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Investigation of Fluid Catalytic Cracking Catalyst Performance in a Laboratory ACE FCC Unit During Processing Gas Oils Containing H-Oil Gas Oils with a Variable Quality and a Variable Quantity

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Abstract

Three vacuum gas oils containing different amount of H-Oil VGO (between 20 and 32%) having different H-Oil quality have been cracked on six commercial catalysts in a laboratory ACE FCC unit. It was found that the catalyst rare earth (RE_2O_3) content is the main factor controlling the catalyst activity and selectivity. The highest RE_2O_3 content catalysts were the most active and most coke selective. The higher the catalyst RE_2O_3 content, the higher the conversion, the lower the HCO cut yield, the lower the LPG olefins content, the lower the cracked naphtha naphthenes content and the higher the naphtha aromatics content are. An improvement in the catalyst formulation directed to suppressing the bimolecular reactions of hydrogen transfer between alkene and coke could decrease the coke selectivity and deviate from the typical linear relation of increasing of coke selectivity with magnification of the catalyst RE2O3 content in a direction of coke selectivity reduction.

Keywords*: Fluid catalytic cracking; Advanced Cracking Evaluation (ACE); Catalyst activity; Coke selectivity; FCC yields; H-Oil VGO.*

1. Introduction

The aim to convert as maximum as possible the bottom of the barrel is the main target of modern petroleum refining. Different process schemes can be applied to achieve this target [1-2]. The LUKOIL Neftohim Burgas (LNB) refinery selected the configuration of its petroleum processing scheme to include the heavy oil conversion processes: the ebullated bed vacuum residue H-Oil hydrocracking, and the fluid catalytic cracking (FCC) of vacuum gas oil (VGO). The conversion of the vacuum residue in the LNB H-Oil hydrocracker has varied between 55 and 93% and the vacuum gas oil generated in the H-Oil unit has been processing in the FCC unit along with a hydrotreated straight run VGO. The quality of the H-Oil VGO has been altering as a function of the severity applied in the H-Oil hydrocracker and the quantity of FCC slurry oil processed along with the vacuum residue in the H-Oil unit [2-3]. To process vacuum gas oil feedstock with a variable quantity and quality of H-Oil VGO in the FCC unit is a real challenge [4]. The proper catalyst selection can address this challenge. Advanced cracking evaluation (ACE) fixed fluid bed solid, plug flow gas FCC laboratory unit has been used to evaluate the effect of catalyst properties and feedstock quality on the conversion and product yields distribution in the FCC process [5-8]. In this study we evaluated six different commercial FCC catalysts, which cracked three distinct vacuum gas oils containing dissimilar amount of H-Oil VGO with a variable quality. The evaluation was performed in an ACE FCC laboratory unit. The aim of this study is to distinguish the catalyst which could be the most appropriate for processing refractory feeds like those originating from the H-Oil vacuum residue hydrocracking.

2. Experimental

Properties of the vacuum gas oil feeds employed in this study are summarized in Table 1. Properties of the catalysts investigated in this work are presented in Table 2. The laboratory cracking experiments were carried out at an automated fixed-fluidized-bed ACE unit at 527°C and 30 s time on stream. Conversion is defined as 100 - (LCO+HCO). Light cycle oil (LCO) and heavy cycle oil (HCO) are the yield fractions in the cracking products as wt.% of the feed with cut-points of 210°C<LCO<343°C<HCO. In order to obtain yield curves as a function of conversion, the catalyst-to-oil (CTO) ratio was varied between 3 and 8 wt./wt.

Table 1. Properties of FCC feeds which have been cracked in the laboratory FCC ACE unit

Nr FCC feed properties	1 Feed 06.12.2018	2 Feed 21.08.2019	2 Feed 15.02.2016
$D_{15}{}^{0}{}_{C}$, g/cm^3	0.9101	0.916	0.9087
Sulphur, %	0.294	0.2691	0.38085
Nitrogen, %			
Basic N, ppm	414	393	
Concarbon, %	0.08	0.24	
IBP	291	287	282
5% wt.	350	353.4	328
10% wt.	369	371	350
50%wt.	436	443.8	433.6
90% wt.	514	529.2	518.4
95% wt.	533	555.6	540.2
FBP	588		606.6
Kw-factor	11.9	11.9	11.9
H content, %	12.4	12.2	12.4
Saturates, wt.%			56.4
Light aromatics, wt.%			18
Middle aromatics, wt.%			7.1
Heavy aromatics, wt.%			17.4
Resins, wt.%			1.0
% H-Oil VGO in the FCC feed blend	22	20	32
H-Oil VGO density at 15°C, g/cm^3	0.956	0.965	0.920
FCCU conversion, wt.% (T90%=172°C)	75.2	74.0	76.3
ACE conversion at CTO 7.5 wt./wt.	70.0	68.6	71.3
ACE Δ coke, wt.%	0.30	0.32	0.35

Table 2. Properties of the catalysts employed to study the effect of feed quality on ACE FCCU conversion, product yields and product properties

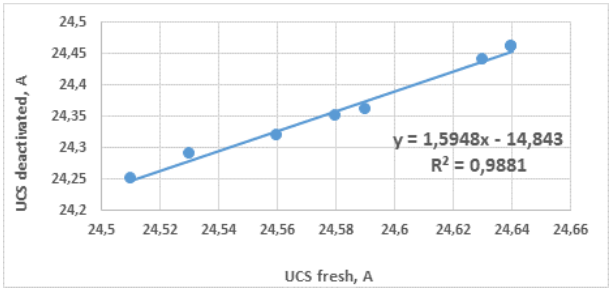
Properties		Catalyst B	Catalyst G	Catalyst C	Catalyst D	Catalyst E	Catalyst F
Al_2O_3	%	40.9	42.2	42.2	41.9	40.5	43.0
RE_2O_3	%	1.9	2.5	2.9	1.6	2.3	2.6
P_2O_5	%	<0.01		<0.01	<0.01	<0.01	<0.01
Na_2O	%	0.3			0.36	0.36	0.27
SA	m²/g	325	348	283	311	343	278
ZSA	m²/g		284	235	262	293	237
MSA	m²/g		64	48	49	50	41
Deactivated							
SA	m²/g	192	191	152			
ZSA	m²/g	155	151	122			
MSA	m²/g	37	40	30			
SA-retention	%	-	54.9	54			
ZSA-retention	%	-	53.2	52			
UCS	Å	24.28	24.28	24.30	24.28 *	24.31*	24.32*
V	mg/kg	12	21.8	14			

[1] *The fresh catalysts have been deactivated following the procedure described in [75]*
**UCS has been calculated based on the equation developed using the data reported in [9] and shown in Figure 1c.*

3. Results and discussion

The six catalysts employed in this study are ultra stable faujasite (USY) partially exchanged zeolite containing catalysts. All studied catalysts, except Catalyst G contain inactive matrix.

Catalyst G contains an active matrix. In order to decipher the meaning of the figures for the catalysts from Table 2 graphs relating the zeolite unit cell size (UCS) to catalyst rare earth (RE_2O_3) content and the catalyst Al_2O_3 content to the zeolite surface were prepared using the data of Wallenstein *et al.* [9] and are shown in Figure 1.



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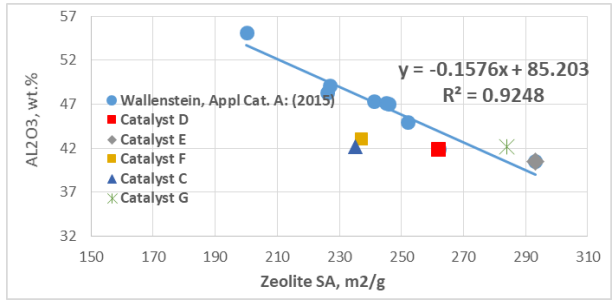

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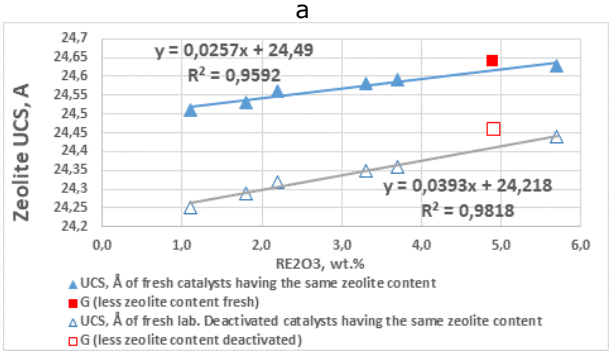

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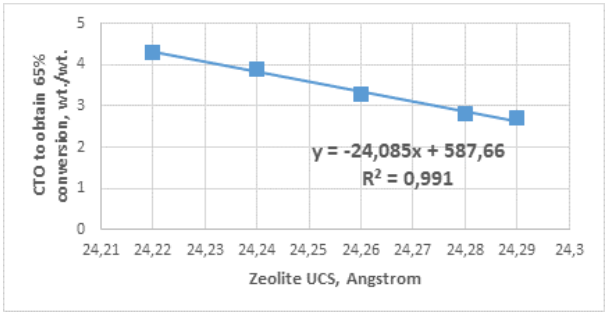
Figure 1. Relation of zeolite UCS of fresh and laboratory deactivated FCC catalysts to RE_2O_3 content and of Al_2O_3 content to zeolite surface area (Data extracted from ref. 9)



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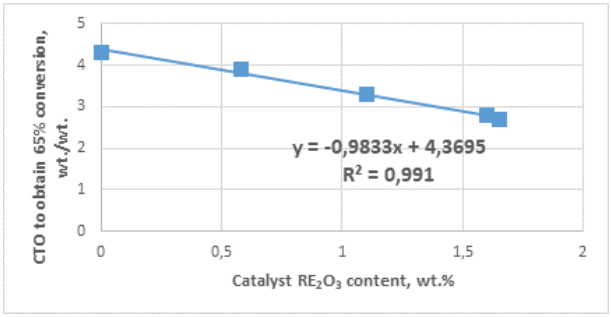

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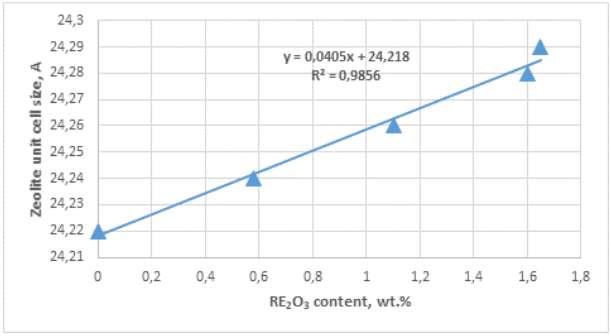

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Figure 2. Relation of zeolite unit cell size, and rare earth content to FCC catalyst activity (CTO to obtain 65% conversion), (Data extracted from ref. 11)

The data in Figure 1 shows the presence of a linear relation of the zeolite UCS to the catalyst RE_2O_3 content (Figure 1 c) with a bigger slope for the laboratory deactivated catalysts (slope=0.0393) than that of the fresh catalyst samples (slope=0.0257). The reason for the bigger slope of the deactivated fresh catalyst samples can be explained with the stabilizing effect of the RE_2O_3 on the dealumination of the zeolite crystal lattice. Increasing the RE_2O_3 content leads to

smaller dealumination of the FCC catalysts [9-10]. The bigger UCS, as discussed in [11], leads to a higher catalyst activity (Figure 2). The data in Figure 1 b indicate that the catalysts C and F deviate from the regression line established based on the date reported by Wallenstein *et al.* [9]. Whereas the catalysts B and D lie on the regression line in Figure 1 b. From these data one could expect a similar behavior of the catalysts C and F in the FCC process. The equation developed for the deactivated FCC catalysts to relate catalyst RE_2O_3 content to the zeolite unit cell size (UCS), shown in Figure 1 c, was used to estimate the UCS of the laboratory deactivated catalysts D, E and F. The UCS of the catalyst F (24.32Å) coincides with that of the equilibrium catalyst during employing the catalyst C at the LNB commercial FCCU [4]. This may suggest a similar behavior of the catalysts C and F during catalytic cracking of vacuum gas oil feedstocks.

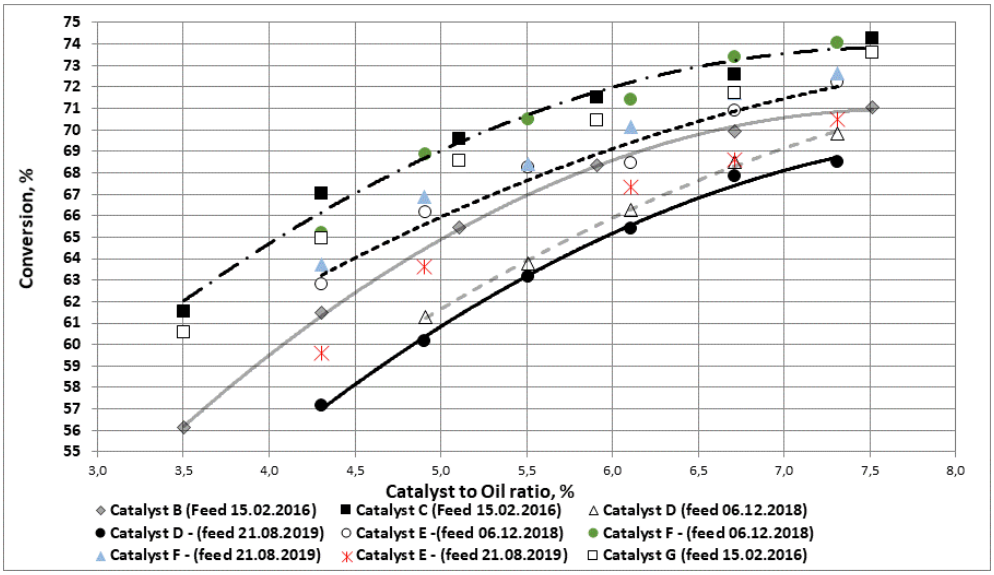
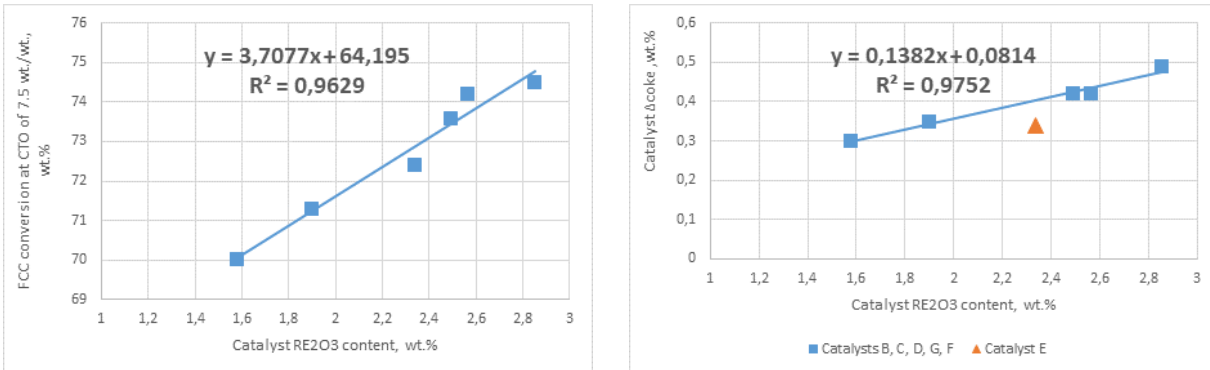


Figure 3 .Dependence of conversion on CTO for the studied catalysts used to crack the three different FCC feeds

Figure 3 depicts graphs of the dependence of conversion on CTO ratio for the studied six catalysts used to crack the three different FCC feeds 15.02.2016, 06.12. 2018, and 21.08. 2019. It is evident from these data that the catalysts C with the feed 15.02. 2016 demonstrates almost the same activity as that of the catalyst F with the feed 06.12. 2018. The supposed similarity in the behavior of the catalysts C and F based on the similar rare earth content, and zeolite and matrix surface area (see Table 2), that assumes similar zeolite content, suggests a similar composition of the feeds 15.02. 2016 and 06. 12. 2018. If we look at the data in Table 1 we can see that both feeds 15.02. 2016 and 06.12. 2018 have the same Kw-characterization factor (11.9), and the same content of hydrogen (12.4%). Therefore, we could expect the same crackability as deduced based on the studies reported in [4,12]. The Δ coke of Catalyst C with the feed 15. 02. 2016 was 0.49% versus 0.46% of the Catalyst F with the feed 06. 12. 2018. The confidence limits according to [13] for that case is 0.07%. Therefore, the difference of 0.03% cannot be considered meaningful. Based on these laboratory FCC ACE results a conclusion could be made that both feeds 15. 02. 2016 and 06. 12. 2018 are similar and the catalysts C and F are also similar. Many studies have been dedicated to the evaluation of the FCC catalyst performance in different laboratory FCC units [7, 9-11, 14-20]. Typically, the catalyst performance evaluation tests include about five tests performed at different catalyst-to-oil ratios and then selectivity curves are modeled by interpolation and the comparisons are made at constant conversion, constant coke yield, and constant CTO [21]. Before discussing the catalyst selectivities an assessment of the relation of the catalyst activity to the RE_2O_3 was made by comparing the conversions obtained during cracking of the feeds 15. 02. 2016, or 06. 12. 2018 at CTO of 7.5 wt./wt. This CTO was selected as the average CTO at which the commercial LNB FCCU operates. It is evident from the data in Figure 4 a that the activity of the investigated six

commercial catalysts correlates with the catalyst RE_2O_3 content. The data in Figure 4 b shows that the catalyst Δ coke, in turn, also correlates with the RE_2O_3 content. Catalyst E exhibited some deviation from the regression line for the Δ coke dependence on the RE_2O_3 content. Its behavior concerning coke selectivity will be discussed later in this work. This data suggest the RE_2O_3 content of the commercial catalysts controls their activity and coke selectivity. Haas and Nee [11] reported that for catalysts having the same zeolite content their RE_2O_3 content was linearly dependent on their activity (Figure 2). Therefore, the commercial catalysts employed in this study could be supposed to have the same zeolite content. An increase in coke selectivity with increasing rare earth content was also reported in other studies [22-23].



a b

Figure 4 Dependence of the feed 06.12.2018 (15.02.2016) conversion at CTO=7.5 wt./wt. and of the catalyst Δ coke on the RE_2O_3 content of the investigated six catalysts in this work

Figures 5-7 present graphs of selectivity curves for the product yields: dry gas, LPG, gasoline, LCO, HCO, and coke as a function of conversion. It is evident from the data in Figure 5 that the least selective towards dry gas production is Catalyst F, while the most selective one is Catalyst B. The most selective catalyst towards LPG production is Catalyst D, while the least selective ones are Catalysts C and F. The data in Figure 6 show that the most selective catalyst towards gasoline production is Catalyst F, while the least selective one is Catalyst D. The most selective catalyst towards LCO production is Catalyst G, while the least selective one is Catalyst F. Concerning the bottoms cracking activity, as evident from Figure 7, the most active catalyst is Catalyst G, while Catalyst F is the least bottoms cracking active catalyst providing the higher yield of HCO. The data in Figure 7 also indicate that Catalyst C is the most coke selective catalyst, while the catalysts D and E are the least coke selective ones.

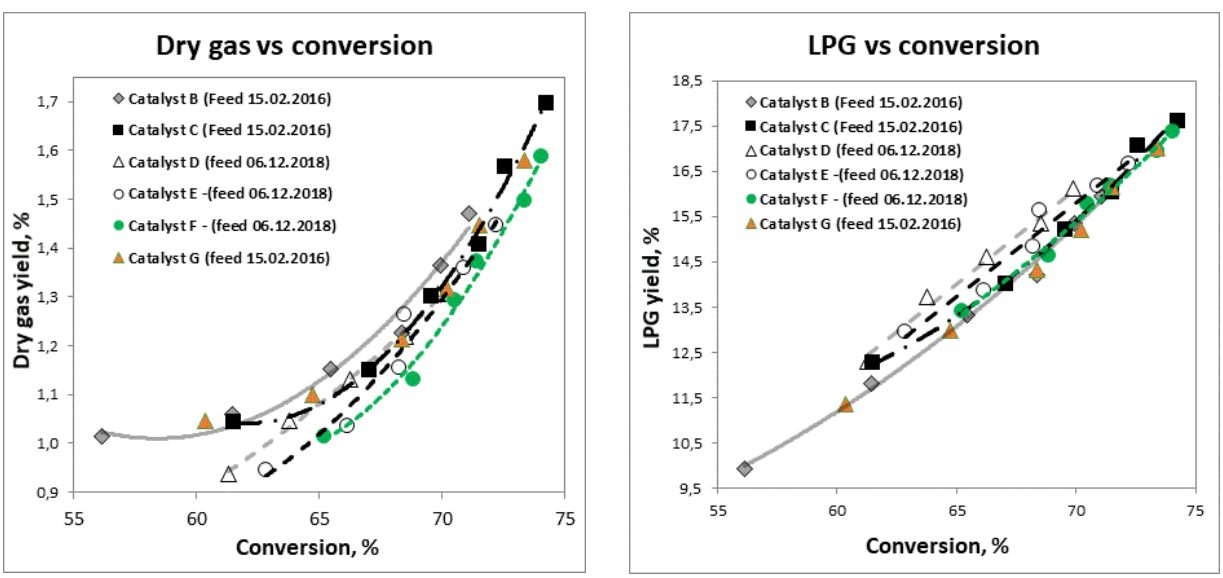


Figure 5. ACE yields of dry gas and LPG as a function of conversion for the six studied catalysts

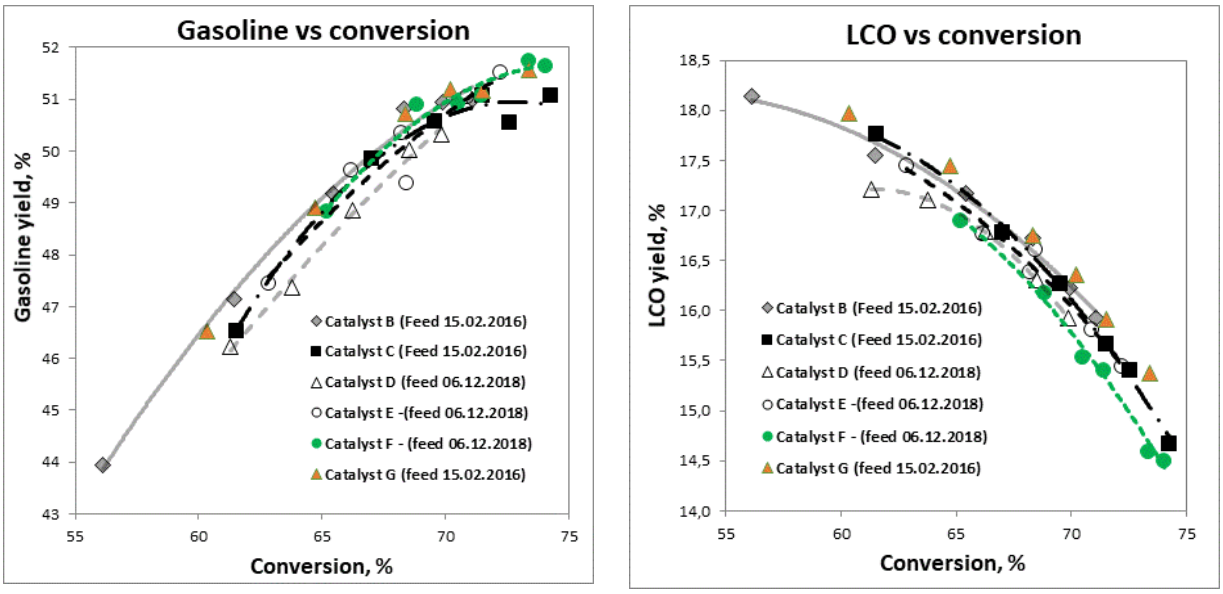


Figure 6. ACE yields of gasoline and LCO as a function of conversion for the six studied catalysts

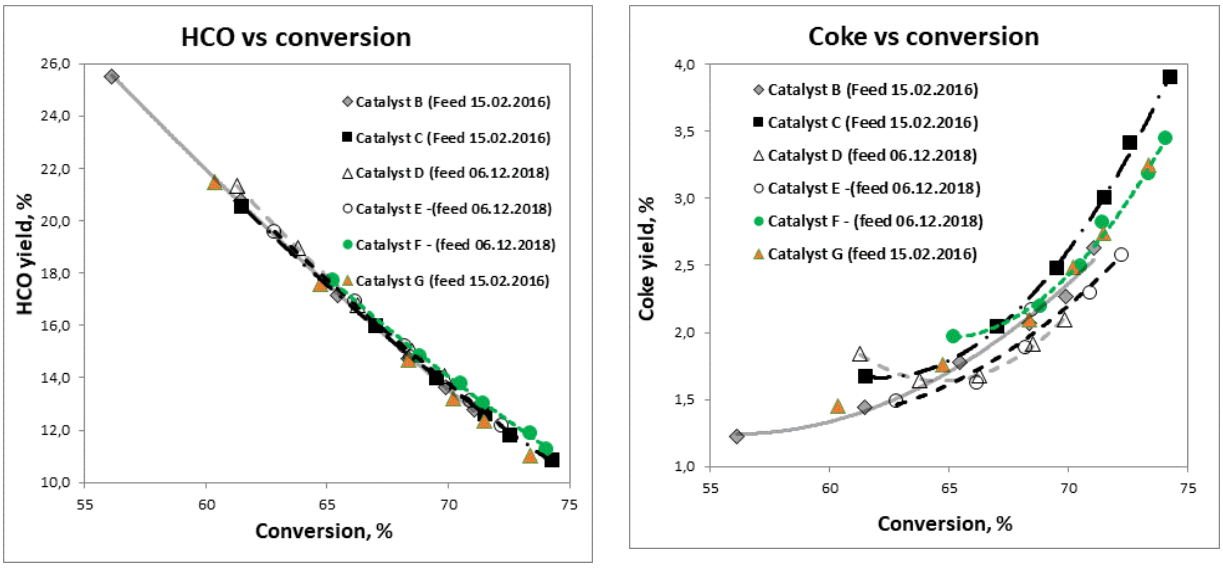


Figure 7. ACE yields of HCO and coke as a function of conversion for the six studied catalysts

Figure 8 presents graphs of LPG olefinicity, and gasoline olefin content for the six studied commercial catalysts as a function of conversion. This data indicates that Catalyst F is the catalyst most active towards hydrogen transfer reactions giving the smallest content of olefins in both LPG and gasoline. Catalysts B, and D are the least reactive catalysts towards hydrogen transfer reactions providing the highest olefin content in both LPG and gasoline products.

Figure 9 exhibits graphs of gasoline n-paraffins, and i-paraffins contents as a function of conversion for the six studied commercial catalysts. These data show that Catalyst F provides obtaining of gasoline with the highest n-paraffins, and iso-paraffins contents, which is completely in line with the discussed above highest hydrogen transfer activity of this catalyst. Logically the Catalyst D provides obtaining of gasoline with the lowest n-paraffins, and iso-paraffins contents. Hydrogen transfer reaction includes the bimolecular reaction between alkene and cycloalkane, the bimolecular reaction between alkene and alkene, the bimolecular reaction between cycloalkene and cycloalkene and the bimolecular reaction between coke forehand and alkene. The reaction equations are shown as follows [24-25]:

$$3C_nH_{2n}(\text{alkene})+C_mH_{2m}(\text{cycloalkane})\rightarrow 3C_nH_{2n}+2(\text{alkane})+C_mH_{2m}-6(\text{arene}) \quad (1)$$
$$4C_nH_{2n}(\text{alkene})\rightarrow 3C_nH_{2n+2}(\text{alkane})+C_nH_{2n}-6(\text{arene}) \quad (2)$$
$$3C_mH_{2m-2}(\text{cycloalkene})\rightarrow 2C_mH_{2m}(\text{cycloalkane})+C_mH_{2m}-6(\text{arene}) \quad (3)$$
$$xC_nH_{2n}(\text{alkene})+\text{cokeforehand}\rightarrow xC_nH_{2n}+2(\text{alkane})+\text{coke} \quad (4)$$

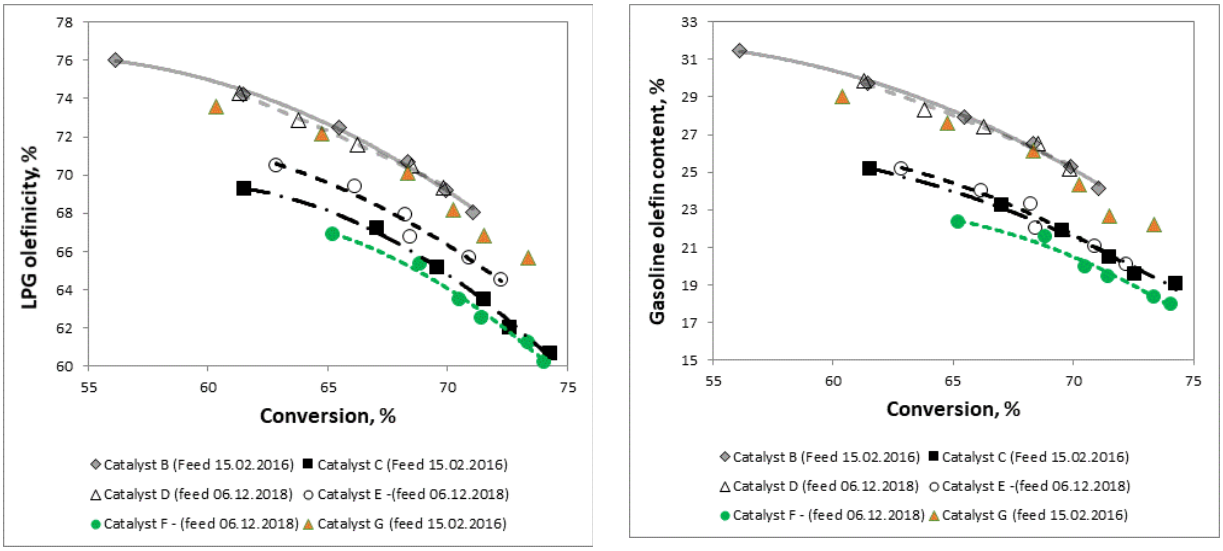


Figure 8. LPG olefinicity and gasoline olefin content as a function of conversion for the six studied catalysts

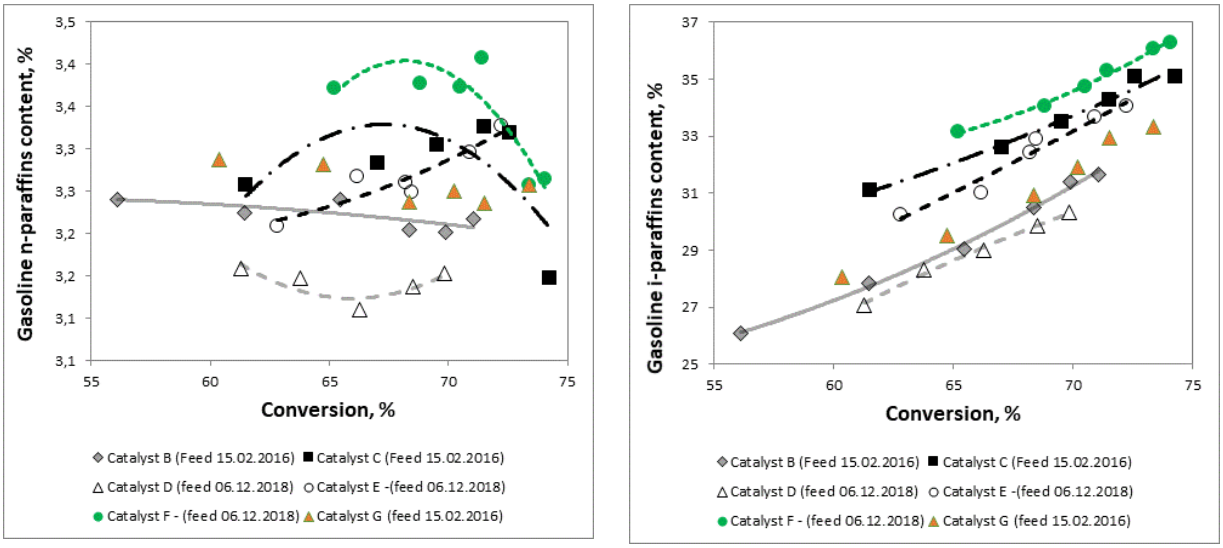


Figure 9. Gasoline n-paraffins and i-paraffins contents as a function of conversion for the six studied catalysts

When alkene is saturated by hydrogen transfer reaction, alkane and arene are generated at the same time. But with the hydrogen transfer reaction progress, coke yield rate presents the increasing trend [25]. The data in Figure 9 indicate that catalysts B, D, and G provide obtaining of gasoline with the highest olefins and the lowest aromatics content, which is completely in line with the reactions 1-4 discussed above. Catalysts C, E, and F provided the obtaining of gasoline with the highest aromatics content and lower olefins content. However, Catalyst C demonstrated the highest coke selectivity, as evident from Figure 7. This suggests that the hydrogen transfer reaction between alkene and coke forehand for this catalyst (reaction 4) has not been optimized. Catalyst E exhibited the best coke selectivity (Figure 7) while at the same time it provided the production of gasoline with the highest aromatic content as shown in Figure 10. This finding suggests that the Catalyst F 1 has optimized performance providing good hydrogen transfer activity, relatively good overall activity and the best (lowest) coke selectivity.

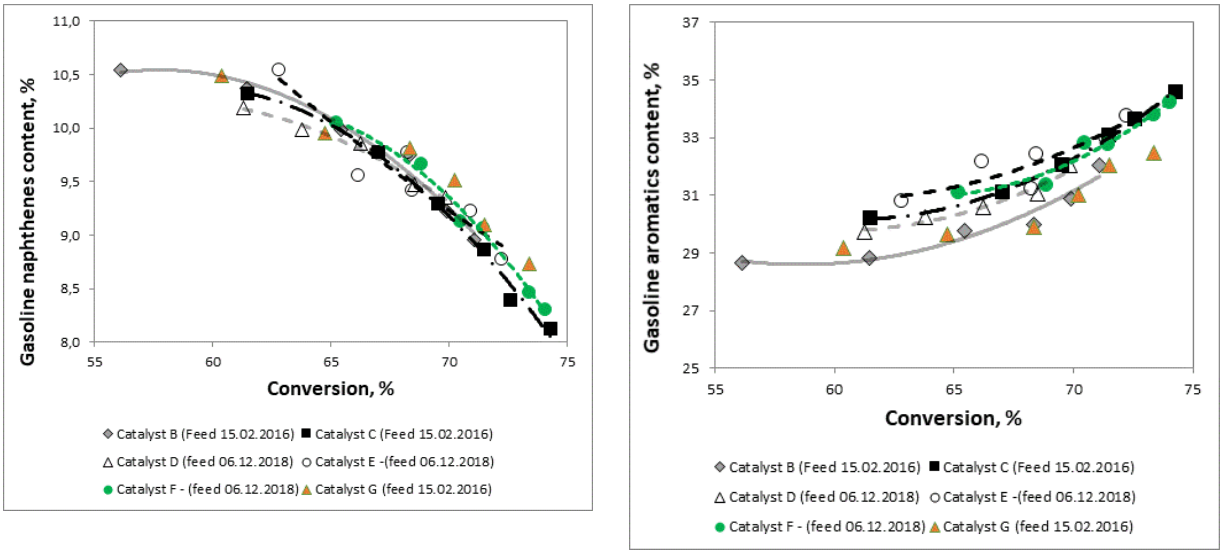


Figure 10. Gasoline naphthenes and aromatics contents as a function of conversion for the six studied catalysts

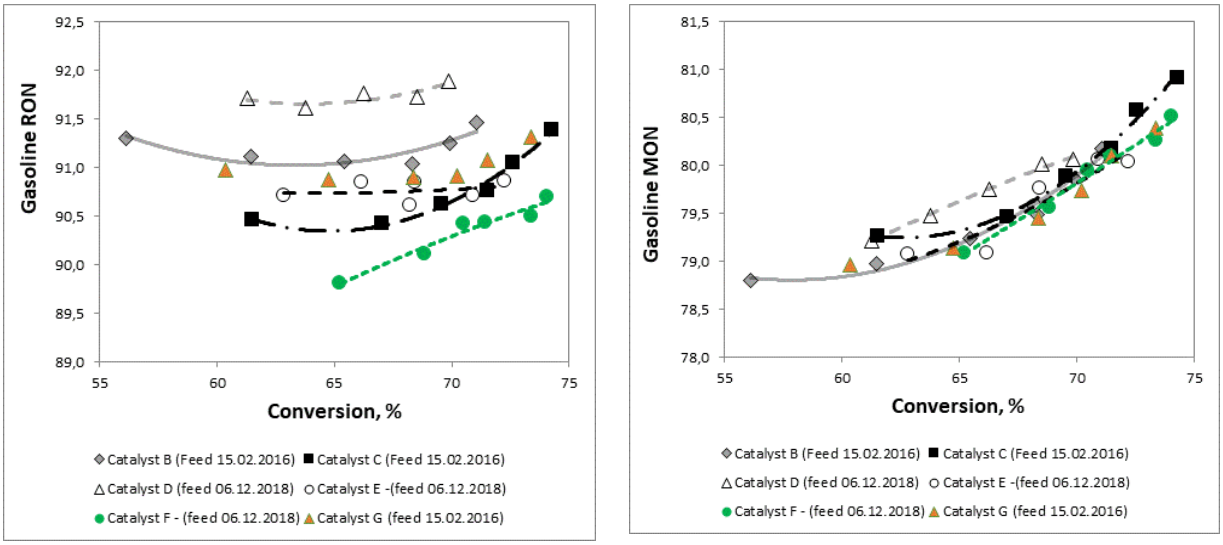


Figure 11. Gasoline RON and MON as a function of conversion for the six studied catalysts

Figure 11 shows graphs of gasoline RON, and MON as functions of conversion for the six studied catalysts. It is evident from this data that Catalyst D provides the obtaining of gasoline with the highest RON, while the gasoline from Catalyst F gives the lowest RON. Concerning gasoline MON there is no a considerable difference between the performance of all studied catalysts.

The final goal of any catalyst-feedstock test is to select the best catalyst feedstock combination that is supposed to provide the best economical results in the commercial FCC unit [26-28]. Wallenstein *et al.* highlighted the importance of catalyst performance comparison at constant coke, and constant catalyst-to-oil ratio as a better approach to the translation of lab testing results into commercial operation in contrast to the comparison via the classical approach of comparing the product selectivities alone [9]. For that reason we compared the performance of all six studied catalysts at the same CTO ratio of 7.5 wt./wt. This value of the CTO ratio is the most representative for the commercial FCCU performance [29].

Table 3 presents data for the conversion, product yields, and properties obtained from the six catalysts at CTO ratio of 7.5 wt./wt. during cracking the feeds 15.02.2016 and 06.12.2018. For a better following the relationships between the different yields, product properties and the catalyst RE_2O_3 content a correlation matrix was made and it is presented as Table 4. Based

on the data in Table 4 one may conclude that the catalyst RE_2O_3 content controls the catalyst activity (R=0.98), LPG and gasoline olefinicity (R=-0.96 and -0.94 respectively), gasoline naphthene content (R=-0.98), and aromatics content (R=0.97). The catalyst RE_2O_3 content has no effect on RON (R=0.64, that is lower than 0.75 meaning the lack of statistically meaningful relation) and a weak effect on MON (R=0.81). The dependence of RE_2O_3 content on coke is a medium statistically meaningful relations (R=0.93), which is because of the deviation of Catalyst E 1 coke selectivity, as illustrated in Figure 3 b. This is a testimony that the RE_2O_3 content is not the only catalyst property that controls its behavior during VGO catalytic cracking.

Table 3. Conversion. product yields and quality for the six studied catalysts at CTO of 7.5 during cracking the feeds 15.02.2016 and 06.12.2018

Yields, and properties	Catalyst B	Catalyst C	Catalyst D	Catalyst E	Catalyst F	Catalyst G
Conversion. wt. %	71.3	74.5	70.0	72.4	74.2	73.6
Dry Gas. wt. %	1.5	1.7	1.3	1.4	1.6	1.6
C3, wt. %	5.1	5.8	5.2	5.5	5.8	5.5
C4, wt. %	10.8	11.8	10.9	11.2	11.6	11.5
CN, wt. %	51.0	51.1	50.3	51.5	51.6	51.6
LCO, wt. %	15.9	14.7	15.9	15.4	14.5	15.4
HCO, wt. %	12.8	10.8	14.1	12.2	11.3	11.0
Coke, wt. % %	2.6	3.9	2.1	2.6	3.4	3.2
LPG Of., wt. %	68.1	60.7	69.3	64.5	60.2	65.6
CN Of, wt. %	24.1	19.0	25.2	20.1	18.0	22.2
CN nPf, wt. %	3.2	3.1	3.2	3.3	3.3	3.3
CN iPf, wt. %	31.7	35.1	30.3	34.0	36.3	33.3
CN Nf, wt. %	9.0	8.1	9.4	8.8	8.3	8.7
CN. Ar, wt. %	32.0	34.6	32.0	33.8	34.2	32.5
GC-RON	91.5	91.4	91.9	90.9	90.7	91.3
GC-MON	80.2	80.9	80.1	80.0	80.5	80.4

Note: CN=cracked naphtha (gasoline); LPG = liquefied petroleum gas (C3+C4 hydrocarbons); Of = olefins (alkenes); nPf = normal paraffins (alkanes); iPf = iso-paraffins (alkanes); Nph = napthenes (cyclo-alkanes); Ar = aromatics (arenes); RON = research octane number of gasoline estimated on the base of gas chromatographic analysis of gasoline and the use of octane model; MON = research octane number of gasoline estimated on the base of gas chromatographic analysis of gasoline and the use of octane model

The three FCC feedstocks used in this study differ in their properties as can be seen from the data in Table 1. They contain different amount of H-Oil VGO, and the density of the H-Oil VGO that is an indicator for the aromatics content in the vacuum gas oil was also different. The conversion achieved at the commercial LNB FCC unit during processing these three FCC vacuum gas oil feeds decreases in the order feed 15.02.2016 (76.3%) > feed 06.12.2018 (75.2%%) > feed 21.08.2019 (74.0%). The density of these three vacuum gas oils follows the same trend as can be seen from the data in Table 1. Based on these data one should expect that in the ACE test the feed crackability has to follow the same trend as that observed in the commercial FCC unit. In fact, this has been the case for the feeds 06.12.2018 and 21.08.2019 with the three catalysts D, E, and F. The data in Figure 1 clearly shows that the least crackable in this study feed 21.08.2019 exhibited lower conversion than the feed 06.12.2018 with the three catalysts D, E, and F. Catalyst D, as has been discussed in our recent study [4] demonstrated a lower dependence of the performance on the feed quality. As evident from the data in Figure 2 the conversion of both feeds 06.12.2018 and 21.08.2019 on Catalyst D is almost the same at CTO ratio higher than 6.5 wt./wt. This is a confirmation of the statement of Harding *et al.* [30] that the catalyst performance is feedstock dependent. In the light of this reasoning it is difficult to judge to what extent Catalyst C and F have the same performance as previously suggested. Feed 15.02.2016 demonstrated a better performance in the LNB commercial FCC unit than that of the feed 06.12.2018, while Catalyst C exhibited a slight almost indiscernible better performance with the feed 15.02.2016 than that of Catalyst F with the feed 06.12.2018 in the laboratory FCC ACE unit. This comparison of the performance between the ACE and the commercial FCC units raises questions about

the extent to which the laboratory ACE FCC unit mimics the performance of the real commercial FCC unit. These concerns have been already discussed in our recent study [31].

Table 4. Correlation matrix of conversion. product yields and quality for the six studied catalysts at CTO of 7.5. and catalyst RE_2O_3

	Conv.	*C2*	*C3*	*C4*	*CN*	*LCO*	*HCO*	*Coke*	*LPG Of*	*CN Of*	*CN nPf*	*CN iPf*	*CN Nph*	*CN. Ar*	*RON*	*MON*	*RE_2O_3*
Conv.	1.00																
C2	**0.94**	1.00															
C3	**0.94**	0.81	1.00														
C4	**0.95**	0.89	0.98	1.00													
CN	0.72	0.56	0.60	0.52	1.00												
LCO	**-0.96**	-0.85	-0.98	-0.96	-0.64	1.00											
HCO	**-0.99**	-0.96	-0.88	-0.91	-0.74	0.91	1.00										
Coke	**0.95**	0.99	0.87	0.93	0.51	-0.90	-0.95	1.00									
LPG Of	**-0.99**	-0.88	-0.97	-0.96	-0.73	0.99	0.95	-0.91	1.00								
CN Of	**-0.95**	-0.79	-0.94	-0.90	-0.83	0.94	0.92	-0.81	0.98	1.00							
CN nPf	0.16	-0.07	0.09	-0.05	0.78	-0.09	-0.18	-0.13	-0.19	-0.39	1.00						
CN iPf	**0.96**	0.83	0.93	0.89	0.85	-0.95	-0.94	0.84	-0.98	-0.99	0.38	1.00					
CN NF	**-0.99**	-0.97	-0.91	-0.94	-0.67	0.94	0.99	-0.98	0.97	0.91	-0.08	-0.93	1.00				
CN. Ar	**0.94**	0.82	0.96	0.95	0.70	-0.93	-0.92	0.84	-0.96	-0.97	0.23	0.94	-0.92	1.00			
RON	-0.68	-0.46	-0.61	-0.50	-0.98	0.64	0.67	-0.44	0.71	0.83	-0.81	-0.84	0.61	-0.68	1.00		
MON	0.83	0.92	0.79	0.88	0.22	-0.81	-0.81	0.95	-0.78	-0.63	-0.42	0.66	-0.87	0.72	-0.15	1.00	
RE2O3	**0.98**	**0.93**	**0.92**	**0.95**	0.70	-0.91	**-0.99**	**0.93**	**-0.96**	**-0.94**	0.17	**0.93**	**-0.98**	**0.97**	-0.64	**0.81**	1.00

Note: CN=cracked naphtha (gasoline); LPG = liquefied petroleum gas (C3+C4 hydrocarbons); Of = olefins (alkenes); nPf = normal paraffins (alkanes); iPf = iso-paraffins (alkanes); Nph = napthenes (cyclo-alkanes); Ar = aromatics (arenes)

4. Conclusions

The investigation of the behavior of six different commercial FCC catalysts in a laboratory ACE unit during cracking of three distinct vacuum gas oils revealed that the catalyst rare earth (RE_2O_3) content is the main factor controlling the catalyst activity and selectivity. The highest RE_2O_3 content catalysts were the most active and most coke selective. Besides the very strong relation of the catalyst RE_2O_3 content to the conversion other very strong relations of the catalyst RE_2O_3 content to the C_4 cut yield, HCO cut yield, LPG olefins content, cracked naphtha naphthenes and aromatics contents were determined. The higher the catalyst RE_2O_3 content, the higher the conversion, the lower the HCO cut yield, the lower the LPG olefins content, the lower the cracked naphtha naphthenes content and the higher the naphtha aromatics content are. The coke make may also goes up with the catalyst RE_2O_3 content augmentation. However, improvement in the catalyst formulation directed to suppressing the bimolecular reactions of hydrogen transfer between alkene and coke could decrease the coke selectivity and deviate from the typical linear relation of increasing of coke selectivity with magnification of the catalyst RE_2O_3 content in a direction of coke selectivity reduction.

The worsening of FCC feed quality a result from a poor quality of the H-Oil VGO affects the level of conversion. One of the investigated catalysts (catalyst D) demonstrated a lower dependence of FCC performance on feedstock quality variation, confirming earlier finding that the catalyst performance is feedstock dependent.

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