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Magnetic Separation of FCC Equilibrium Catalyst by HGMS

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Abstract

Effects of magnetic field and carrier gas velocity on the magnetic separation of FCC catalyst by a high gradient magnetic separator were studied. The activities of the equilibrium catalyst ,the magnetic particles and the nonmagnetic particles were evaluated in a fixed bed microreactor . The results showed that heavy metal contaminated catalyst can be selectively separated by means of high gradient magnetic separation at magnetic field 0.5T and carrier gas velocity $0.3 m.s^{-1}$, and lightly metal contaminated catalyst retained high catalytic activity .

Key words: Magnetic separation; FCC equilibrium catalyst; High gradient magnetic separator

1.Introduction

Fluid catalytic cracking (FCC) of residual oil is developing rapidly because of the growing demand for light fuel oil and tight supplies of regular cracking stocks. However, one problem especially serious in the FCC of residual oil is the continuous deposition of nickel, iron and vanadium contained originally in the residual oil on the catalyst surface. Such metals play as catalyst poisons, greatly decreasing the activity of the catalyst and the efficiency of the cracking process[1].

It is therefore the usual practice, for refinery to maintain the activity of the catalyst at a certain fixed level by means of steadily or periodically withdrawing a part of the catalyst to exchange it with a fresh catalyst. The amount of the catalyst to be withdrawn is very large, and the withdrawn catalyst is usually discarded. Such a means is often uneconomical because some lightly metal contaminated catalyst retain high catalytic activity and selectivity and can be returned back to the circulating system of the FCC unit for reuse without adverse effects on the conversion rate and selectivity[2,3].

One method proposed in this paper attempted to solve this problem is magnetic separation of the equilibrium catalyst. Here studies are concerned with magnetic separation of the equilbrium catalyst by a high gradient magnetic separator (HGMS) which is an effective and economical device to remove very fine, weakly magnetic catalyst particles which are difficult to separate by conventional magnetic separators[4-6].

2. Experiment

2.1. Catalyst sample

FCC equilibrium catalyst sample was obtained from Jinan Refinery. It was actually used in

FCC units processing residual oils. The catalyst was classified into several size ranges using a set of screens. The size and metal distributions, some physical and chemical properties of the catalyst sample are listed in Tables 1 and 2. As shown in Tables 1 and 2, the mean specific magnetic susceptibility of catalyst sample is $8.9 \times 10^{-8} m^3/kg$ and 90.83% of catalyst particles are less than 75Πm in size. It is difficult to separate the fine, weakly magnetic catalyst particles using conventional magnetic separators. In our studies, a high gradient magnetic separator was used to separate the fine, weakly catalyst particles.]

Table 1 Physical and chemical properties of the catalyst sample

Metal content (ppm)			Surface area	Porosity	Susceptibility	conversion
Ni	V	Fe	(m^2/g)	volume (ml/g)	(m^3/kg)	(%)
9047	131	1090	137.8	0.29	8.9×10^{-8}	65.3

Table 2 Size and metal distributions of the catalyst sample

Size	Yield	Metal Ni		Metal V		Metal Fe	
(Πm)	(%)	ppm	distrib.(%)	ppm	distrib.(%)	ppm	distrib.(%)
+75	9.17	5024	5.16	115	8.56	2245	16.05
+65-75	12.18	6815	9.29	118	11.67	1300	12.34
+45-63	50.60	8911	50.47	122	50.12	1133	44.70
+38-45	7.67	9909	8.51	126	7.87	1141	6.82
-38	20.38	11645	26.57	132	21.78	1265	20.09

2.2. Experimental unit and operation

Figure I illustrates the experimental unit, in which the main apparatus is a HGMS. It consists of a canister, a cylinder 80 mm in diameter, packed with ferromagnetic matrices immersed in a uniform magnetic field generated by a solenoid coil inducing regions of highly nonuniform magnetic field intensity. The solenoid coil is enclosed by a magnetic iron yoke. In the present studies, the ferromagnetic matrices are expanded metal of 800 micron wire gauge.

The unit is operated as follows:

First, the blower and magnet of HGMS are switched on and a catalyst sample is put into the unit by a feeder. The sample is then carried down by an air current into the separation zone. Particles heavily loaded with metals are held in the matrices by magnetic force while particles loaded with much less metals pass through the matrices and are collected in the receiver No.1, namely nonmagnetic particles (nonmags). Then the magnet is switched off. The highly metal loaded particles on the matrices are flushed with air and collected in the receiver No.2. They are called magnetic particles (mags).

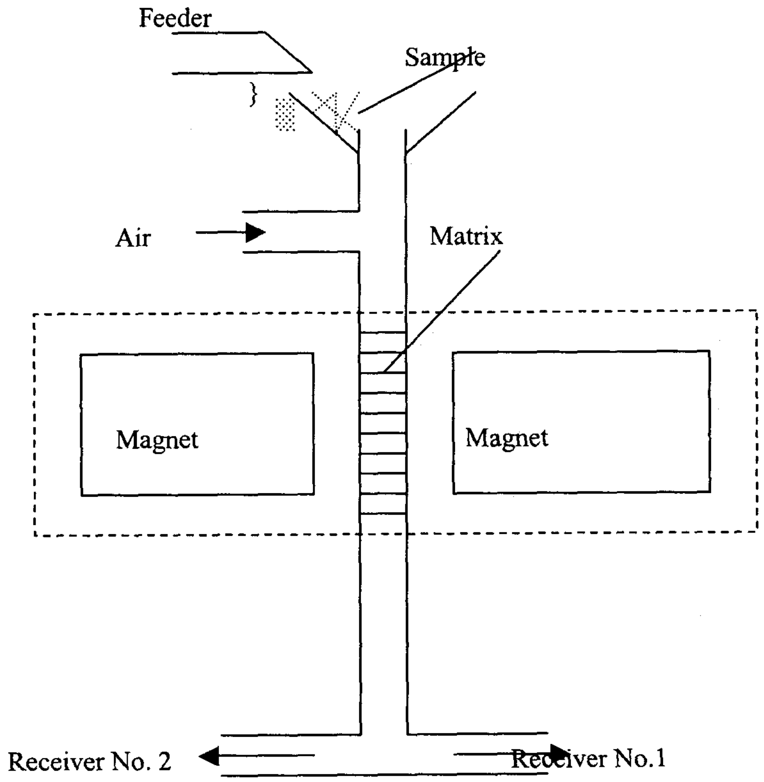

Figure I the experimental unit(HGMS)

2.3. Magnetic susceptibility measurement

The specific magnetic susceptibility of FCC equilibrium catalyst sample was determined using WCF2 Magnetic Property Analyser, which is a force type magnetic balance usually used in laboratory to measure magnetic susceptibility of the weakly magnetic minerals[7].

The balance employs the Faraday method of weighing a sample in gravitational and magnetic fields. The magnetic force on FCC equilibrium catalyst sample of mass, m, in a non-uniform magnetic field can be written as:

$$F_m = m(x/\mu_0)B(dB/dz) \tag{1}$$

where , x is the specific magnetic susceptibility in m^3/kg, μ_0 is the permeability of free space taken as $4\pi \times 10^{-7} N/A^2$, B is the magnetic induction in Tesla, and dB/dz is the field gradient in T/m.

The field gradient is confined to the z direction by the shape of the pole pieces. Since the magnetic induction is constant, then

$$B(dB/dz) = \text{constant} \tag{2}$$

Hence, the specific magnetic susceptibility can be given by:

$$x \quad \frac{F_m \Gamma_0}{mB(dB/dz)} \tag{3}$$

From equation 3, the susceptibility of FCC equilibrium catalyst can be caculated.

2.4. Activity test

The activities of the equilibrium catalyst, the magnetic particles and the nonmagnetic particles were evaluated in a fixed bed microreactor under similar industrial operating conditions[8]. Dagang standard diesel oil was used in activity test. The reaction was carried out at a reaction temperature of 460℃, a liquid space velocity of $16hr^{-1}$, a reaction time of 70 seconds and a catalyst loading of 5g. The results of activity test were shown in Table 4 (in the part 3.4.).

3. Results and discussion

3.1. Effect of magnetic field

Figure 2 shows the effect of magnetic field strength at a constant carrier gas velocity (air, in this case) on the mags yield, its magnetic susceptibility and the contents of nickel, vanadium and iron in the magnetic fraction. As shown in Figure 2, as magnetic field increased, mags yield also increased while magnetic susceptibility of mags decreased, because the catalyst portion of even the lower magnetic susceptibility was also caught in the matrices of HGMS. Increased magnetic field also gave rise to decrease in the contents of nickel and iron in the magnetic fraction, which suggested that a separation according to susceptibility is the same as the separation according to the metal contents of the catalyst. It is also noticed that vanadium was less sensitive to the variations of magnetic field, due to the small vanadium content and the low magnetic susceptibility of vanadium.

3.2. Effect of carrier gas velocity

In Figure 3, the mags yield and the contents of iron, nickel and vanadium in the magnetic fraction are plotted against the velocity of the carrier gas at a constant magnetic field. As seen in Figure 3, the higher the carrier gas velocity was, the lower the mags yield was and the higher the contents of iron, nickel and vanadium became in the magnetic fraction. The results indicate that only catalyst particle of higher magnetic susceptibility can be captured in the matrices by the carrier gas of higher velocity.

3.3. Magnetic separation of FCC equilibrium catalyst

Magnetic separations of FCC equilibrium catalyst were carried out using high gradient magnetic separator under various operating conditions. Contents of iron, nickel and vanadium are summarized in Table 3. As shown in the table, catalyst of higher metal content can be obtained as mags and catalyst of lower metal content as nonmags. These results suggest that highly metal contaminated catalyst can be selectively removed by adjusting magnetic field intensity and the carrier gas velocity.

Table 3 Results of magnetic separation

Test No.	Field (T)	Velocity ($m.s^{-1}$)	Feed (g)	Yield (%)	Metal Ni (ppm)	Metal Fe (ppm)	Metal V (ppm)
1	0.5	0.30	25	M 17.2	14438	2031	175
				N 82.8	8072	964	134
2	0.5	0.25	20	M 25.4	10852	1792	151
				N 74.6	8351	897	127
3	0.6	0.25	15	M 34.7	10783	1465	142
				N 65.3	8214	905	132

M: Mags
N: Nonmags

3.4. Activity evaluation

The activities of equilibrium catalyst, mags and nonmags in Table 3 were evaluated in a fixed bed microreactor. These results were summarized in Table 4. A clear difference is noticed between the conversion rates of mags and those of nonmags. The results of Table 4 show that in tests No.1 to 3, the conversion rates of the nonmagnetic particles were close to those of fresh catalyst, which suggested these nonmagnetic particles retained high catalytic activity and can be returned to FCC unit for recycling, which will permits much saving of the amount of the make-up fresh catalyst and give rise to a considerable reduction of total catalyst consumption in residual oil FCC processing.

Table 4 micro-activity test results

Test No.	Conversion(% by weight)			
	Mags	Nonmags	Withdrawn catalyst	Fresh catalyst
1	59.6	70.3	65.3	72.0
2	62.4	68.8	65.3	72.0
3	62.0	68.1	65.3	72.0

4. Conclusions

(a) Highly metal contaminated catalyst can be selectively separated from lightly metal contaminated catalyst by means of high gradient magnetic separation.
(b) The conversion rates of nonmagnetic particles were close to those of fresh catalyst. These particles retained high catalytic activity and can be returned back to the circulating system of FCC unit for reuse.
(c) A magnetic separation of the withdrawn equilibrium catalyst by HGMS can give rise to a considerable reduction of total catalyst consumption in residual oil FCC processing and it is advantageous economically.

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