

More Propylene in FCC Units

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Abstract

The demand for propylene has been increasing worldwide recently and consequently the propylene production from FCC units has also been attracting more attention. From the view point of catalysts, ZSM-5 additive brings an effective impact on propylene production and JGC C&C has developed an advanced ZSM-5 additive named "OCTUP- α ".

In addition, FCC catalyst itself should be properly designed to maximize the performance of ZSM-5 additive for more propylene production.

This paper shows the advanced technology to maximize propylene yield by a combination of the ZSM-5 additive developed and the base catalyst named "LMV Catalyst".

1. Introduction

In recent years, the global demand for propylene has expanded in line with the economic growth of newly developing countries such as China, India, South-east Asia etc and is expected to grow at approximately 5% per year from now on. Approx. 70% of the source of propylene supply is from steam cracking when producing ethylene and the remaining 30% is from FCC units. As it is not expected that the propylene yield from steam cracking is going to increase greatly, attention is being focused on increasing production from FCC units. ¹⁾ In light of this, operations for improving propylene yield by changing operating conditions and improving both the conventional FCC units and constructing new FCC units for maximum light olefin production from a process point of view is occurring. On the other hand, from the catalyst point of view, the use of ZSM-5 additive is the most efficient method of increasing propylene production and is used in almost all FCC units trying to achieve this. In addition, the design of FCC catalyst (hereafter called base catalyst) where ZSM-5 additive performance is exhibited to its fullest is important. In this study, we will discuss the catalyst design that maximizes propylene yield by combining the base catalyst with the optimizing technology - LMV (Leitmotiv) catalyst with newly developed, high performance ZSM-5 additive "OCTUP- α ".

2. Increasing propylene production in FCC units

2.1 FCC Reaction

Generally, the contact time between the catalyst and the feedstock within the FCC unit riser is only a few seconds, and various reactions such as cracking, hydrogen transfer, isomerization and condensation reactions etc occur. The important reactions with regard to improvement of propylene yield are the cracking and hydrogen transfer reactions.

The cracking reaction can be classified into 2 types of reaction – catalytic cracking and thermal cracking. Catalytic cracking is where β -scission occurs under the existence of catalyst and yields high C3, C4 olefins. As this catalytic cracking reaction is endothermic and occurs over the acid sites it affects the reaction temperature and acidic properties of the catalyst. The thermal cracking reaction is also mainly a free radical reaction which generates C2 components. Accordingly, with regards to increasing propylene production it is more advantageous to have a catalytic cracking-type reaction than a thermal cracking-type. It is not desirable to have a hydrogen transfer reaction in the production of propylene as it consumes the olefins generated by the catalytic cracking. This hydrogen transfer is generally known to have a bimolecular reaction, secondary reaction and endothermic reaction and it greatly affects the solid acidity of the solid catalyst, contact time and reaction temperature.

2.2 The process/operations side of increasing propylene production

Reaction temperature, Cat/Oil ratio, contact time and characteristics of feed oil can all be offered as operating factors that have an effect on improving propylene yield. Raising the temperature is most effective in controlling the exothermic reaction's hydrogen transfer and accelerating the catalytic cracking which is endothermic. In a commercial unit, the reaction temperature is raised by raising the catalyst circulation, reaction rate of the catalytic cracking is improved due to the cat/oil ratio being higher and the propylene yield also improves. In addition, as the hydrogen transfer reaction is a secondary reaction, a short contact time is better for reducing hydrogen transfer. Reactions with only a short contact time are led to controlling overcracking.

Maximum light olefin production FCC units are operated at short contact time, high reaction temperature (550~600°C) and higher cat/oil ratio than conventional FCC units in order to accelerate catalytic cracking and control the hydrogen transfer

3. The catalyst side of increasing propylene production

The use of ZSM-5 additive is the most effective way of increasing propylene production on the catalyst side. Furthermore, optimizing the FCC (base) catalyst in order to fully utilize the performance of ZSM-5 additive is also an effective method. However, where FCC catalyst alone is directed at increasing propylene production the effect is relatively small and it has a greatly negative influence on gas and coke yield.

3.1 Use of ZSM-5 additive

3.1.1 ZSM-5 zeolite

ZSM-5 zeolite shows 1) shape selectivity, 2) low hydrogen transfer, 3) high hydrothermal stability, 4) low coke formation.

ZSM-5 zeolite has 10-membered oxygen rings with tunnel-shaped pores with perpendicular zig-zags to form a three-dimensional pore structure (Fig. 1). The pore diameter is 0.56nm x 0.53nm and 0.55 x 0.51nm and is smaller than the 12-membered rings of Y-zeolite (0.74nm x 0.74nm and has shape selectivity which restricts the reaction molecules ²⁾. In addition, as it does not have a supercage like Y-zeolite (approx. 1.3nm diameter), bulky by-products such as coke do not tend to be formed. Furthermore, due to its three-dimensional pore structure, there does not tend to be the activity loss by coke deposition..

The ZSM-5 zeolite used in additive has a higher silica/alumina ratio and higher hydrothermal stability than Y-zeolite. Due to its high silica/alumina ratio, the acid density is also low and the pore diameter is small, therefore the hydrogen transfer activity which is a bimolecular reaction is also low.

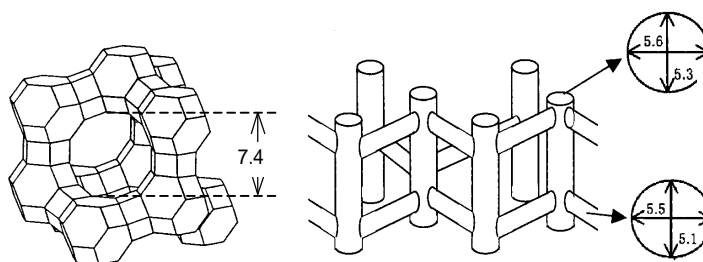


Fig.1 Schematic Illustration of Zeolite Y and ZSM-5

3.1.2 ZSM-5 additive

Most refineries that are focussing on increasing propylene production are use ZSM-5 additive for the three main reasons below.

(1) The most effective way for increase propylene yield

The propylene production scheme occurring in the FCC reaction is shown in Figure 2. LPG yield is increased due to the ZSM-5 additive cracking the olefins (mainly C₆= to C₈=) and transforming them into light olefins (mainly C₃= to C₅=). Furthermore, as the hydrogen transfer activity of the ZSM-5 additive is low, the olefin selectivity (olefinicity) is higher and the propylene yield improves.

(2) Effect on yields other than LPG and gasoline is relatively small

There is almost an even trade-off gasoline and LPG yield due to the ZSM-5 additive cracking the olefins in gasoline and cracking them to light olefins. In addition, as described above as one of ZSM-5's characteristics, heavy hydrocarbon (feedstock) cracking virtually does not occur and coke does not form easily therefore the effect on yields other than those of LPG and gasoline is

relatively small.

(3) High operational flexibility

As the effect of ZSM-5 additive is seen as soon as it is started to be added, the yield can be adjusted by the amount added hence it is possible to have operational flexibility.

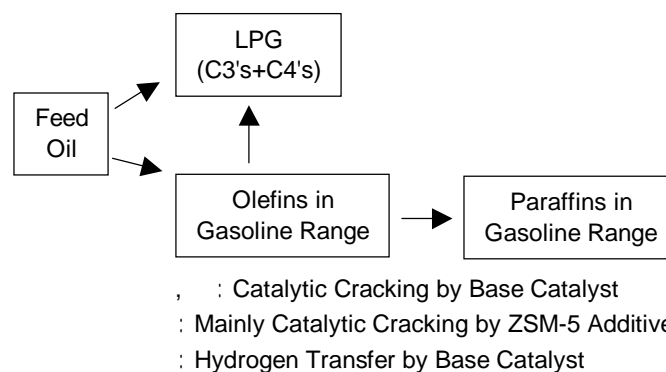


Fig.2 Reaction Scheme of Propylene Production in FCC

3.2 Combination of FCC (base) catalyst + ZSM-5 additive

ZSM-5 additive cracks the olefins in the gasoline range formed by the base catalyst cracking the feedstock and forms light olefins. Accordingly, it is believed that if the base catalyst is designed so that the olefins in the gasoline range are increased, this will also contribute to improved propylene yield.

In order to increase the olefins in the gasoline range, it is necessary to improve the olefinicity and the gasoline yield and progressing the catalytic cracking and controlling hydrogen transfer by the base catalyst is effective. When ZSM-5 additive is added to base catalyst designed this way, the effect can be maximized.

The LMV catalyst from JGC C&C with optimal technology in the base catalyst is described in detail in section 5.

4. Olefins cracking on ZSM-5 Additive

In order to be clear on the reaction properties of olefin, C6 to C8 olefins were reacted with ZSM-5 additive and the reactivity and product distribution were confirmed by experiments. C6 to C8 olefins were used as the feed oil and pseudo-deactivated ZSM-5 additive was added to an inactive substance and diluted. The results of the reactions in a fixed bed reactor MAT are shown in Figure 3.

With regards to the reactivity of olefins it is generally said that long-chain hydrocarbons are more reactive than short-chain hydrocarbons.³⁾

In these experiments, 1-octene has the highest conversion among normal olefins. With regards to product distribution, 1-hexene had the highest propylene yield and 1-octene the lowest. Considering the scission properties, it is thought that, theoretically, the catalytic cracking reactions of olefins are mainly the reactions shown below in ZSM-5.

C6= C3= + C3=
 C7= C3= + C4=
 C8= C3= + C5= or C4= + C4=

However, various reactions such as bimolecular reaction, isomerization reaction etc occur at the same time.

Experiments were also conducted on octene isomers in order to confirm the effects of shape selectivity of ZSM-5. From Figure 3 shows that linear olefins had an even higher conversion than branched olefins and that the shape selectivity of ZSM-5 has an effect.

In addition, with regards to propylene selectivity, 1-octene and 2-methyl-1-heptene are almost the same however 2,4,4-trimethyl-1-heptene has a low propylene yield. In this way it can be seen that as ZSM-5 zeolite shows shape selectivity properties, the products distribution changes greatly depending on the isomer.

According to Buchanan et al ³, olefins with a relatively low carbon number such as C6 olefin isomerizes faster than catalytic cracking however the catalytic cracking of C8 olefins is even faster. Accordingly, it is thought that the difference in isomers will be shown greatly in actual FCC reactions with regards to C8 olefin.

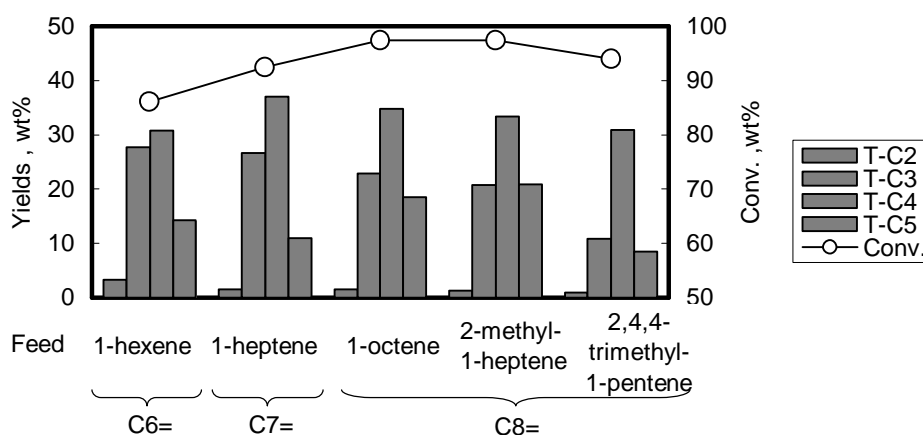


Fig.3 Yields and Conversion for Cracking C6-C8 Olefins

Deactivation (OCTUP-11S) : 750 -13hr-100%Steaming
 MAT : Rx.Temp.525 , C/O 1

5. High activity ZSM-5 additive “OCTUP-α”

5.1 Development concept of OCTUP-α

Up until now, JGC C&C has been selling ZSM-5 additive as our “OCTUP” series. In 2005, OCTUP-11S with improved pore size distribution and phosphorus modification technology was developed and commercialized and has a lot of commercial experience in a large number of refineries in Japan and overseas. We have now newly developed ZSM-5 additive, “OCTUP- ” with even better performance.

The following four points are considered important points when designing a high activity

ZSM-5 additive: 1) high ZSM-5 zeolite content, 2) ZSM-5 zeolite with high hydrothermal stability, 3) pore size control technology, 4) phosphorous modification technology. ⁴⁾ In comparison with OCTUP-11S, OCTUP- has a higher ZSM-5 zeolite content and by optimizing the pore size distribution of matrix has been able to surpass those of our existing OCTUP series.

Ordinarily, when the ZSM-5 content increases, the physical properties of the additive (apparent bulk density, attrition resistance) deteriorate and have a negative effect however JGC C&C has made it possible to keep these properties by applying their catalyst preparation technology.

With regards to the pore design of ZSM-5 additive, it is important to improve the diffusion of the reactants (gasoline components) within the pores of ZSM-5 additive. 5) By increasing the pore volume of OCTUP- the gasoline components become easy to diffuse to the active sites (ZSM-5 zeolite) within the additive pores and is thought to have high performance.

5.2 Solid acid, pore size distribution properties of OCTUP- α

The solid acid distribution properties of our conventional OCTUP-11S and our newly developed OCTUP- are shown in Figure 4.

As OCTUP- has a higher ZSM-5 content than OCTUP-11S, there is more acidity after pseudo-deactivation. Strong acids and medium acids in particular increased.

Next, the pore size distribution of pseudo-deactivated ZSM-5 additive measured by mercury porosimetry is shown in Figure 5. Improvement in diffusion of reactants is expected due to OCTUP- having a larger pore volume in the macropore region of 50nm~200nm than OCTUP-11S.

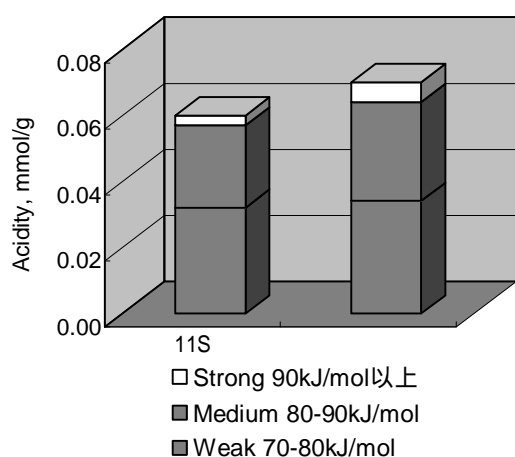


Fig.4 Solid Acid Distribution of OCTUP-11S and OCTUP- α

measured by Micro Calorimetry of NH₃ adsorption
deactivated sample : 750 °C-13hr-100% steaming

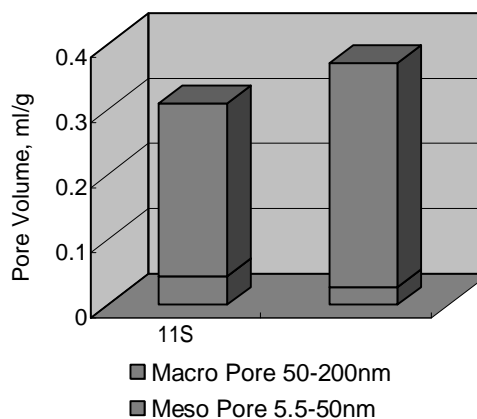


Fig.5 Pore size Distribution of OCTUP-11S and OCTUP- α

measured by mercury porosimetry
deactivated sample : 750 °C-13hr-100% steaming

5.3 OCTUP- α performance

The results of the pilot tests (Midget) on OCTUP- are shown in Table 1. 6% of

pseudo-deactivated OCTUP-11S and OCTUP- (750oC for 13hr at 100%) were each added to FCC equilibrium catalyst and evaluated using DSVG0 as feedstock. OCTUP- had a 0.9% higher propylene yield than OCTUP-11S. The performance has improved because of the increase in macropore volume from pore size control technology and increase of acidity from greater ZSM-5 zeolite content as described in the above development concept.

OCTUP- has improved olefinicity in LPG, as it has a higher activity but the lower hydrogen transfer. In addition, the propylene selectivity in LPG is improved yet a large amount of C6, C7 olefins with high propylene selectivity are cracked due to the high activity of OCTUP- .

Table 1 Performance of OCTUP Series

Base Catalyst		E-Cat				
ZSM-5 Additive		-	+OCTUP-11S	+OCTUP- α		
		-	6%	6%		
Cat./Oil		7.0	7.0	7.0		
Conversion	wt%	73.5	72.0	-1.5	72.1	-1.4
Dry Gas	wt%	1.1	1.6	-	1.6	-
H ₂	wt%	0.05	0.05	-	0.05	-
C1	wt%	0.3	0.3	-	0.3	-
C2	wt%	0.7	1.2	-	1.2	-
LPG	wt%	13.0	21.7	+8.7	23.6	+10.6
C3	wt%	0.7	1.1	+0.4	1.2	+0.5
C3=	wt%	4.5	9.0	+4.5	9.9	+5.4
i-C4	wt%	3.2	4.5	+1.3	4.7	+1.5
n-C4	wt%	0.5	0.6	+0.1	0.7	+0.2
C4=	wt%	4.1	6.5	+2.4	7.1	+3.0
Gasoline	wt%	57.0	46.6	-10.4	44.8	-12.2
LCO	wt%	19.3	19.9	-	19.8	-
HCO	wt%	7.2	8.1	-	8.1	-
Coke	wt%	2.4	2.1	-	2.1	-
Total	wt%	100.0	100.0	-	100.0	-
LPG Properties						
LPG Olefinicity		<u>0.662</u>	<u>0.714</u>	-	<u>0.720</u>	-
C3=/LPG		<u>0.346</u>	<u>0.415</u>	-	<u>0.419</u>	-
C3=/C4=		<u>1.098</u>	<u>1.385</u>	-	<u>1.394</u>	-
Gasoline Properties						
RON		92.3	93.8	+1.5	94.1	+1.8
Paraffins		35.2	28.7	-	28.3	-
Olefins		26.4	27.6	-	28.3	-
Naphtens		9.1	9.9	-	9.8	-
Aromatics		29.3	33.8	-	33.6	-

Deactivation (OCTUP) : 750 -13hr-100% Steaming
Midget : DSVG0, Rx. Temp. 500

Figure 6 shows the distribution of LPG and gasoline components just before and after the addition of ZSM-5 additive. By using ZSM-5 additive, C6~C8 olefins are reduced and C3~C4 olefin yield is increased. This is because the ZSM-5 additive cracks the C6~C8 olefins and C3~C4 olefins are formed. In addition, by using ZSM-5 additive, iso-paraffins and aromatics are reduced. This is due to the catalytic cracking to C3~C4 olefins from C6~C8 olefins over ZSM-5 progressing

and hydrogen transfer reaction to C6~C8 isoparaffins/aromatics from C6~C8 olefins over base catalyst reducing, proportionally.

OCTUP- has a greater reduction of C6-C8 olefins and iso-paraffins compared with OCTUP-11S and shows higher cracking activity.

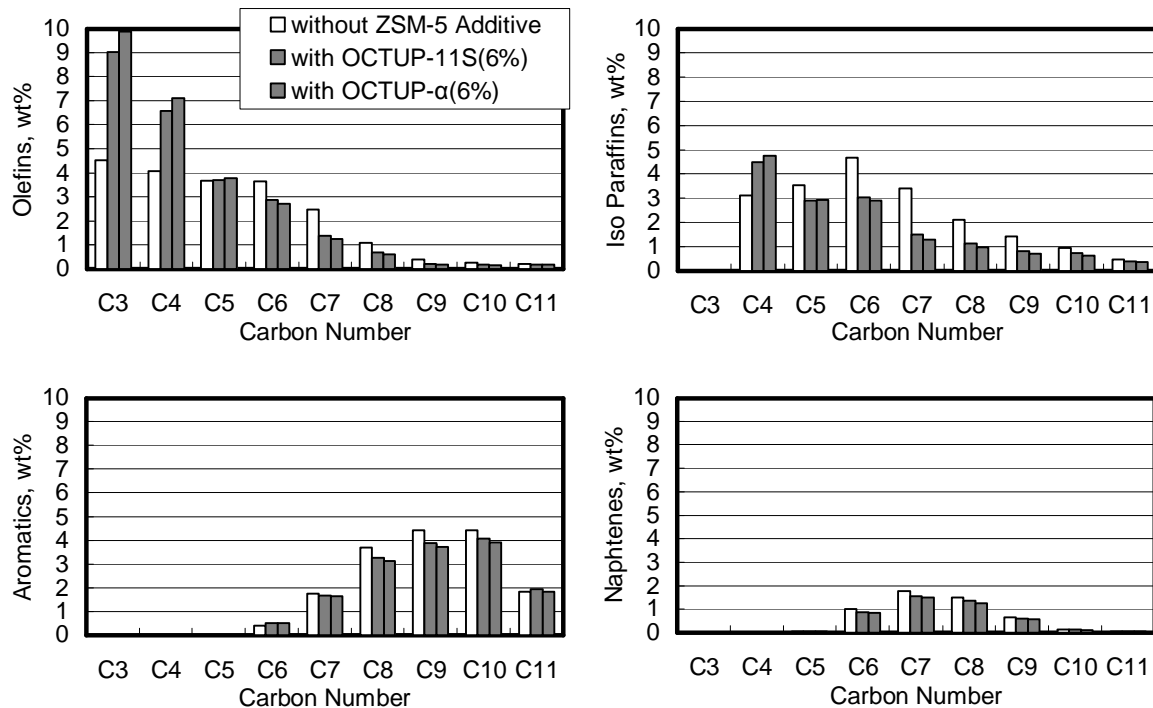


Fig.6 Yields vs. number of carbon atoms

5.4 Dilution effect of base catalyst by ZSM-5 additive

In cases where a large amount of ZSM-5 additive is used in FCC units directed at increasing propylene production, the ratio of FCC catalyst is decreased (dilution effect) and there is the problem of the conversion dropping. It was noticeable that the amount of ZSM-5 additive used was around 10% in a large number of cases such as in FCC units for maximum light olefin production in particular.

The results of tests using ACE-MAT of the conversion change and propylene yield when the amount of ZSM-5 additive used is increased are shown in Figure 7. Propylene yield improves along with increased usage of ZSM-5 additive however the rate of increase (slope) becomes less. This is because the amount of gasoline olefins which ZSM-5 additive can crack easily diminishes. The base catalyst is diluted and conversion drops along with increases in the amount of ZSM-5 additive due to the ZSM-5 zeolite pores being only approximately 5 Å and it not retaining its cracking activity towards FCC feedstock.

For example, in Figure 7, if the target propylene yield is 12wt%, OCTUP-11S required approx. 15% to be added where high activity OCTUP- required only 10%. By using a high activity ZSM-5 additive such as OCTUP- the addition rate will be less, the dilution effect will be

minimized and the drop in conversion will be eased.

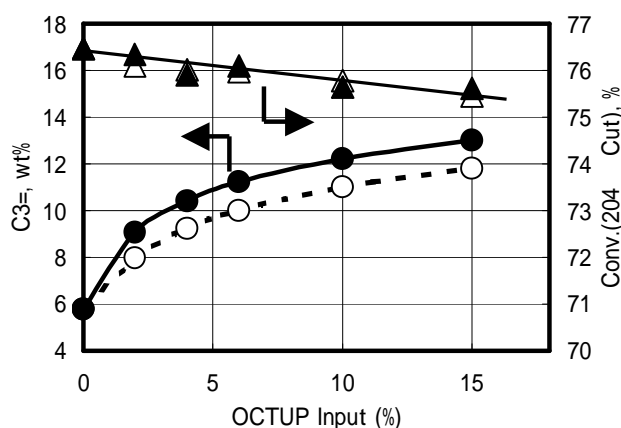
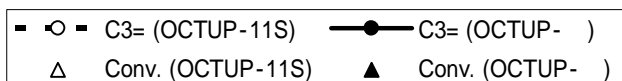


Fig.7 Influence of Dilution by OCTUP Addition

Base Catalyst : ECat

Deactivation (OCTUP) : 750 -13hr-100%Steaming

ACE : 50%DSAR, 510 , 8WHSV, 5C/O



6. Design of base catalyst (LMV catalyst) to maximize ZSM-5 additive performance

As shown in Figure 7, the rate of propylene increased becomes less with increased usage of ZSM-5 additive. This is due to the C6~C8 olefins being cracked by the ZSM-5 additive and reduced.

To make ZSM-5 additive even more effective, it is necessary to design a base catalyst that produces a large number of gasoline olefins. In order to do this, it is necessary to control the hydrogen transfer reaction of the base catalyst.

There are three approaches to controlling the hydrogen transfer reaction of the base catalyst – 1) RE_2O_3 /Zeolite ratio, 2) Pore size distribution, 3) Solid acid distribution. Each of these has its own degree of hydrogen transfer control effect and its own disadvantages and it is necessary to optimize this together within the constraints of the commercial unit. The catalyst designed from this optimization technology is LMV catalyst.

6.1 RE_2O_3 / Zeolite ratio of base catalyst

The solid acid density must be lowered in order to control the hydrogen transfer which is a bimolecular reaction. The most effective way of lowering the solid acid density is to lower RE_2O_3 /Zeolite ratio. The rare earth elements position themselves on the ion exchange sites of the zeolite and have the effect of preventing de-aluminization in the regenerator of the commercial unit under high temperature hydrothermal conditions. By lowering the RE_2O_3 /Zeolite ratio, the de-aluminization becomes easier to progress and in order to lower the solid acid density, the

hydrogen transfer is reduced and the olefinicity improves.

OCTUP- was added to three types of catalyst (Cat. A, Cat. B, Cat. C) with different RE_2O_3 /Zeolite and the results of pilot tests are shown in Figure 8. Furthermore, the C3 yield in the table is the value of propylene yield from catalyst with OCTUP- added minus that with no OCTUP- .

The lower the RE_2O_3 /Zeolite ratio of the base catalyst, the greater the improvement in propylene yield. This is due to the hydrogen transfer activity of the base catalyst with low RE_2O_3 /Zeolite ratio being low and the improvement in the yield of C6--C8 olefins that can be cracked by OCTUP- .

However, if the RE_2O_3 /Zeolite ratio is lowered to dramatically, the hydrothermal resistance deteriorates. In addition, in the catalyst with the low RE_2O_3 /Zeolite ratio, in order to maintain the same level of activity the amount of zeolite was increased however where it is increased greatly such as in Catalyst C, the physical properties of the catalyst (apparent bulk density, attrition resistance) deteriorate therefore it is necessary to control the catalyst preparation technology and optimize.

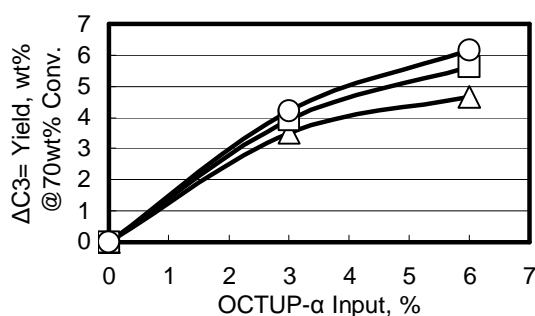


Fig.8 Effect of RE_2O_3 /Zeolite ratio on Base Catalyst with OCTUP- α

Cat. A (High) Cat. B (Medium) Cat. C (Low)
 $\Delta C3 = C3 \text{ Yields}(\text{Base Cat.} + \text{OCTUP-}) - C3 \text{ Yields}(\text{Base Cat.})$
 Deactivation : 780 °C-13hr-100% Steaming
 Midget : DSVG0, Rx.Temp.500

6.2 Pore size distribution of base catalyst

Next there is the catalyst pore control method as a way of reducing hydrogen transfer reaction. By increasing the volume of mesopores and macropores, the diffusion of feedstock within the catalyst pores is improved and the secondary reaction, hydrogen transfer, can be reduced.

We prepared two types of catalyst, D and E, with differing pore structures using our pore control technology. Catalyst E has a larger macropore volume than Catalyst D and diffusion of feed oil into catalyst pores will improve.

The pilot evaluation on catalysts D and E with OCTUP- is shown in Figure 9. In cases where 6% OCTUP- is added, Cat. E showed a 0.3wt% greater propylene yield than Cat. D.

The effect is not as great as the effect of RE_2O_3 /Zeolite ratio however the propylene yield can be improved by attaining a suitable pore size distribution in the base catalyst.

Furthermore, Cat. E with the large volume of macropores showed improvement in diffusion within the pores of the feedstock and the bottoms cracking was also improved. The strippability of the reaction products improved and a reduction in coke yield was also seen.

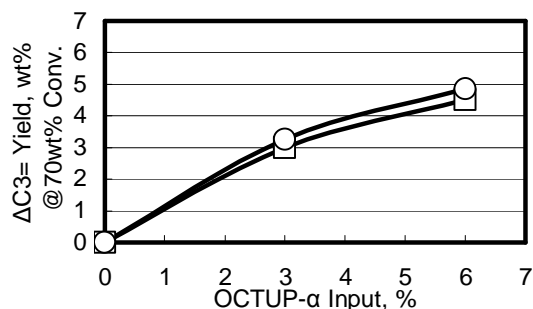


Fig.9 Effect of Macro pore Volume on Base Catalyst with OCTUP-α

Cat. D (Low) Cat. E (High)
 $\Delta C3 = C3 = \text{Yields}(\text{Base Cat.} + \text{OCTUP-}\alpha) - C3 = \text{Yields}(\text{Base Cat.})$
 Deactivation : 780 -13hr-100% Steaming
 Midget : DSVG0, Rx.Temp.500

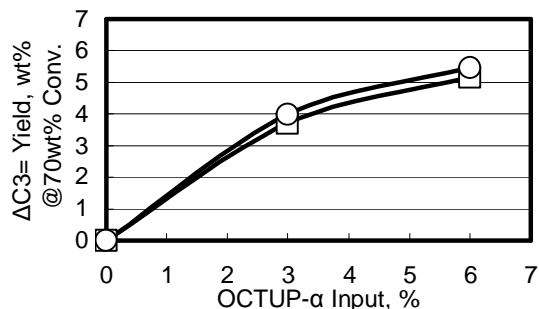


Fig.10 Effect of Zeolite / Matrix Ratio on Base Catalyst with OCTUP-α

Cat. F (High) Cat. G (Low)
 $\Delta C3 = C3 = \text{Yields}(\text{Base Cat.} + \text{OCTUP-}\alpha) - C3 = \text{Yields}(\text{Base Cat.})$
 Deactivation : 780 -13hr-100% Steaming
 Midget : DSVG0, Rx.Temp.500

6.3 Effect of solid acidity of base catalyst

The third way of controlling the hydrogen transfer reaction is controlling the solid acids in the base catalyst. As the hydrogen transfer is a bimolecular reaction, it is affected by the acidity density of the catalyst. Ordinarily, zeolite has a higher acidity density than even matrix and the hydrogen transfer activity is also high. The acidity of the zeolite/matrix ratio is lowered and the hydrogen transfer can be controlled depending on the amount the acidity of the matrix is increased.

We prepared Cat. F and Cat. G which had different zeolite/matrix acidity ratios. Cat. G had a lower zeolite/matrix acidity ratio. The results of pilot test on Cat. F and Cat. G with OCTUP-α are shown in Figure 10. Cat. G with the low zeolite/matrix ratio tended to show increased propylene yield. Due to controlling the effect on the hydrogen transfer of the base catalyst.

However, if the solid acidity is simply raised, the coke selectivity deteriorates therefore optimization is necessary.

6.4 Base catalyst for increasing propylene production (LMV catalyst)

Lowering the RE_2O_3 /Zeolite ratio is the most effective way of controlling the hydrogen transfer of base catalyst as described above however there is a limit as if it is lowered too much the hydrothermal stability decreases. This is why the combination of solid acidity distribution and

pore size distribution should be optimal. The catalyst constructed from technology optimizing the above hydrogen transfer control technologies (RE₂O₃/Zeolite ratio, pore size distribution, solid acidity optimization) is called LMV catalyst.

Here we will describe an example of our laboratory evaluation into LMV catalyst. LMV catalyst has a lower RE₂O₃/Zeolite ratio and zeolite/matrix solid acidity ratio and higher macropore volume (pore diameter 50-2000nm) using JGC C&C's pore control technology (MIP technology) than the currently used CVZ catalyst.

The results of these pilot tests are shown in Table 2. Compared to the current CVZ catalyst, LMV catalyst with 4% OCTUP- added the propylene yield improved approximately 5.6wt%.

The hydrocarbon distribution is then shown in Figure 11. When OCTUP- is not added, the isoparaffins have decreased and the olefins over C4 have increased dramatically due to the LMV catalyst controlling the hydrogen transfer reaction. This shows that the hydrogen transfer activity is very low. By applying the LMV catalyst, the ZSM-5 additive effect is put to work by increasing the C6-C8 olefins and the propylene yield can be vastly improved.

Table 2 Pilot Performance of LMV Catalyst

Base Catalyst		CVZ		LMV	
MIP Technology		No		Yes	
RE ₂ O ₃ /Zeolite ratio		Base		Lower	
Pore Volume		Base		Higher	
Zeolite/Matrix		Base		Lower	
OCTUP-		-	4%	-	4%
Cat/Oil		5.0	5.0	5.0	5.0
Conversion wt%		69.9	69.0	70.1	69.2
Yields	Dry Gas wt%	2.1	2.2	2.3	2.5
	H ₂ wt%	0.5	0.4	0.6	0.5
	C1+C2 wt%	1.6	1.8	1.7	2.0
	LPG wt%	11.6	20.6	11.8	21.9
	C3 wt%	0.6	0.9	0.6	1.0
	C3= wt%	4.0	8.8	4.1	9.6
	C4 wt%	2.4	3.4	1.9	2.5
	C4= wt%	4.6	7.5	5.2	8.8
	Gasoline wt%	51.4	41.7	51.1	40.2
	LCO wt%	19.2	18.7	20.6	20.5
	HCO wt%	10.9	12.3	9.3	10.3
	Coke wt%	4.8	4.5	4.9	4.6
Total wt%		100.0	100.0	100.0	100.0
LPG Properties					
LPG Olefinicity		0.74	0.79	0.79	0.84
Gasoline Properties					
RON -		91.9	93.5	92.9	94.6
Paraffins		29.7	25.0	21.8	18.1
Olefins		34.6	35.5	43.3	43.0
Naphthens		8.3	9.2	7.0	7.4
Aromatics		27.4	30.2	27.9	31.4

Deactivation : CMD Method (Ni/V=2000ppm/4000ppm)

Midget : DSAR 100%, Rx. Temp. 520

Gasoline : C5 ~ 204 , LCO : 204 ~ 343

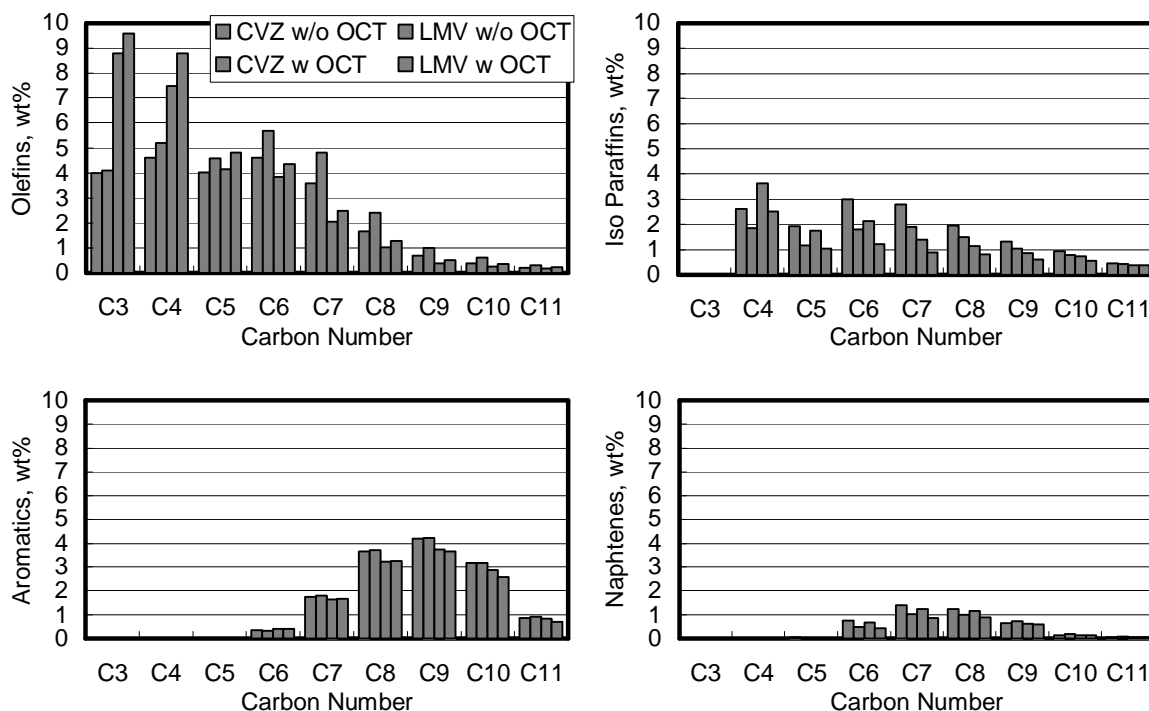


Fig.11 Yields vs. number of carbon atoms

Figure 12 shows the propylene trend when LMV catalyst is applied for increasing propylene production. By adding OCTUP- to CVZ catalyst, propylene yield could be greatly improved. When the base catalyst is then changed to LMV catalyst with its low hydrogen transfer activity the propylene yield could be even further improved.

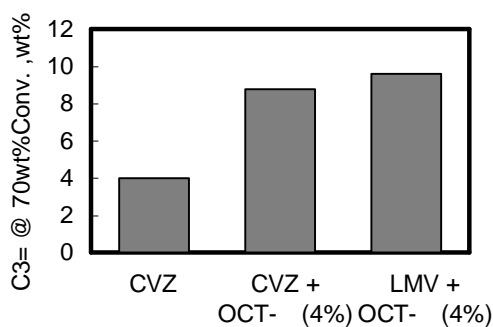


Fig.12 Application of LMV Catalyst for Propylene Production

4. Conclusion

We have described the catalyst design considering the reaction scheme in response to increasing propylene production in FCC units. As a result of pursuing rigorous development of ZSM-5 additive, OCTUP- α was developed which surpassed the performance of conventional

OCTUP-11S. In addition, by optimizing the LMV technology from our company as the base catalyst with added ZSM-5 additive we believe that we have been able to realize the maximum performance of OCTUP- α .

Refiner's needs for increased propylene yield from FCC units will only become greater from now on and JGC C&C intends to continue to have new proposals for catalysts.

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