

Feature of Chinese vehicular fuels

Qiu Yansheng

(Research Institute of Petroleum Processing, Beijing 100083, P. R. China)

Abstract

China has the 10th crude oil resource in the world, however, it must import around 100 million metric tons of crude oils by 2010 for meeting the domestic demand. Chinese crude oils have less naphtha compared with foreign ones. One of the features of Chinese petroleum refining industry is that the catalytic cracking capacity is much more than the capacities of catalytic reforming and catalytic hydrotreating. The principle characteristics of Chinese gasoline are high olefin and sulfur contents, meanwhile, the diesel fuel has high sulfur content. In recent years, the environmental protection regulations became stringent, consequently, the quality of Chinese fuels improved markedly. The olefin of gasoline and sulfur of diesel fuel have reduced. The updating of gasoline and diesel fuel specifications is underway.

Key words: gasoline; diesel fuel; olefin; sulfur

1 Chinese crude oil and petroleum industry

1.1 Characteristics of Chinese crude oils

Petroleum is a non-renewable energy resource, and the global proven reserves are 139 billion metric tons by end of 1999^[1]. At present time, the consumption of crude oils reaches 3.4 billion metric tons annually. Most of the crude oil resources distribute in the Middle East, following by America and Africa, on the contrary, Asia and West Europe

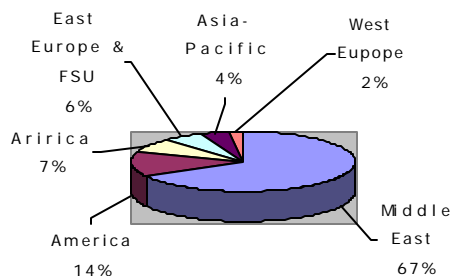


Fig.1 Worldwide proven crude oil reserve at end 1999

have less resources, shown in Figure 1.

Table 1 lists the top 10 petroleum countries. Despite China is the 10th largest petroleum country in the world, its proven crude oil reserves are only 2.4 percent of the world total by weight. Considering the big population, it should believe that China does not have enough petroleum resources to meet its domestic demand.

Table 1 Proven crude oil reserve of top 10 major petroleum countries

No.	Country	Estimated proven reserve at end 1999	
		Million metric tons	%*(m/m)
1	Saudi Arabia	35,750	25.7
2	Iraq	15,410	11.1
3	Kuwait	12,880	9.3
4	Abu Dhabi	12,630	9.1
5	Iran	12,290	8.8
6	Venezuela	9,950	7.1
7	Russia	6,650	4.8
8	Libya	4,040	2.9
9	Mexico	3,890	2.8
10	China	3,290	2.4

* Based on the worldwide total estimated proven reserve

In China, the processing amount of crude oils increased constantly in the last decade as shown in Figure 2. According to the prediction^[2], by 2010, China will need crude oil of 270 to 310 million metric tons per year. Unfortunately, the domestic supply will just reach 165 to 200 million metric tons per year. Therefore, crude oil of 105 to 110 million metric tons must be imported.

Chinese crude oils contain less naphtha as shown in Table 2^[3]. The naphtha content is related to the geometric region of crude oil field. One country possibly has several oil fields; Table 2 presents the middle value for a given country.

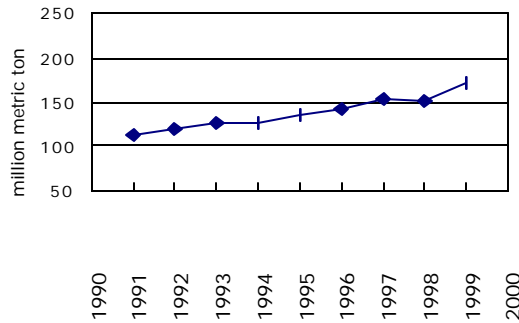


Fig. 2 Crude oil operation

Table 2 Straight run naphtha of crude oils from major petroleum countries

Region	Boiling point range*	Content % m/m
Saudi Arabia	20-150	13.7
Iraq	C-175	18.2
Kuwait	IBP-154	14.5
Abu Dhabi	C ₅ -150	18.5
Iran	C ₅ -150	12.4
Venezuela	205	18.2**
Russia	180	21.6
Libya	20-150	20.2
Mexico	16-204	19.7**
China		
Daqing oil field	IBP-199	13.0**
Shengli oil field	IBP-199	9.0

* Fraction related to gasoline ** %(v/v)

1.2 Petroleum refining industry

China has petroleum processing capacity of 250 million metric tons annually, occupying the fourth position in the world following US, FSU and Japan. In 1999, China processed 170 million metric tons of crude oils, produced 34 million metric tons of gasoline and 54 million metric tons of diesel fuel, meeting the domestic demand.

China has big catalytic cracking capacity, which possesses 35 percent of its distillation capacity as seen in Table 3. From this table, it can be found that China has less catalytic reforming capacity than US, because of the shortage of naphtha, which is the feedstock of catalytic reforming process. Besides, catalytic hydrocracking and catalytic hydrotreating capacities are not enough. As a result, the refining industry has limited power to supply advanced gasoline and diesel fuel components.

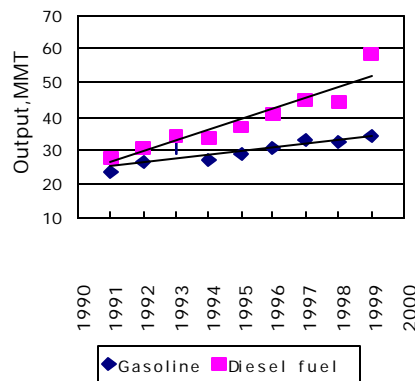


Fig. 3 Production of gasoline and diesel fuel in China

Table 3 China and US Refining capacities

Refining process	China		US ^[4]	
	Capacity, 1,000 metric tons annually	% *(m/m)	Capacity, 1,000 metric tons annually	% *(m/m)
Distillation	249,450	100	821,135	100
Cat. reforming	14,877	6.0	153,910	18.7
Cat. cracking	87,655	35.1	270,995	33.0
Cat. hydrocracking	12,920	5.2	74,280	9.0
Hydrorefining	5,200	2.1	84,080	10.2
Hydrotreating	35,105	14.1	447,260	54.5

*Based on distillation capacity

The production of gasoline and diesel fuel is demonstrated in Figure 3, which discloses that the growth rate for diesel fuel production is higher than that for gasoline. In the last decade, the consumption of diesel fuel raised fast, which was fueled on the one hand by the increasing of light and middle trucks using diesel engines, and on the other hand by the increasing of agricultural vehicles and equipment.

In China, almost all gasolines are used in transportation, while only half of diesel fuels are for this use, as presented in Table 4.

Table 4 Consumption balance of diesel fuels in China

Consumer	1995	1997
Agriculture, % (m/m)	26.17	23.4
Fishery, % (m/m)	11.93	11.4
Transportation, % (m/m):	48.17	50.5
Highway	29.82	34.4
Railway	10.32	8.8
Marine	8.03	6.8
Electricity, % (m/m)	6.88	9.5
Others, % (m/m)	6.88	5.7
Total, % (m/m)	100	100

2 Gasoline

2.1 Gasoline quality

In Chinese gasoline pool, the biggest proportion is catalytic cracking component; unfortunately, catalytic reforming, catalytic hydrotreating and alkylation components are not enough compared with the US counterparts, which can be found in Table 5.

Table 5 Gasoline blending composition

Composition	% (m/m)	
	China 1997	US 1995
Cat. cracking	78.9	34.5
Straight run	11.1	
Cat. reforming	5.4	33.5
Cat. hydrofinishing	1.0	
Cat. hydrocracking		1.5
Aromatics	0.8	
Thermal cracking	0.3	
Alkylation	0.2	12.5
Isomerization		10.0
Butane		5.5
MTBE		2.5
Others*	2.3	

* Including MTBE, C₅ fraction, etc.

The survey of Chinese gasolines in 1999 revealed that the feature of the gasoline is of high olefin and sulfur contents as listed in Table 6.

Olefins in gasoline cause the deposits in intake system and fuel injector of gasoline engines, and increase the photochemical reaction activity of engine exhaust gas. Sulfur compounds poison the catalysts of the exhaust gas converters. Nowadays, China is carrying out the improvement of gasoline quality. Several measures have been adopted, which include using of innovative catalytic cracking, increasing of catalytic reforming capacity, and stalling of hydrodesulfurization facilities, etc.

Table 6 1999 Survey of Chinese gasoline

Compound	%*(m/m)
Sulfur	
1000ppm	95.1
800ppm	91.4
500ppm	80.4
Benzene	
5.0%	98.2
2.5%	92.1
1.0%	79.4
Aromatic	
40%	99.6
35%	98.0
30%	95.2
Olefin	
50%	81.5
40%	34.8
35%	20.4

*Weighted average of the production output of the gasoline inspected

2.2 Gasoline specifications

In recent years, environmental protection has been concerned greatly in China, especially in the mega-cities, such as Beijing, Shanghai and Guangzhou. Consequently, the engine emission regulations became stringent, it has strong impact on fuel industry. The updating of gasoline specification is the highlight concerned by the government, the automotive industry and the petroleum refining industry. A new state specification came to effect in July, 2000. The significant difference between the new specification and the original one is the set-up of the limitation of olefin and aromatics contents. Although the maximum limits of olefin and sulfur contents are higher than the standard of the US gasoline, it is a marked progress, considering the current status of Chinese petroleum refining industry. Table 7 is the new gasoline specification GB 17930-1999^[5].

The gasoline quality will continuously update; the next aim is reducing sulfur content down to 0.02 percent by weight. The approach of controlling the total amount of olefins and aromatics in gasoline pool will be adopted. The total amount of olefin and aromatics is limited at the level of 60 percent by volume maximum, while the limit of olefin content is 35 percent by volume maximum. The next gasoline specification will be implemented in 2003.

Table 7 Unleaded petrol specification for motor vehicle GB17930-1999

Item	Limit		
	90	93	95

Research octane number	min.	90	93	95
Antiknock index	min	85	88	90
Lead g/L	max.	0.005		
Distillation				
T10,	max.	70		
T50,	max.	120		
T90,	max.	190		
FBP,	max.	205		
Residue, % v/v	max.	2		
Vapor pressure, kPa				
From September 16 to March 15	max.	88		
From March 16 to September 15	max.	74		
Existent gums mg/100ml	max.	5		
Oxidation stability, min	min.	480		
Sulfur, % m/m	max.	0.10		
Mercaptan (one of the following properties must be met)				
Doctor's test		pass		
Sulfur of mercaptan, % m/m	max.	0.001		
Copper corrosion rating, (50 °C, 3h)	max.	1		
Aqueous acid of alkali		nil		
Water and sediment		nil		
Benzene, % v/v	max.	2.5		
Aromatic, % v/v	max.	40		
Olefin, % v/v	max.	35		

3 Diesel fuel

3.1 Diesel fuel quality

Chinese diesel fuel contains small proportion of hydrotreating components as shown in Figure 4. As a result, the diesel fuel has high sulfur content as demonstrated in Table 8. From Table 8 it can be seen that the sulfur content increased from 1995 to 1997, since the increasing of imported sour crude oils. The sulfur content decreased from 1997 as the enhancing of catalytic hydrotreating operation.

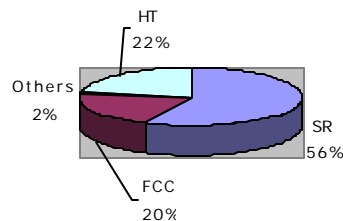


Fig.4 Blend composition of Chinese diesel fuels

Table 8 Sulfur contents of Chinese diesel fuels

Sulfur content*, % (m/m)	1995	1996	1997	1998
Minimum	0.03	0.03	0.03	0.03

Maximum	0.33	0.35	0.37	0.35
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*Average sulfur content of refinery's diesel fuel pool

3.2 Diesel fuel specifications

The current state specification of diesel fuel is GB 252-1994 as listed in Table 9^[6], which involves three grades, regular, premium and super, based on sulfur content. The sulfur contents of the three grades of diesel fuels are 1.0, 0.5 and 0.2 percent by weight maximum, respectively. The cetane number limit is 45 minimum, except for the diesel

Table 9 Diesel fuel specification GB252-1994

Brand number		10	0	-10	-20	-35	-50
Solidifying point,	max.	10	0	-10	-20	-35	-50
CFPP,	max.	12	4	-5	-14	-29	-44
FP (PM),	min.	65			60	45	
Cetane number*	min.	45					
Distillation, :							
50% vol. recovered at	max.	300					
90% vol. recovered at	max.	355					
95% vol. recovered at	max.	365					
Density at 20 ,	kg/m ³	report					
Viscosity at 20 ,	mm ² /s	3.0-8.0		2.5-8.0		1.8-7.0	
Particulates		nil					
Aqueous acid or alkali		nil					
Copper corrosion rating (50 , 3h)	max.	1					
Ash, % (m/m)	max.	0.01(super and premium); 0.02(regular)					
Carbon residue on 10% distillation residue, % (m/m)	max.	0.3 (0.4 for 10 ^u and 0 ^v of regular grade)					
Acidity, mg KOH/100 ml	max.	5(super); 7(premium); 10(regular)					
Water, % (v/v)	max.	trace					
Sulfur, % (m/m)	max.	0.2(super); 0.5(premium); 1.0(regular)					
Sulfur of mercaptan, % (m/m)	max.	0.01(super and premium); no requirement for regular					
Color number	max.	3.5					
Iodine number, g I/100 g	max.	6(super); no requirement for premium and regular					
Oxidation stability (insoluble), mg/100 ml	max.	2.0(premium); no requirement for super and regular					
Existent gums, mg/100 ml	max.	70(regular); no requirement for super and premium					

*40 minimum for diesel fuels made from naphthenic or paraffin-naphthenic crude oils, and for diesel fuel containing catalytic cracking components

fuels made from naphthenic or paraffin-naphthenic crude oils, as well as the diesel fuel containing catalytic cracking components, which have the cetane number limit of 40 minimum.

The updating of diesel fuel specification is underway. The new specification is presented in Table 10^[7].

Table 10 Diesel fuel specification (draft for approval)

Brand number		10	0	-10	-20	-35	-50	
Solidifying point,	max.	10	0	-10	-20	-35	-50	
CFPP,	max.	12	4	-5	-14	-29	-44	
FP (PM),	min.	55				45		

Cetane number*	min.	45		
Distillation, :				
50% vol. recovered at	max.	300		
90% vol. recovered at	max.	355		
95% vol. recovered at	max.	365		
Density at 20 , kg/m ³		report		
Viscosity at 20 , mm ² /s		3.0-8.0	2.5-8.0	1.8-7.0
Particulates		nil		
Copper corrosion rating (50 , 3h)	max.	1		
Ash, % (m/m)	max.	0.01		
Carbon residue on 10% distillation residue, % (m/m)	max.	0.3		
Acidity, mg KOH/100 ml	max.	7		
Water, % (v/v)	max.	trace		
Sulfur, % (m/m)	max.	0.2		
Color number	max.	3.5		
Oxidation stability (insoluble), mg/100 ml	max.	2.5		

*40 minimum for diesel fuels made from naphthenic or paraffin-naphthenic crude oils

In the proposal of the new specification, the sulfur content limit is 0.2 percent by weight maximum. The cetane number limit is 45 minimum with an except for the diesel fuels made from naphthenic or paraffin-naphthenic crude oils, which have cetane number limit of 40 minimum. It implies that the cetane number of the diesel fuels containing catalytic cracking components has limit of 45 rather than 40 minimum. The new specification is going for approval. In addition, China Petroleum & Chemical Corporation (SINOPEC) issued a city diesel fuel specification Q/SHR 006-2000 last year, as shown in Table 11^[8]. In this industrial specification, the sulfur content limit is 0.05 percent by weight maximum, and the cetane number limit is 45 minimum without exception.

The further development of diesel fuel specification focuses on reducing sulfur content down to 0.035 percent by weight maximum, and increasing cetane number limit up to 49 minimum. The next specification will come to practice in 2003.

Table 11 City diesel fuel specification Q/SHR 006-2000

Brand number		10	5	0	-10	-20	-35	-50
Solidifying point,	max.	10	5	0	-10	-20	-35	-50
CFPP,	max.	12	8	4	-5	-14	-29	-44
FP (PM),	min.	55					45	
Cetane number	min.	45						
Distillation, :								
50% vol. recovered at	max.	300						
90% vol. recovered at	max.	355						
95% vol. recovered at	max.	365						
Density at 20 , kg/m ³		report						
Viscosity at 20 , mm ² /s		3.0-8.0		2.5-8.0		1.8-7.0		
Particulates		nil						
Copper corrosion rating (50 , 3h)	max.	1						
Ash, % (m/m)	max.	0.01						
Carbon residue on 10% distillation residue, % (m/m)	max.	0.3						
Acidity, mg KOH/100 ml	max.	7						
Water, % (v/v)	max.	trace						
Sulfur, % (m/m)	max.	0.05						
Color number	max.	3.5						
Oxidation stability (insoluble), mg/100 ml	max.	2.5						

4 Conclusion

As the economies develop, the demand for petroleum products grows dramatically in China, consequently, the shortage of crude oil resource becomes apparent. By 2010,

crude oil of around 100 million metric tons must be imported annually for making up the shortage of the domestic supply.

China is improving the quality of gasoline and diesel fuel for meeting the stringent requirement of environmental protection and automotive industry. The main goal focuses on the reducing olefin content of gasoline, and reducing sulfur contents of gasoline and diesel fuel.

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