Alternative to visbreaking or delayed coking of heavy crude oil through a short contact time, solid transported bed cracking process

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Electronic Supporting Information

Table S1. T Yields and cracked liquid properties for the cracking of extra-heavy crude oil in the presence of kaolin in the 510-580°C temperature range.

ID	10b	11b	12b	13b	14b	15	16	17	18
Trx (°C)	510	510	510	510	545	580	580	580	580
Residence time (s)	0,3	0,3	2,2	2,2	1,25	0,3	0,3	2,2	2,2
STO	8	12	8	12	12	12	20	12	20
Conversion (wt%)	35,4	38.9	39,3	41,0	36,9	36,5	42,6	42,5	34,2
Gases(wt%)	3,8	4,5	4,1	4,2	6,2	8,4	7,6	10,1	9,9
- Dry Gas (H_2 + C_1-C_2)	1,7	2,1	1,8	1,9	2,9	4,2	3,9	5,1	5,1
- LPG(C_3-C_4)	2,1	2,4	2,3	2,3	3,3	4,2	3,7	5,0	4,8
Liquids (wt%)	**72,7**	**70,1**	**72,1**	**73,0**	**76,5**	**74,2**	**72,5**	**73,4**	**73,1**
-Gasoline (C_5-216°C)	8,0	9,0	9,0	9,5	10,7	13,5	13,5	16,0	15,6
- LCO(216-359°C)	21,6	22,3	22,1	22,9	23,9	25,4	26,1	24,5	25,1
- HCO (359-537°C)	36,4	33,9	35,4	35,0	35,1	31,7	30,0	28,4	28,3
- Resid (>537°C)	6,6	4,9	5,6	5,6	6,8	3,6	2,9	4,5	4,1
Coke (wt%)	23,6	25,4	23,8	22,8	17,3	17,4	19,9	16,5	17,0
Cracked liquids properties									
density (15°C)	0,9343	0,9313	0,9354	0,9337	0,9369	0,9302	0,9281	0,9365	0,9360
API (60°F)	19,8	20,3	19,6	19,9	19,4	20,5	20,8	19,5	19,5
Viscosity (cst,, 40°C)*	24,20	19,38	24,37	20,70	18,80	11,67	10,22	11,57	10,82
Metals (ppm) V	11	10	10	10	10	11	10	11	10
Ni	1	2	2	<1	1	<1	<1	2	<1
CCR (wt%)	2.0	2.0	2.2	2.2	3.1	3.1	2.8	5.0	4.7
n-C_7 insolubles (wt%)	0,2	0,2	0,1	0,1	0,1	0,2	0,1	0,2	0,2

Table S2. Yields obtained with cracking Chichimene crude oil with kaolinite in the presence of a variable amount of Silica-Alumina (SA). 530-580ºC temperature range.

ID	19	20	21	22	23	24	25	26	27
% SA in inventory		5			25			100	
Trx (°C)	530	555	580	530	555	580	530	555	580
Residence time (s)	0,3	1.2	2,0	0,3	1.2	2,0	0,3	1.2	2,0
STO	8	12	20	8	12	20	8	12	20
Conversion (wt%)	34,0	41,4	48,4	40,0	44,2	49,2	62,5	56,7	62,6
Gases(wt%)	4,2	6,9	10,3	4,6	6,7	9,7	4,9	7,2	9,8
- Dry Gas (H_2 + C_1-C_2)	2,0	3,4	5,4	2,1	3,2	4,6	1,6	2,7	3,9
- LPG(C_3-C_4)	2,2	3,5	4,9	2,5	3,5	5,1	3,3	4,5	5,9
Liquids (wt%)	**74.5**	**70,1**	**66,3**	**70,5**	**69,9**	**67,5**	**53,4**	**65,5**	**61,4**
-Gasoline (C_5-216°C)	8,5	11,5	14,7	10,5	14,1	16,7	15,9	22,2	24,0
- LCO(216-359°C)	23,8	24,1	24,5	25,0	27,0	24,9	23,4	28,1	25,5
- HCO (359-537°C)	37,9	31.4	24,8	32,7	26,9	24,8	13,9	15,0	11,5
- Resid (>537°C)	4,3	3,1	2,3	2,3	1,9	1,1	0,3	0,2	0,4
Coke (wt%)	21,3	23,0	23,4	24,9	23,4	22,8	41,6	27,2	28,9

Table S3. Visual inspection for solvent instability of the cracked liquids. Solvent composition was 70 wt% o-xylene and 30 wt% n-octane. A sample unstable with this solvent composition (or higher o-xylene concentration) is considered unsuitable for pipeline transportation.

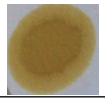
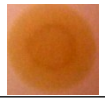
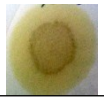
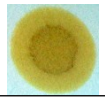
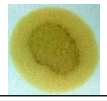
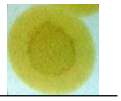
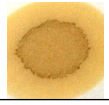
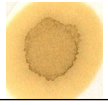
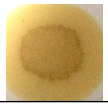
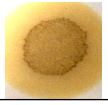
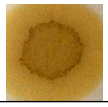
Thermal cracking									
Run ID	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
									
Cracking in the presence of Kaolin									
Run ID	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
									
	% Silica-Alumina								
		5 wt%			25 wt%				
Run ID	*19*	*20*	*21*	*22*	*23*	*24*			
									
Mixture of liquids from primary (crude oil) and secondary cracking (residual fraction) with kaolin									
Run ID	*12+30*	*18+30*							
									
Distilled liquid from recycle loop scheme(<537°C)									
Run ID	*31*								
									

Table S4. Summary of operating conditions for 2 reactors process combination

Cracking severity	low	medium	high
Trx (°C)	530	555	580
residence time (s)	0.3	1.1	2.2
STO	8	12	20

Combination ID	first reactor	second reactor
C01	low	low
C02		medium
C03		high
C04	medium	low
C05		medium
C06		high
C07	high	low
C08		medium
C09		high

Figure S1. Main yields obtained at 530ºC, 0.3 second residence time and solid to oil ratio of 8 with kaolin, repeated runs. Number of runs do not correlate with Run ID in other tables, but indicates the number of tests performed with this same solid batch.

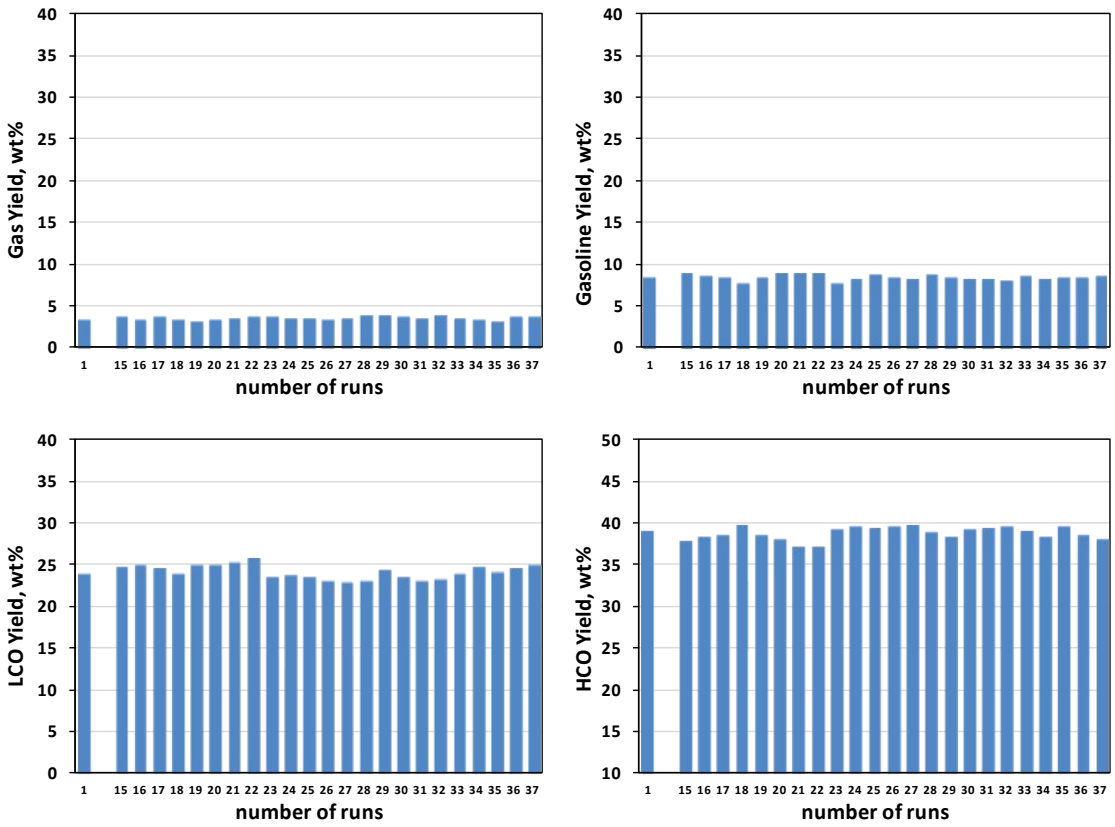


Figure S1, continued

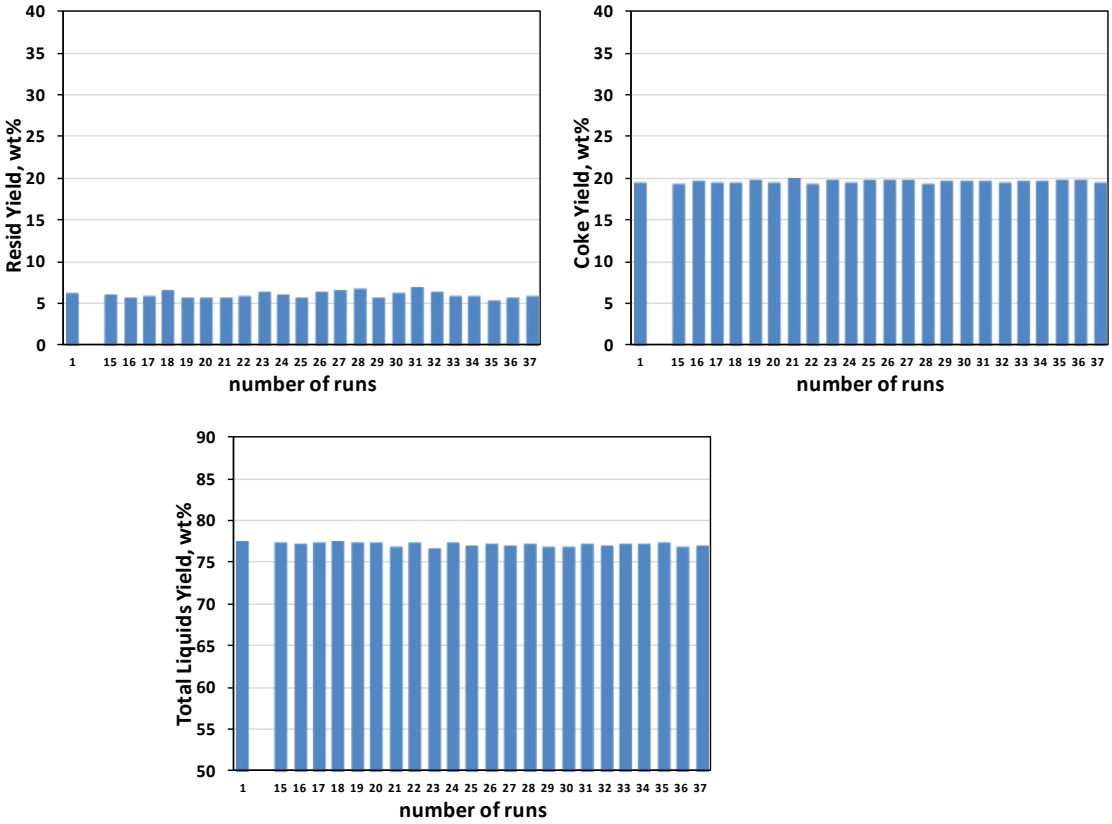


Figure S2. Mass balance for simulating a process with two reactors, combining the experimental yields from Run ID 10 and 28. Distillation Bottoms are assumed to contain 59.2 wt% resid (537+ fraction) and 40.8 wt% HCO (359-537°C fraction). Low severity cracking in both reactors (C#01)

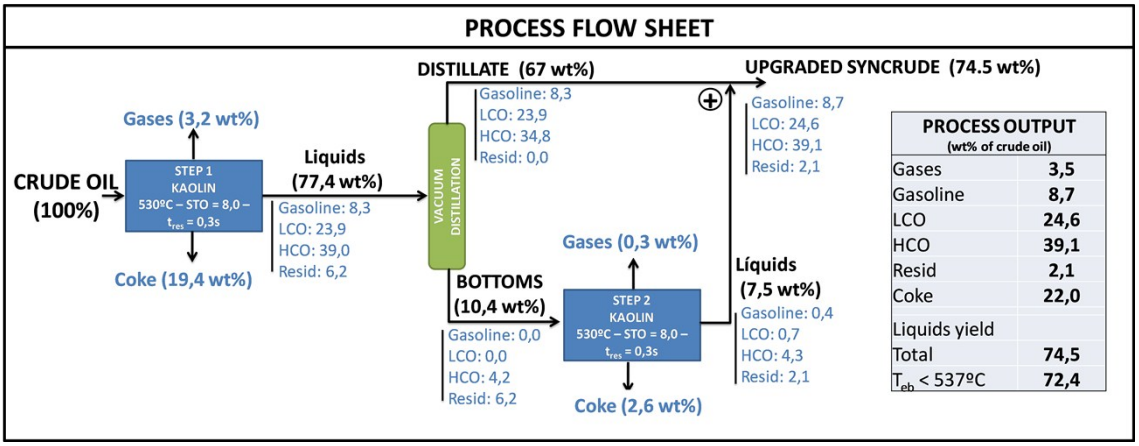


Figure S3. Mass balance in the two reactor scenario including a recycle loop combining the experimental yields from Run ID 10 and 28. Distillation Bottoms are assumed to contain 59.2 wt% resid (537+ fraction) and 40.8 wt% HCO (359-537°C fraction). Recycle ratio (Distillation Bottoms yield) is calculated to obtain 537+ fraction (resid fraction) elimination.