is approximately 27% of the total quantity of coal. Moreover, 29 billion Nm³ coking gas containing H₂ and CH₄ was released. These large amounts of coking gas can be used as raw material to produce methanol and ether, and can produce more cheaply coal-based methanol and ether fuel.

Based on the background and consideration as above, the fundamental researches on “Basic researches on the polygeneration application of the syngas from the combination of gasified and pyrolyzed coal gas” supported by the MOST (the Ministry of Science and Technology of China) have carried out in Taiyuan University of Technology since 2005^[7-9]. The general goals of this project are to realize that the produce alternative fuel with the features of low cost, the high efficiency, fewer pollution and CO₂ reduction. Moreover, realize the multi-production of electric power, alcohol and ether fuel, coke and the tar multi-components.

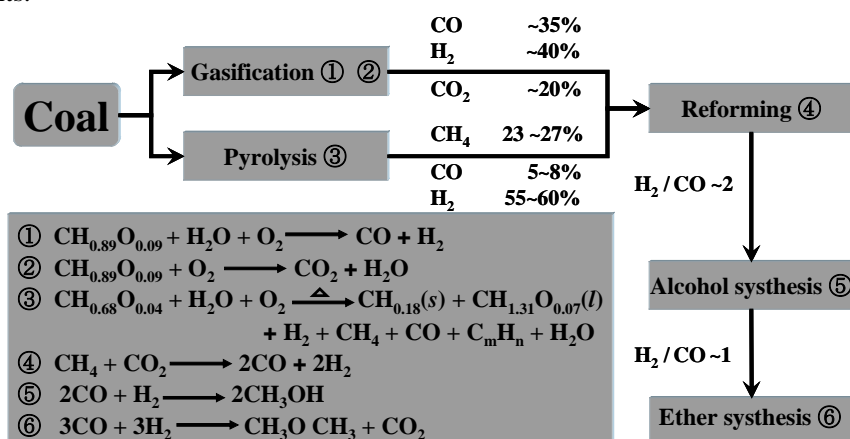


Fig-2 Syngas from the combination of gasified and pyrolyzed coal gas and the alcohol ether synthesis

As Fig-2 shown coke oven gas contains 55~60% H₂, 23~27% CH₄, and gasified outlet gas contains about 20% CO₂. However, if the CO₂ from gasification can mixed with the coke oven gas to get the mixture with the similar proportion of CO₂ and CH₄, the mixture will form syngas with H/C close to two at higher temperature. This kinds of syngas is suitable to used synthesize alcohol and ether fuel.

Using the process, the resources can be utilized adequately; and the CO₂ emission is reduced realizing almost zero carbon dioxide release, without the water gas shift reaction.

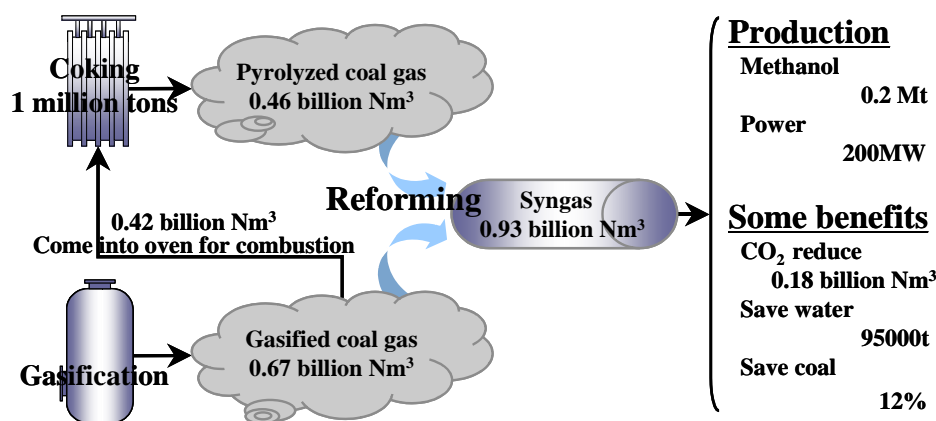


Fig-3 some benefits and production on application novel polygeneration

For an example (see Fig-3), a coking oven with the capacity of 1 million tons chars can produce 0.46 billion Nm³ oven gas. Generally, 50% of them should return to the oven for combustion. So, hydrogen rich coke oven gas will be consumed largely. The new idea of the novel polygeneration system is that let partial coal gasified outlet gas (CO rich) come into coking oven as the combustion gas to provide heat. Oven gas mixed with gasified gas and combustion tail gas to make the similar proportion of CO₂ and CH₄ to reforming produce syngas. Compared with the same coking and gasification process, this sketch will realize both

multi-production and CO₂ emission reduce. Moreover, save largely water resources and coal.

3. The practice of methanol as engines fuel in Shanxi province

Since the beginning of 1980s, Shanxi province has organized systematic research on coal derived methanol vehicles. During 6th five years plan period, there were 475 vehicles and 4 M15 (15% methanol with gasoline) fuelling stations running for demonstrating In Shanxi province. After 80 millions km accumulative total running, proved that methanol is suitable to use as alternative vehicles fuel in Shanxi province. In 1994, State Science and Technology Committee (the former of MOST) put forward the feasibility study for “Multi-production alcohol for alternative fuel in Shanxi chemical fertilizer plant”.

During the 9th five years plan period, the program study on 3E (economic, environmental and energy life cycle) assessment of methanol as engines fuel in Shanxi were completed. The conclusion is that coal-based methanol is suitable to Shanxi province situation and would possibly put into practice earlier. In 2000, two kinds of methanol fuel engines named HL495JIQ and HL495IQ have been developed. Now, M100 and M85 engines were employed by city bus system, more than 1000 vehicles have been installed this kinds engine. With catalysis cleaner, the formaldehyde contains in the outlet gas has down from 88.22 to 2.99 mg/m³.

In 2002, 2 standards have been issued by Shanxi government. Hundreds of gasoline stations have been rebuild made them can sale coal-base alternative fuel. Three preparation plants and seven service stations have been built in Taiyuan. There are total four cities, include Taiyuan, Yangquan, Datong and Linfen (All of tem are coal rich regions), have beginning the put into practice.

According to the experiences from the Shanxi province’s practice, both M15 and M100 can partial substitute the gasoline used as vehicles fuel. Considering of the price, cost of production of methanol from coal only 900~1200 Yuan/ton. It is has very nice market foreground in Shanxi. Using the new technology, for an example that the novel polygeneration system that has mention above, the cost of production can be bring down further.

The issues on the health, safety, environment, and risks of methanol alternative fuel often are considering of by public. Table-2 provides a relative comparison of each alternative fuel that affects the safety, health, or environmental effects associated with its use in Shanxi.

Table-2 comparison of each alternative fuel that affects the safety, health, or environmental

		Diesel oil	Gasoline	M100	M85
Flammability	The open place	2	8	4	7
	The close place	5	2	8	3
	Fire	8	10	3	4
	Flame	9	10	7	8
Toxicity					
Inhalation (exposure to fuel vapors)	Low concentration	3	10	3	7
	Hazard rating	3	10	10	10
	High concentration	5	10	10	10
	Hazard rating	2	8	9	10
Skin contact	Health effects	5	8	9	10
	Hazard rating	2	4	3	4
Eat up	Health effects	10	10	10	10
	Hazard rating	3	3	8	3

Notes: 1~3 low-level risk; 4~6 medium; 7~9 high; 10 severe

Mainly fruits obtained from the practice of methanol as engines fuel in Shanxi province have been listed as follow:

- 1, The effect on environment (including atmosphere, soil and water) is little than the gasoline does.
- 2, During the engineering demonstrate period, no fire and explode occurs from methanol leaks.
- 3, No death occurs because of eat or drink methanol fuel in error.
- 4, In a 6-years study, there was no evidence of adverse effects on people whom exposed to methanol vapors. And no occupational disease has been found among the drivers and others participants.
- 5, Corrosive characteristics of methanol can be overcome by use the anti-corrosive seal on the engine, containers, and transfer lines.
- 6, Outstanding economical on used methanol as alternative fuel in Shanxi province.

4. Conclusions

China is scarce of oil and gas but rich relatively in coal resource. So depending on coal to develop alternative fuel is the most reliable way to solve the problem. The coal based alcohol ether fuel will be a better substitute of the petroleum products (gasoline, diesel oil), the development of coal based alcohol ether fuel have already become into true from the point of view of the energy substitution strategy. Some provinces in China including Shanxi have obtained some useful experiences on production and application of methanol fuel. The results are shown that coal-based methanol is suitable to the regions rich coal.

Development the new technology on the production of alcohol and ether fuels can not only cut down the production costs, but also obtain many environmental benefits. Therefore, it's suggested that China should hasten to develop the coal based alcohol and ether fuel, to drive the related industries such as the energy, chemical and mobile, and to create new economic increasing point.

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