A forecast of research octane number of FCC gasoline with changing weight hour space velocity

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Research Octane Number (RON) of FCC gasoline has been studied using Lanlian FCC gasoline and Lanlian aromatization products as feedstocks and LBO-A as catalyst, and research octane number have been put forward with changing weight hour space velocity (WHSV). The mathematical model forecasts research octane number of modified FCC gasoline with changing weight hour space velocity. The results from experimental data are in accordance with the quantitative analytical conclusions drawn from the calculated data.

With increasing environmental regulations to petroleum products, America, Japan, and others European countries[1] had to issue a new gasoline standard to decrease the olefin contents of gasoline, towards 25% (by volume) or even lower[2]. A new gasoline standard was put into practice from January 2003 in China because of the requirement of environmental protection[3]. As requested, the contents of olefin, sulfur, benzene, and aromatics had lower than 35v%, 0.08m%, 2.5v%, and 40v%, respectively, and research octane number (RON) should be above 90[4]. Owing to the enforcement of the new standard, many refineries would have to face the challenge[5]. But at present, the portion of FCC gasoline in commercial gasoline is about 85% and their olefins concentration is roughly 50 to 60% with the improvement of fluid catalytic cracking technology in China, and the olefin average amounts of gasoline in 60 refinery plants reaching 44.2% has contrasted much difference with the new standard[6]. In order to satisfy the Chinese new standard, the new aromatization catalysts[7] studied make the olefins contents of gasoline change into the i-paraffins and aromatics and gradually improve the gasoline's stability and decrease the harmfully emitted amounts in the tail gas of cars and ensures the gasoline octane number[8].

During usage of FCC gasoline, it is necessary to know its research octane number (RON) in FCC gasoline. On the other hand, research octane number of FCC gasoline is seldom reported in the literature. Thus, in this article, forecasting research octane number of modified FCC gasoline model, which can predict the product's research octane number with changing weight hour space velocity (WHSV), is set up for a confined fluidized bed reactor.

Experimental Section

Feedstock

Lanlian FCC gasoline was obtained from a FCC Unit of Lanlian Petrochemical Company. Lanlian aromatization products came from Lanlian FCC gasoline after reaction. The compositions of Lanlian FCC gasoline and Lanlian aromatization products were shown in Table 1.

Catalyst

Catalyst (LBO-A) obtained from Lanzhou Petrochemical Institute was researched. LBO-A in a confined fluidized bed reactor was aged with 2 mL/min vapour at temperature 700, 750 or 800°C, respectively. Its properties are presented in Table 2.

The micro-activity test index (MATI) is obtained by using the micro-reactor. The material oil provided by Beijing Petroleum Chemical Institute is light oil for the micro-reactor and its distillation range is from 225 to 337°C. The reaction temperature, time, inflow oil, catalyst weight in the micro-reactor are stable, that is 460°C, 70 s, 1.56 g , 5.0030 ± 0.0010 g,

Table 1 — Compositions of Lanlian FCC gasoline and Lanlian aromatization products (wt%)

Compositions	Lanlian FCC gasoline	Lanlian aromatization products
n-Paraffins	4.78	4.85
i-Paraffins	27.45	33.69
Olefins	36.99	19.66
Cycle paraffins	7.12	9.13
Aromatics	23.66	32.67
RON	93.61	95.25

respectively. By applying SP 3420 Gas Chromatograph the liquid product of above reaction is distilled and analyzed. MATI is given as follows:

$$M = 1 - \frac{(m * W_2)}{m_1} \qquad \ldots (1)$$

where M is MATI, %; m is liquid product weight, g; m_1 is total inflow oil weight, g; W_2 is the mass fraction of diesel oil in the liquid product.

Apparatus

A confined fluidized bed reactor was applied in the Lanlian FCC gasoline aromatization and was shown in Fig. 1. It consisted of five parts: oil and stream input system, reaction zone, temperature control, product separation and collection system. Variable amount of distilled water was pumped into the furnace to exchange into steam, and then mixed with fraction of Lanlian FCC gasoline pumped by another pump simultaneously at the outlet of a constant temperature box. The mixture was heated to approximately 450°C in a preheated room before it entered the reactor.

Results and Discussion

Research octane number is an important physical property of FCC gasoline. Much research has been done about improving FCC gasoline's property[9], but research octane number of modified FCC gasoline model is seldom reported in literature. According to the literature[10] and experimental results listed below, research octane number is between 94 and 97. In this research, It is found that research octane number changes with the increase of weight hour space velocity.

The experimental results of Lanlian FCC gasoline and Lanlian aromatization products are presented in Tables 3 and 4, respectively, where RON represents research octane number, RON_0 means initial research octane number of FCC gasoline, W represents weight hour space velocity, h^{-1}.

It is supposed that research octane number and weight hour space velocity are correlated with exponential equations:

$$RON = RON_0 + ae^{bW} \qquad \ldots (2)$$

(wt%)

Research octane number of modified FCC gasoline model are obtained based on the above data and the least squares method. Eqs. (3) and (4) for Lanlian FCC gasoline (LFG) and Lanlian aromatization products (LAP), respectively, are shown as follows:
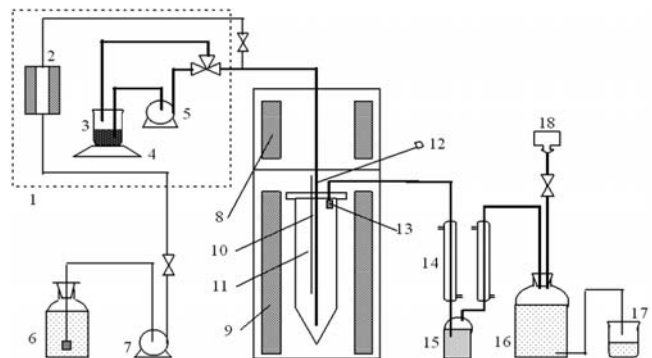
1-constant temperature room; 2-steam furnace; 3-feedstock; 4-electronic scale; 5-gasoline pump; 6-water tank; 7-water pump; 8-preheated room; 9-furnace; 10-thermocouple; 11-reactor; 12-catalyst inlet; 13-filter; 14-condenser; 15-liquid product collection bottle; 16-collection gas bottle; 17-beaker; 18-gas sample bag

Fig. 1 — Schematic drawing of experimental apparatus

Table 2 — Properties of LBO-A catalyst

Parameters	Value
Micro-activity Test Index (MATI), %	56
Apparent density, g/ml	0.8
Pore volume, ml/g	0.3
Surface area, m^2/g	85
Particle size distribution, % (by mass)	
<45.8 μm	20.6
45.8~111.0 μm	60.3
>111.0 μm	19.1
micro-activity test index (MATI)	56

Table 3 — Effect of different weight hour space velocity on the product conversion (wt%)

WHSV, h^{-1}	Off-gas	Liquefied gas	gasoline	Diesel	coke	RON
5	0.40	9.03	86.53	2.38	1.66	94.01
10	0.38	8.77	86.57	2.73	1.55	94.23
15	0.37	8.60	86.72	2.92	1.39	95.78
20	0.34	8.49	86.83	3.00	1.34	97.46
25	0.31	8.13	87.17	3.08	1.31	96.58
30	0.28	7.89	87.38	3.19	1.26	96.83
35	0.25	7.65	87.50	3.35	1.25	96.55
40	0.22	7.18	87.95	3.43	1.22	96.35

Table 4 — Effect of different weight hour space velocity on Lanlian aromatization products conversion (wt%)

WHSV, h^{-1}	Off-gas	Liquefied gas	gasoline	Diesel	coke	RON
20	0.27	7.44	86.40	4.34	1.55	96.89
25	0.22	7.16	86.84	4.35	1.43	97.04
30	0.19	6.76	87.19	4.59	1.27	97.42
35	0.16	6.41	87.42	4.78	1.23	97.10
40	0.13	6.16	87.54	5.00	1.17	96.89

Table 5 — Relative errors of experimental value and calculated values (wt%)

WHSV, h^{-1}	Lanlian FCC gasoline	Lanlian aromatization products
5	0.02	-
10	0.13	-
15	1.58	-
20	3.07	0.17
25	1.91	0
30	1.79	0
35	1.02	-0.80
40	0.18	-1.60

$$RON_{LFG} = RON_0 + 0.28856e^{0.054669W} \qquad \dots (3)$$

$$RON_{LAP} = RON_0 + 0.683634 \times e^{0.038502W} \qquad \dots (4)$$

The relative errors of experimental value and calculated values are obtained as shown in Table 5, which indicates that relative error values of experimental value and calculated values for Lanlian FCC gasoline and Lanlian aromatization products are below 3.07%. This shows Eqs. (3) and (4) can describe research octane number of Lanlian FCC gasoline (LFG) and Lanlian aromatization products (LAP).

Conclusion

In this article, the author has found that research octane number of modified FCC gasoline model leads to and is closely in accordance with the practical experimental value. Research octane number of Lanlian FCC gasoline and Lanlian aromatization products can be accurately estimated by studying weight hour space velocity.

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