

Catalytic Cracking of Light Hydrocarbons for Light Olefin Production: A Comparative Study of F-T Gasoline Fraction and Reforming Aromatic Raffinate

Qingbo XI*

Sinopec Engineering Group Luoyang R&D Center of Technology, Luoyang 471000, China

Abstract Catalytic cracking experiments were conducted in a circulating fluidized bed reactor using a proprietary QTCC catalyst, with an F-T gasoline fraction and a reforming aromatic raffinate as feedstocks. The effects of reaction temperature and space velocity on product distribution and liquid-phase properties were systematically investigated. The F-T gasoline fraction, rich in α -olefins (60.57%), is demonstrated to be an excellent feedstock for light olefin production. At 630 °C and a space velocity of 1.5 h⁻¹, the yield of ethylene plus propylene reached 41.10%, and the yield of ethylene, propylene plus butylene was up to 50.04%. Increasing the temperature to 670 °C further raised the ethylene plus propylene yield to 43.37%, with a liquid aromatic content of 79.20%. In contrast, the aromatic raffinate, characterized by high saturated hydrocarbon content, exhibited lower reactivity. At 645 °C, its ethylene plus propylene yield was 27.53%, and the liquid aromatic content was 34.10%. Significant differences in cracking performance were observed between the two feedstocks. The F-T gasoline fraction is highly suitable for the high-yield production of light olefins and aromatics, while the aromatic raffinate requires intensified reaction conditions for efficient conversion. This study provides experimental evidence and technical support for the high-value utilization of these two light hydrocarbon streams.

Key words Catalytic cracking; Light olefins; F-T gasoline fraction; Aromatic raffinate

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Light olefins (ethylene, propylene, butylene) are the core building blocks of the petrochemical industry, and their production capacity directly determines the scale and economic benefits of the chemical sector^[1]. Currently, light olefins are mainly produced by steam cracking of petroleum-based feedstocks such as naphtha and hydrogenated tail oil. However, the growing supply-demand imbalance and price volatility of petroleum resources^[2], coupled with the trend toward lighter steam cracking feedstocks, have made the development of alternative routes such as catalytic cracking increasingly important for light olefin production^[3-4].

Fischer-Tropsch (F-T) synthesis is a key technology for converting coal, natural gas, or biomass into liquid fuels. With the large-scale commissioning of coal-to-liquid projects in China, substantial amounts of F-T synthetic distillate are produced as by-products. These distillates feature ultra-low sulfur, nitrogen, and oxygen contents, and their light fractions are rich in α -olefins, providing a high-quality feedstock base for catalytic cracking^[5]. Meanwhile, reforming aromatic raffinate, a by-product of petroleum refining, is primarily composed of alkanes and cycloalkanes with negligible olefin content, resulting in limited direct utilization value. Catalytic cracking offers a viable pathway to convert aromatic raffinate into high-value light olefins and aromatics, thereby significantly improving its economic benefits^[6].

Catalytic cracking is a process in which heavy hydrocarbons undergo complex reactions including cracking, isomerization, and

aromatization over acidic catalysts to selectively produce light olefins and aromatics. It exhibits advantages such as broad feedstock adaptability, mild reaction conditions, and tunable product distribution^[7]. In this work, the catalytic cracking performance of an F-T gasoline fraction and a reforming aromatic raffinate was systematically investigated. The effects of reaction temperature and space velocity on product distribution, light olefin yield, and liquid aromatic content were examined to identify optimal operating conditions, providing experimental basis and technical support for the high-value utilization of the two feedstocks.

1 Materials and methods

1.1 Feedstock properties The feedstocks used in the experiments were an F-T gasoline fraction and a reforming aromatic raffinate. Their basic properties are listed in Table 1.

1.2 Catalyst A proprietary QTCC catalyst was used throughout the experiments. The catalyst employs ZSM-5 molecular sieve as the active component, exhibiting high cracking activity, excellent hydrothermal stability, and good anti-coking performance.

1.3 Reaction apparatus and experimental procedure The experiments were performed in a circulating fluidized bed reactor consisting of five units: feed delivery, reaction-regeneration, product recovery, metering and flow control, and computer monitoring. The reactor has a height of 3.5 m with a catalyst loading of 5 kg^[8]. A schematic diagram of the experimental setup is shown in Fig. 1.

The preheated feedstock oil was mixed with steam via an atomizing nozzle and introduced into the bottom of the reactor for re-

action. After reaction, the oil gas and catalyst were separated in a settler, and the spent catalyst was stripped and then sent to a regenerator for coke combustion regeneration. The oil gas was cooled by two-stage water cooling followed by deep cooling to recover liquid products. The cracked gas and regenerated flue gas were me-

tered, vented, and sampled for analysis, with C5 + components included in the liquid yield. The condensate was fractionated into gasoline, middle distillate, and heavy oil fractions by true boiling point distillation, and their yields, compositions, and properties were determined^[18].

Table 1 Properties of feedstock oils

Feedstock oil	Density (20 °C) g/cm ³	Sulfur content μg/g	Nitrogen content μg/g	Initial boiling point/10% recovered//°C	Final boiling point//°C	Final boiling point//°C	Normal paraffins wt%	Isoparaffins wt%	Cycloalkanes wt%	α-olefins wt%
F-T gasoline fraction	0.705 9	0.79	0.30	52/66	123/192	231	29.16	–	–	60.57
Reforming aromatic raffinate	0.719 4	98.00	1.81	52/63	86/131	174	18.61	35.39	38.66	1.27

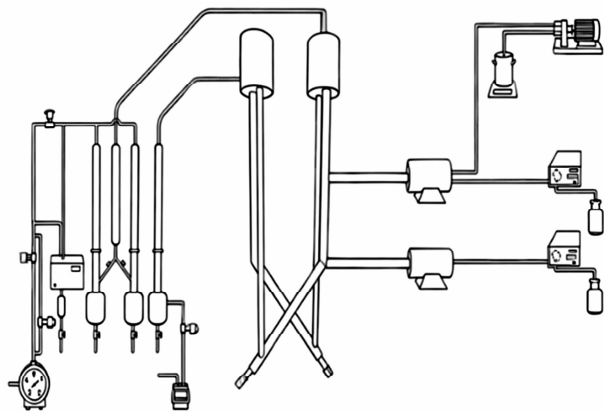


Fig. 1 Schematic diagram of the experimental setup

2 Results and analysis

2.1 Catalytic cracking performance of F-T gasoline fraction

2.1.1 Effect of reaction temperature on product distribution.

Reaction temperature is a critical parameter governing the reaction pathway and product distribution in catalytic cracking. The product distribution of F-T gasoline cracking at different temperatures is presented in Table 2. As the temperature increased from 590 °C to 670 °C, the gas yield increased from 63.41 wt% to 68.44 wt%, accompanied by a significant rise in dry gas yield (from 19.86 wt% to 33.52 wt%), indicating that high temperature intensified deep cracking of hydrocarbons. The ethylene yield rose continuously from 13.12 wt% to 20.20 wt%. The yields of propylene and butylene exhibited a volcano-shaped trend, reaching maximum values of 23.81 wt% and 8.94 wt% at 630 °C, respectively. The yields of ethylene plus propylene and ethylene plus propylene plus butylene increased steadily, reaching 43.37 wt% and 50.23 wt% at 670 °C, respectively. Ethylene selectivity increased gradually with temperature (from 20.70% to 29.52%), while propylene selectivity peaked at 35.00% at 650 °C and then decreased slightly.

The properties of liquid products at different temperatures are summarized in Table 3. With increasing temperature, the contents of saturated hydrocarbons and olefins in the liquid products declined continuously, while the aromatic content increased, reaching 79.20 wt% at 670 °C. High temperature promoted aromati-

tion and dehydrogenation condensation of cracking intermediates, enhancing aromatic selectivity. Meanwhile, the distillation range became slightly heavier, with the final boiling point rising from 234.99 to 263.2 °C.

Table 2 Product distribution of F-T gasoline cracking at different temperatures

Product	Temperature//°C				
	590	615	630	650	670
Gas	63.41	66.20	68.28	66.63	68.44
Dry gas	19.86	23.57	26.41	28.32	33.52
Hydrogen	0.38	0.44	0.48	0.55	0.66
Methane	2.39	3.11	3.83	4.92	6.80
Ethylene	13.12	15.56	17.29	18.56	20.20
Ethane	3.96	4.47	4.81	4.28	5.86
Liquefied petroleum gas	43.55	42.63	41.87	38.31	34.92
Propylene	20.13	22.26	23.81	23.32	23.17
Propane	11.23	8.87	7.12	5.53	3.94
Butylene	8.62	8.90	8.94	8.01	6.86
Liquid + coke	36.59	33.80	31.72	33.37	31.56
Ethylene + propylene	33.25	37.82	41.10	41.88	43.37
Ethylene + propylene + butylene	41.87	46.71	50.04	49.90	50.23
Ethylene selectivity//%	20.70	23.50	25.31	27.86	29.52
Propylene selectivity//%	31.74	33.62	34.87	35.00	33.85

Table 3 Properties of liquid products from F-T gasoline cracking at different temperatures

Property	Temperature//°C				
	590	615	630	650	670
Density//g/cm ³	0.780 3	0.780 5	0.791 3	0.797 6	0.817 7
Hydrocarbon composition//wt%					
Saturated hydrocarbons	22.67	21.74	19.90	16.73	11.54
Olefins	13.92	14.88	12.75	13.05	9.26
Aromatics	63.41	63.38	67.35	70.22	79.20
Distillation range//°C					
Initial boiling point	49.53	49.72	49.98	48.96	49.60
Final boiling point	234.99	233.56	234.60	236.54	263.20

2.1.2 Effect of space velocity on product distribution. Space velocity determines the residence time of feedstock in the catalyst bed and thus influences the extent of cracking reactions. At 630 °C, the product distribution of F-T gasoline cracking at space velocities of 1.0 – 2.0 h⁻¹ is shown in Table 4. The maximum

yield of ethylene plus propylene (41.10 wt%) was obtained at a space velocity of 1.5 h^{-1} , with a corresponding ethylene plus propylene plus butylene yield of 50.04 wt%. A low space velocity (1.0 h^{-1}) resulted in prolonged residence time, promoting secondary cracking and hydrogen transfer reactions, which increased dry gas yield and decreased butylene yield. A high space velocity (2.0 h^{-1}) led to insufficient reaction and incomplete olefin conversion, reducing the yield of ethylene plus propylene.

Table 4 Product distribution of F-T gasoline cracking at different space velocities

Product	Space velocity // h^{-1}			wt%
	1.0	1.5	2.0	
Gas	67.36	68.28	66.21	
Dry gas	28.05	26.41	24.37	
Ethylene	17.18	17.29	16.71	
Ethane	5.65	4.81	4.12	
Liquefied petroleum gas	39.30	41.87	41.85	
Propylene	22.41	23.81	23.40	
Propane	7.17	7.12	7.06	
Butylene	7.92	8.94	9.29	
Liquid + coke	32.64	31.72	33.79	
Ethylene + propylene	39.59	41.10	40.11	
Ethylene + propylene + butylene	47.51	50.04	49.40	
Ethylene selectivity // %	25.51	25.31	25.24	
Propylene selectivity // %	33.27	34.87	35.34	

The properties of liquid products at different space velocities are listed in Table 5. With increasing space velocity, the density of liquid products decreased, the contents of saturated hydrocarbons and olefins increased, and the aromatic content decreased. A high space velocity shortened residence time, inhibited aromatization, reduced aromatic formation, and increased residual unconverted olefins.

Table 5 Properties of liquid products at different space velocities

Property	Space velocity // h^{-1}		
	1.0	1.5	2.0
Density // g/cm^3	0.809 1	0.791 3	0.780 3
Hydrocarbon composition // wt%			
Saturated hydrocarbons	15.32	19.90	23.11
Olefins	9.56	12.75	15.66
Aromatics	75.12	67.35	61.23
Distillation range // $^{\circ}\text{C}$			
Initial boiling point	52.28	49.98	49.60
Final boiling point	240.78	234.60	232.59

2.2 Catalytic cracking of aromatic raffinate

2.2.1 Effect of reaction temperature on product distribution. Aromatic raffinate has a high saturated hydrocarbon content and low olefin content, making it more refractory than F-T gasoline. The product distribution at different temperatures is presented in Table 6. As the temperature increased from 615 to 645 $^{\circ}\text{C}$, the gas yield increased from 41.23 wt% to 44.06 wt%, accompanied by increases in the yields of dry gas, ethylene, propylene, and butyl-

ene. The yield of ethylene plus propylene rose from 24.88 wt% to 27.53 wt%, and the yield of ethylene plus propylene plus butylene increased from 29.01 wt% to 32.11 wt%. The selectivities of ethylene and propylene increased slightly, reaching 27.31% and 35.16% at 645 $^{\circ}\text{C}$, respectively.

Table 6 Product distribution of aromatic raffinate cracking at different temperatures

Product	Temperature // $^{\circ}\text{C}$			wt%
	615	630	645	
C4 ⁻ in gas	41.23	44.09	44.06	
Dry gas	17.55	19.71	20.11	
Hydrogen	0.47	0.51	0.54	
Methane	2.69	3.52	3.59	
Ethylene	10.66	11.68	12.04	
Ethane	3.73	3.99	3.94	
Liquefied petroleum gas	23.68	24.38	23.95	
Propylene	14.23	15.38	15.49	
Propane	4.34	3.61	3.14	
Butylene	4.13	4.57	4.59	
Butane	0.98	0.82	0.73	
Liquid + coke	58.77	55.91	55.94	
Ethylene + propylene	24.88	27.06	27.53	
Ethylene + propylene + butylene	29.01	31.64	32.11	
Ethylene selectivity // %	25.84	26.50	27.31	
Propylene selectivity // %	34.51	34.89	35.16	

2.2.2 Effect of reaction temperature on liquid product composition. As shown in Table 7, with increasing temperature, the density of liquid products from aromatic raffinate cracking increased, the saturated hydrocarbon content decreased slightly, and the aromatic content increased gradually, reaching 34.10 wt% at 645 $^{\circ}\text{C}$. Compared with F-T gasoline, the liquid aromatic content from aromatic raffinate cracking was much lower, which is attributed to its feedstock composition (high saturated hydrocarbons, and low olefins). Higher temperatures enhanced aromatization and improved aromatic yield.

Table 7 Composition of liquid products from aromatic raffinate cracking at different temperatures

Property	Temperature // $^{\circ}\text{C}$		
	615	630	645
Density // g/cm^3	0.747 1	0.752 1	0.753 4
Hydrocarbon composition // wt%			
Saturated hydrocarbons	61.59	59.18	59.57
Olefins	6.44	6.84	6.33
Aromatics	31.97	33.98	34.10
Distillation range // $^{\circ}\text{C}$			
Initial boiling point	48.63	48.61	48.62
Final boiling point	221.27	223.79	222.50

2.3 Comparison of cracking performance between two feedstocks Significant differences in cracking performance were observed between the F-T gasoline fraction and the aromatic raffinate.

2.3.1 Light olefin yield. The yields of ethylene plus propylene and ethylene plus propylene plus butylene from F-T gasoline cracking were substantially higher than those from aromatic raffinate. At 630 °C and 1.5 h⁻¹, the ethylene plus propylene yield of F-T gasoline (41.10 wt%) was 1.52 times that of aromatic raffinate (27.06 wt%), which is ascribed to the high α -olefin content of F-T gasoline, facilitating β -scission to form light olefins.

2.3.2 Liquid aromatic content. At the same temperature, the aromatic content of liquid products from F-T gasoline cracking was much higher than that from aromatic raffinate, reaching 79.20 wt% at 670 °C versus only 34.10 wt% for the latter. Olefins exhibited higher aromatization activity than saturated hydrocarbons.

2.3.3 Reaction condition adaptability. The optimal temperature for F-T gasoline cracking was 630–650 °C, balancing olefin yield and selectivity. In contrast, aromatic raffinate required a higher temperature (645 °C) to enhance cracking and aromatization.

3 Conclusions

(1) The F-T gasoline fraction, containing 60.57 wt% α -olefins and ultra-low heteroatom contents, is an excellent feedstock for catalytic cracking to light olefins. Under optimized conditions (630 °C, 1.5 h⁻¹, and 0.05 MPa), the yield of ethylene plus propylene reached 41.10 wt%. At 670 °C, the yield of ethylene plus propylene increased to 43.37 wt%, with a liquid aromatic content of 79.20 wt%.

(2) The reforming aromatic raffinate can be upgraded via catalytic cracking for high-value utilization. At 645 °C, a yield of ethylene plus propylene of 27.53 wt% and a liquid aromatic content of 34.10 wt% were achieved. Higher temperatures favored both light olefin production and aromatic formation.

(3) Space velocity significantly influenced the cracking per-

formance of F-T gasoline. A space velocity of 1.5 h⁻¹ was optimal; lower space velocity promoted over-cracking, while higher space velocity resulted in insufficient conversion.

(4) Marked differences in cracking behavior existed between the two feedstocks. The F-T gasoline fraction was highly suitable for high-yield production of light olefins and aromatics, whereas the aromatic raffinate required more severe conditions for efficient conversion. The results provide a technical basis for the industrial application of these light hydrocarbon streams.

References

- [1] WANG JM, YUAN QT. Strategic thinking on high-quality development of petrochemical industry in China [J]. *Engineering Science*, 2021, 23 (2): 1–8.
- [2] HUANG GS, HU J, LI JS, *et al.* Development status and trend analysis of coal-to-olefin technology in China [J]. *Chemical Industry and Engineering Progress*, 2020, 39(10): 3966–3974.
- [3] LIU ZM. Progress and industrial application of methanol-to-olefin technology [J]. *Scientia Sinica Chimica*, 2020, 50(7): 903–916.
- [4] MA AZ, WANG ZJ, KONG LJ, *et al.* Conception and exploration of light hydrocarbon and naphtha conversion technology under the background of "reducing oil and increasing chemicals" [J]. *Petroleum Refining and Chemical Industry*, 2026, 57(3): 1–8.
- [5] SUN QW, ZHANG ZS, WU JM. High-temperature fischer-tropsch synthesis technology and high-value utilization of products [J]. *Journal of China Coal Society*, 2020, 45(4): 1234–1242.
- [6] CHAI YM, LIU CG, ZHAO RF. Study on catalytic cracking of aromatic raffinate to light olefins [J]. *Petroleum Refining and Chemical Industry*, 2020, 51(9): 45–50.
- [7] XU YH, ZUO YF, SHU XT. Progress in catalysts and processes for catalytic cracking to light olefins [J]. *CIESC Journal*, 2018, 69(5): 1801–1815.
- [8] TANG HN, WANG MD, ZHENG HX, *et al.* Development of C4 hydrocarbon cracking to olefin technology [J]. *Petroleum Refinery Engineering*, 2012, 42(10): 5–8.

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lain from a meteorological perspective. Firstly, it clarifies the symbolic political attributes of "blue after rain" beyond aesthetic imagery, which is a visual extension of the imperial cosmology. Secondly, relying on the theory of "practical knowledge", it reveals that the essence of traditional Ru porcelain firing techniques is an "ecological adaptive technology" that integrates meteorological perception, physical skills, and phenological rhythms, demonstrating how ancient people internalized "heaven timing and earth qi" into exquisite craftsmanship practices. Finally, this paper focuses on the evolution of Ru porcelain technology from wood burning to modern electric and gas kilns, and constructs a "human – meteorology relationship" from a "phenological dependence model" that "conforms to the natural order" to a "de meteorologization model" that "shields the weather". This is not only a history of improving process efficiency, but also an evolution of the way humans deal with the relationship between the natural world, reflecting the rational pursuit of certainty and control in modern technology, while also gradually distancing itself from the symbi-

otic wisdom and process poetry contained in traditional craftsmanship. Therefore, the core value of Ru porcelain as an intangible cultural heritage should not only lie in its glaze color and form itself, but also in the ecological wisdom and life philosophy of "entering the Dao through technique and crafting art according to the heavens" contained in it. The understanding of this wisdom undoubtedly has profound enlightening significance for us to explore a more harmonious and sustainable form of civilization in today's increasingly tense relationship between technology and nature.

References

- [1] XU WJ, WANG P. Study on the craftsmanship of celadon glaze from official Ru kilns [J]. *China Ceramics*, 2007(8): 73–75.
- [2] WEN RJ. Translation of the *Artificers' Record* [M]. Shanghai: Shanghai Classics Publishing House, 2008.
- [3] MA X. Semantic focus of glaze color lexicon in intercultural context: A case study of celadon [J]. *Southeast Culture*, 2009(6): 123–126.
- [4] HUANG XL, HAI L. Aesthetic and redesigning exploration on Song Dynasty Ru ware [J]. *Journal of Ceramics*, 2014, 35(4): 439–443.