Catalytic Cracking MAT Reactor Performance Using Pseudo Reaction Kinetics

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Abstract : The fluid catalytic cracking(FCC) is one of the key process unit in modern oil refining . FCC process converts heavy distillates like gas oil or residue to gasoline and middle distillates using cracking catalyst. Modeling of FCC riser reactor are generally based on number of lumps classified based on boiling point, chemical type and Structure. Pseudo component based modeling approach consider cracking of large number of lumps in the form of narrow boiling pseudo components. This modeling approach eliminates requirement of determining large number of rate constants compared to conventional Lump models. Two phase flow approach in the riser is also incorporated in the model. Model predictions are compared well with the yield pattern of MAT reactor data reported in the literature. Profiles for various output yields, change of coke content on catalyst, catalyst activity have also been studied. Simulation result shows that tuning parameters, catalyst to oil ratio have significant effect on the yield of products and reactor performance.
Key words : FCC, Cracking Catalyst, Riser ,Pseudo component, MAT reactor, Lumps.

1)   Introduction:

Fluid Catalytic cracking system

Fluid catalytic cracking units (FCCU)are used in most refineries to convert high molecular weight gas oils (Boiling range 280-545° C)[1-2]or residuum charge stocks into more valuable lighter hydrocarbon products like gasoline or LPG inside a riser reactor in a few seconds using cracking catalyst[3-9]. The feeds used include molecules with carbon number from simple C_7 to C_8 molecules to complex structure of 100 or more carbon atoms mainly in form of paraffins(CnH_{2n+2}),cycloparaffins (naphthenes) (CnH_{2n}),aromatics(CnH_{2n-6}) and olefins(CnH_{2n}). Feedstock quality determine the value of product obtained from catalytic cracking. Main products obtained from unit are fuel gases (H_2,C_1,C_2),Liquefied petroleum gas or LPG(C_3& C_4) and gasoline range (C_5-C_{12}),diesel light cycle oil (LCO:C_{11} through C_{18}),heavy cycle oil (HCO:C_{19+}) considered as unconverted feedstock, sour gas (H_2S) and solid Coke. FCC contributes to the bottom up gradation far more than other processes. The fluid catalytic cracking unit is the largest producer of gasoline and light ends in the refinery[10]. The unit can handle a wide range feedstock and can be operated in maximization modes for gasoline, LPG or diesel without involving any hardware changes as per demand in different seasons .FCCU can rightly be called as 'Heart of a Refinery' and the economic benefit of refinery can be increased by proper control & optimization strategies. generator and many operating constraints.
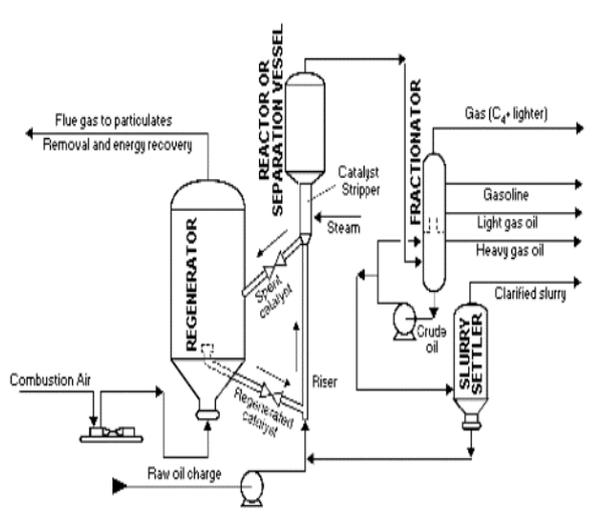
Figure 1 : Fluidized Catalytic Cracking Unit

The control of FCC processes have been known as challenging problems due to complicated and little known hydrodynamics, complex kinetics, strong interactions between the reactor and The FCC units are consist of two major operating parts,the reactor riser & the regenerator.The riser where almost all the endothermic reaction cracking reaction of the hydrocarbon feed and coke deposition takes place. The regenerator reactivates the catalyst by burning the accumulated coke on the catalyst in the riser reactor by use of air. The regenerator process provide heat required for endothermic cracking process[11].Thefeed preheatedto a temperature of 177-327 ^{o} C in a furnace & this feed is injected into the bottom of the riser along with a small amount of steam (0.5-3 wt .% of feed) which leads to good atomization & reduces coke formation. The entering feed is vaporized upon contacting the hot catalyst flowing from the regenerator. A residence time of 2-5 seconds of catalyst & hydrocarbons vapors is preferred in the riser.The riser top temperature in range of 477-547 ^{o} C is controlled by regulating the flow of hot regenerated catalyst to the riser[9]. The reactor temperature is kept constant by adjusting the catalyst/oil ratio or else by keeping the outlet temperature from the preheating surface at a suitable level. The basic tubular design of the riser reactor is common to all existing units. The main difference in the designs is the way the catalyst circulation between the regenerator and reactor is controlled. The disengaging section of the riser used to separate the catalyst particles from the vapors. The product vapors from the disengaging section enters a main distillation column where vapor products are separated into various boiling point fractions. The spent catalyst is separated from the vapor in the reactor cyclone and falls into the stripping section where the hydrocarbons remaining on the surface are removed by the stripping steam. The stripped spent catalyst is recycled through a catalyst transport line to the regenerator.

In the regenerator which is operated in fluidization regime ,the coke is burnt off the catalyst surface by the hot air blown into the bed.Carbon can be converted to CO or CO_2.The combustion reaction serves to reactivate the catalyst and to maintain the bed hot enough to supply the heat required for the vaporization and cracking reaction of the feed in the reactor[12].The typical catalyst residence time in the regenerator ranges from 5-15 min. Typical regenerator temperature range between 650-800° C[13]. Combustion products and entrained catalyst are conveyed upward, out of dense fluidized bed ,into a dilute phase zone where cyclones separate the catalyst ,which is returned to the bed. A FCC regenerator operate in turbulent fluidization and there is considerable carryover of the catalyst to the cyclones. In fact the whole bed circulate through the cyclone every 5 minutes. The regenerated catalysts flows continuously into the riser bottom through catalyst transport line. Cracking units are equipped with one or more coolers to remove excess heat. In modern units the catalyst circulation is controlled using a slide valve in the catalyst transport line feeding the hot catalyst to the reactor, while in the older units the catalyst circulation rate could only be adjusted over a narrow range by the pressure balance.

Catalyst Deactivation:

Deposition of coke on FCC catalyst surface deactivate the catalyst , during the cracking reactions. Most theories on the deactivation are based on the time on stream concept[13-15]. The overall cracking rate is affected by

the catalyst activity, its effect can be incorporated by considering the deactivation model of the Weekman. In this respect, Weekman (1968) employed to describe catalyst deactivation, the following two simple relations;

a)- exponential decay law
$\varphi = \exp(-\alpha t)$ …………………(i)
b) Power decay law
$\varphi = t^{-n}$ ………………………..(ii)

where t represents catalyst time-on-stream, α(catalyst decay coefficient) and n are rate constants of the catalyst decay function.

α the catalyst decay coefficients related to the riser temperature is given by Arrhenius equation:
$\alpha = \alpha_0 \exp(-E/RT)$…………………….(iii)

MAT Reactor:

The laboratory evaluation of fluid catalytic cracking with the use of Micro activity Test (MAT) unit ,is generally used for measuring performance characteristics of experimental and commercial catalyst samples.MAT reactor is commonly used for testing , evaluation of FCC catalyst. The objective of MAT reactor is also used to obtain the catalyst to oil ratio, inside the riser of industrial unit at certain operating conditions.

The Microactivity Test (MAT) unit used for the experiments are generally designed according to the ASTM D-3907 method with some modifications. It is made of a pyrex fixed bed reactor heated by a three zone furnace .The feed is injected on top of the catalyst bed for a fixed periodof time over a measured amount of catalyst, using a controlled syringe pump, through an independently controlled preheat device .
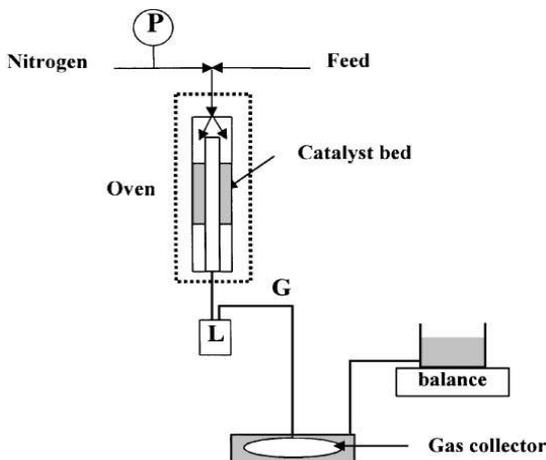
Fig: 2Schematic diagram of MAT reactor adapted from C.Delattreet al 2001.

The products formed have to pass through the remaining part of catalyst bed exposed to secondary reactions before they leave the reactor and collected. Vapour products of the cracking are cooled to 0 °C at the reactor exit where part of them are condensed and collected in a specially designed liquid receiver. The remaining not condensed gaseous products are led to a gas collection system. Nitrogen flows are used during MAT experiments in order to drive the feed and products along the reactor and purge the injection system. The reaction products can be analyzed by gas chromatography . The catalyst activity will diminish during the whole feed injection time and product formed will therefore change with time. Catalyst to oil ratio is calculated over the whole injection time of feed.[16-17]

2. Kinetic Model

When there is cracking reaction then one mole of pseudo component breaks down to form pseudo component of lower molecular weights. In the proposed model there are several possibilities through which , one mole of ith pseudo component PCi crack down , then it will produce one mole of PCm and PCn (or PCn

and PCm) pseudocomponents with some coke formation as byproduct as shown below according to given mechanism:

PCi (ki,m,n)→PCm + PCn +αi,m,n........(2.1)
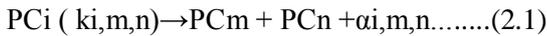
Wherei, m, and n are pseudocomponents' numbers, αi,m,n,is the amount of coke formed (kg). The value of αi,m,n,is calculatedby taking the difference of molecular masses of reactant and product.

αi,m,n=MWi−(MWm +MWn)……..……..(2.2)

The value of **αi,m,n,** calculated according to equation (2.2) iseitherequal to zero, positive or negative. The reaction for which values, according to equation (2.2) is either zero or positive are considered feasible. Those reactions for which its value is negative are eliminated .

Equation 2.1 consider only those equation in which each compound of molecular weight Mwi gives two molecular weights MWm and MWn along with coke. Considering all possible reaction value of m varies from 1 to i , as no product can be heavier than reactant. Value of n ranges from 1 to m , as the products PCm and PCn are interchangeable.

In present work we have considered that one heavier lump breaks into two new lumps of lower molecular weights and for this model equation which has been reported in *Gupta et.al*[18]has been considered.In the below mentioned equation different parameters k_0(frequency factor), E_0, ν , τ_2 , μ and $\tau_1$are being considered and need to be estimated form experimental data reported in literatures.

$$k_{i,m,n} = \left[k_0 MW_i^{\mu} \right] e^{-\tau_1 (MW_m - MW_n)^2} e^{-\frac{E_0 MW_i^{\nu}}{RT}} \left[\frac{e^{-\alpha_{i,m,n}/\tau_2} - e^{-MW_i}}{1 - e^{-MW_i}} \right] \quad\dots\dots\dots\dots\dots\dots(2.3)$$

Which in its final form is reported below after some modification in the equation (2.3), because two parameters μ (frequency factor in term of molecular weight of pseudocomponent)andτ_1 (cock forming tendency of pseudocomponents) does not pose much difference to rate constant (*Gupta et.al)*. So model equation depend only on four parameters k_0, E_0, ν and τ_2.ν correlated activation energy of individual pseudocomponents in term of its molecular weight and τ_2 correlates the coke forming tendency of the feed .The modified form of equation is given below:

$$k_{i,m,n} = k_0 e^{-\frac{E_0 MW_i^{\nu}}{RT}} \left[\frac{e^{-\alpha_{i,m,n}/\tau_2} - e^{-MW_i}}{1 - e^{-MW_i}} \right]$$

$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(2.4)$$

Initial values of four tuning parameters (k_0, E_0, ν and τ_2) were taken from the paper of *Gupta et. al.*These values are tuned to reduce minimum deviation between MAT experimental results which is reported in *C.Deltree el. al*. and the predicted results which comes from model . To find the tuned value for considered experimental system, first of all keep three parameters constant and variation is made in the fourth parameter by increasing or decreasing the value. The value is considered ,which gives minimum deviation between predicted value from model and experimental value. Now that value is fixed and variation in another parameter is made to reach to experimental results of MAT as close as possible.

In the kinetic scheme cracking reactions rate are of first order considered as reported in many literature . For first order reactions, rate of disappearance of *i*th pseudocomponent due to cracking in *j*th volume element through one reaction as indicated in Eq. (2.5) is given by"

$$r_{i,m,n} = A_j \cdot k_{i,m,n} \cdot C_{i,j} \cdot MCAT$$

$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(2.5)$$

The concentration of ith pseudocomponent at the inlet of jth volume element is given by

$$C_{i,j} = \frac{Pscomp_{i,j}}{(u_{g,j})A_r} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(2.6)$$

$Pscomp_{i,j}$ iskmol per second of ith component entering into the jth Volume Element . A_r is area of cross-section of the riser and $u_{g,j}$gas velocity in jth volume element.(A_j) is activity coefficient.*MCAT*in equation (2.5) is the mass of catalyst present inj^{th} volume element. In the considered model activity coefficient is calculated by using equation given by *Pitault et al. (1995).*"

$$A_j = \frac{4.29+1}{4.29+\exp\left(10.4\cdot C_{cj}\right)}\cdot\dots\dots\dots\dots\dots..(2.7)$$

Cc jis the concentration of coke on catalyst surface (wt%)".

Mass of catalyst in each volume element is calculated by:

$$MCAT = \frac{M}{Nt} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2.8)$$

M=mass of catalyst

Nt= no. of volume element.

Material balance:

In cracking process there are several thousands number of ways in which reaction occurs. Finite volume method (FVM) based approach is being used to compute material balance(Gupta.et.al).By applying concepts of finite volume approach, it is assumed that all reactions take place for Δtj time at a constant rate determined by the prevailing pressure, and concentration at the inlet of jth volume element.After elapse of time Δtj the concentration of the stream (which is now outgoing stream from jth element) are determined by the following material balance equations:

Material balance over jth volume element for the gas phase:

Rate of mass in from the (j − 1)th element− rate of mass out from j th element= rate of mass converted to coke in jth element .

or

$$\sum_{i=1}^{N}P_{i,j-1}MW_i - \sum_{i=1}^{N}P_{i,j}MW_i = \left(\sum_{i=1}^{N}\sum_{m=1}^{i}\sum_{n=1}^{m}r_{i,m,n}\alpha_{i,m,n}\right)_{for\,all\,feasible\,reactions} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots....(2.9)$$

"Summation for m is done from 1 to *i* only because no product species can have molecular weight greater than the reactant species, whereas summation over n is done from 1 to m only as the products PC_m and PC_n are interchangeable".

Heat balance:

Heat balance is not considered in proposed model, because temperature assumed remains constant throughout the MAT reactor system **Hydrodynamics:**

Generally riser model consider two phases cluster phase and gas phase. Catalyst particles and coke are assumed to move as a cluster phase.Vaporization of feed and products after cracking constitute gas phase. Variation of gas velocity influence the axial and radial profile of catalyst volume fraction .In the middle section of riser vapor stream carries with it the catalyst particles in suspension and there is some back mixing of these particles because of slip velocity between the solid and vapor phase. Vapor density can be calculated using ideal gas law [19-21].But in the MAT reactor as catalyst bed is fixed ,so in the proposed model single gas phase flow is considered assuming the value of cluster volume fraction δc=0.5.The gas phase volume fraction is then calculated using the relation:

$$\delta_{c+}\delta_g=1 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.10)$$

The pressure drop due to gas phase flow can be calculated using the below mentioned relation (Pugsely and Berruti,1996,Assuming fixed solid bed)

$$\left(\frac{dP}{dz}\right)=\left(\frac{dP}{dz}\right)_{fg} \qquad \dots\dots\dots\dots\dots\dots ..(2.11)$$

The pressure drop due to gas friction between gas and solid $\left(\dfrac{dP}{dz}\right)_{fg}$ can be calculated as:

$$\left(\frac{dP}{dz}\right)_{fg} = \frac{f_g * \rho_g * u_g^2}{2 * D} \qquad \dots\dots\dots..(2.12)$$

Blasius friction factor is used as gas friction factor is calculated by:

$$f_g = 0.316 * Re^{-1/4} \qquad \dots\dots\dots..(2.13)$$

The pressure generated in next volume element is calculated by the following relation:

$$P_j = P_{j-1} - \left(\frac{dP}{dz}\right) * \Delta z \qquad \dots\dots\dots.. (2.14)$$

Gas phase density is calculated from ideal gas law by using following equation:

$$\rho_{gj} \quad = \quad \left(\frac{P_j * \sum\limits_{i=1}^{N} y_{i,j} * Mw_i}{R * T_j}\right) \dots\dots (2.15)$$

and gas phase velocity is given by:

$$u_{gj} \quad = \quad \left(\frac{M_{st} + \sum\limits_{i=1}^{N} P_{i,j} MW_i}{A_r \rho_{g,j} \delta_{gj}}\right) \dots (2.16)$$

3. Results and discussion

The data of pseudocomponents,used in this research , is taken from the paper of Gupta*et al.*(2007)[18]who has divided vacuum distillate (VGO) in 50 components based on their boiling point range. Delattre *et al. (2001)[22]*, ASTM D-3907 MAT reactor specification of data is taken for simulation in the considered model. Various typical operating conditions which were used in the MAT study are given below :

- Catalyst mass: 6 g,
- feed injection time: 25, 50, 100 or 200 s,

- reaction temperature: 803 K,833K
- feed flow rate: 0.02 to 0.01g/ s,
- nitrogen flow rate for flushing: 0.0083Nm/s,
- total duration of flushing: 900 s,

    The result output fora catalyst mass of 6 g, feed flow rate: 0.0192 g/s, injection time: 25 s,reaction temperature :833K are used for considered model tuning and simulation from Delattre et al (2001) MAT experiment.

    There was a need for changes in the parameters, that has beendone by tuning the parameters to match the experimental results obtained by Delattre *et al.* (2001).

Table : 1Properties of the catalyst R & D(Source C.delattre et al 2001)

Sr.no	Properties	Catalyst R	Catalyst D
1	MAT activity	71%	69 %
2	Specific Area ($m^2 g^{-1}$)	124	98
3	Zeolite /matrix specific area	3.0	2.2

Table : 2 MAT reactor operating conditions& Results (Delattre et al. (2001))

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Catalyst	R	R	R	R	R	R	R	R	R	R	R
Temperature (K)	803	803	803	803	803	803	803	803	833	833	833
Feed(g)	3.86	2.16	0.99	0.49	0.49	1.09	2.08	4.18	3.84	0.96	0.48
Catalyst mass(g)	6	6	6	6	3	3	3	3	6	6	6
Duration(s)	200	100	50	25	5	10	20	40	200	50	25
Conversion (wt%)	85.8	93.1	95.3	97.7	95.6	90.9	69.4	52.7	87	96	97.4
FG(wt %)	2.34	3.00	3.83	6.01	3.3	2.0	1.3	0.8	3.7	6.5	8.6
LPG(wt %)	14.6	18.4	21.5	24.5	18.0	14.3	8.4	4.5	16.4	24.2	25.3
Gasoline(wt%)	46.8	51.5	49.2	41.5	55.1	55.8	41.9	30.8	45.1	42.9	36.7
LCO(wt %)	18.4	14.4	10.7	7.3	10.1	14.0	15.4	15.4	17.8	10.1	6.9
HCO(wt %)	14.2	6.9	4.7	2.3	4.4	9.1	30.6	47.3	12.9	4.0	2.6

Table 3 Coefficients of the equation (2.4) obtained in present work and those reported by Gupta *et al.* (2007)

	E_0	v	k_0	τ_2
Present study for considered model	1520	0.35	0.008	16
Gupta et al. (2007)	1500-1540	0.2-0.43	0.045-0.001	13-17

    A comparison of the model results obtained after simulation ,with MAT experiment results that are reported by Delattre*et al*. (2001) are given in Table 4:

Table 4 Comparison of Experimental and Predicted values.

	Gas	Gasoline	LCO	HGO+Coke
Delattre et al. (2001) from literature	33.9	36.7	6.9	22.5
Present work Predicted value by model	33.9343	37.0090	7.0136	22.0472
% error	0.1	0.8	1.65	-2%

3.1

Sensitivity Analysis:

The sensitivity analysis of the process in the proposed model is carried out by varying the parameters and obtained the gases, gasoline, LCO, HCO and coke yields. The Jacobian table is prepared by recording variation of parameters and changes in predicted gases, gasoline ,LCO,HCO and coke yields. The parameters effect were observed in the Jacobian table for sensitivity analysis.In the sensitivity analysis four parameters effects have been studied. The effect of parameters$\tau_1$and µ assumed insensitive and has no effect on product yield(Gupta et.al).

Table : 5 Variation in parameter to get response in term of product yield for Sensitivity Analysis:

	E_0	ν	ko	τ_2
Flue gases(FG)	-0.00881	-79.5033	1386.6	-0.5364
Gasoline(G)	0.00295	1.5133	-998.6	-0.7035
LCO	0.00335	32.27	-441	0.1853
HCO	0.0052	70.6033	-371	0.4942
Coke(C)	-0.000268	-24.8866	424.4	0.5607

Table:6 Jacobiantable for sensitivity analysis:

Sr.N	Eo	ν	ko	τ_2	Response(wt %)				
					Gases	gasoline	LCO	HCO	coke
1	1520	0.32	0.0075	15	36.0878	38.0430	6.1793	5.1508	14.5431
2	1530	0.32	0.0075	15	35.9997	38.0725	6.2128	5.2028	14.5163
3	1520	0.35	0.0075	15	33.7027	38.0884	7.1474	7.2689	13.7965
4	1520	0.32	0.008	15	36.7811	37.5437	5.9588	4.9653	14.7553
5	1520	0.32	0.0075	16	35.5514	37.3395	6.3646	5.6450	15.1038

From table: 6 data, It is observed that in the proposed model by the variation in value of Eo and ν keeping other parameters constant ,the yield of gasoline, LCO and HCO increases, where as yield of gases &coke decreases. The variation of k_0 parameters, increases the yield of gases and coke, where as yield of gasoline, LCO and HCO decreases.By making variation of $\tau_2$parameter, increases the yield of LCO,HCO, coke and decreases the yield of gases and gasoline.

3.2 Details of various graphs plotted from obtained data through simulation on considered model.

3.2.1.Effect of different volume element (Divisions) Nt=30, 50,100

In the finite volume method approach as considered in the present study, results depend on the size of the volume element. Simulation with different number of element size , Nt(number of volume element)= 30, 50, and 100 were done and it has been observed that ,the output results variation are not significant (Fig.3,Fig.4, Fig.5).ThereforeNt=30,number of volume element has been considered for study , due to fast convegence obtained with lesser number of volume element . Fig.6 shows graph of gasoline conversion in case of simulation with different number of volume element (Nt= 30, 50, and 100) in a single graph.
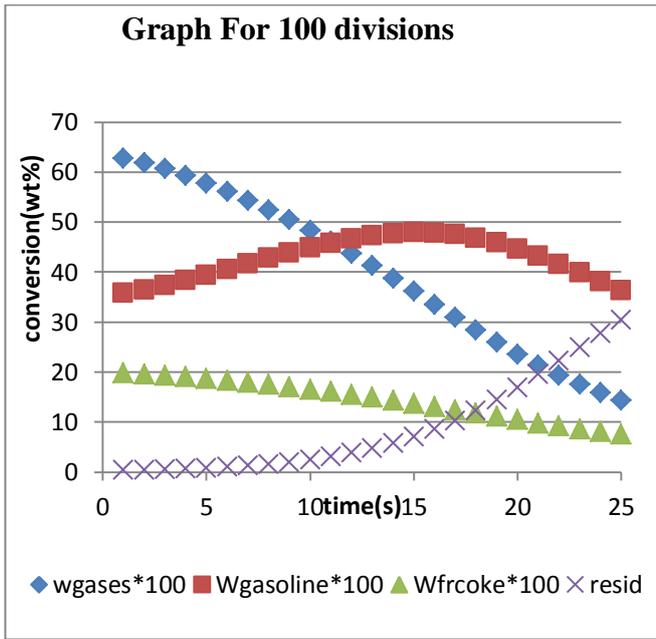
Fig. 3 Graph for 100 divisions
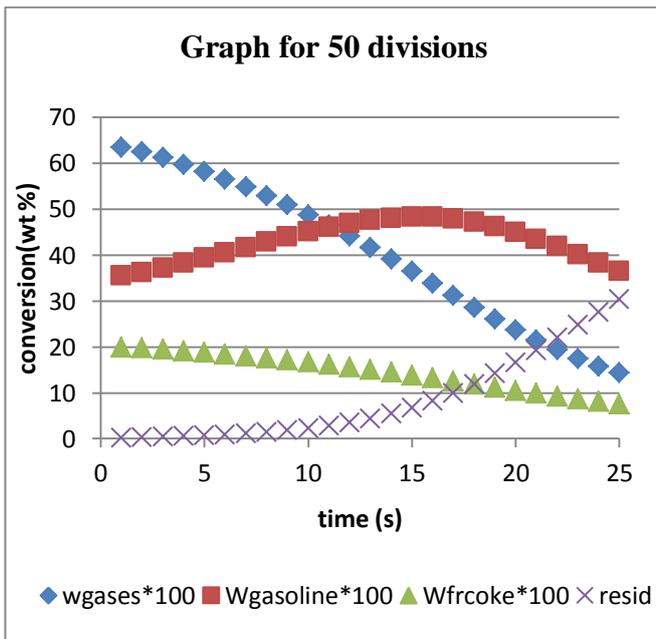
Fig.4 Graph for 50 divisions
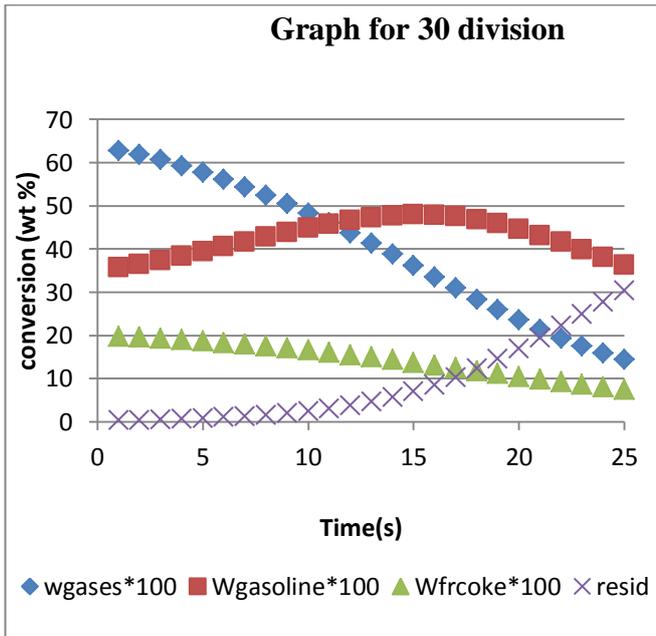
Fig.5 Graph for 30 divisions
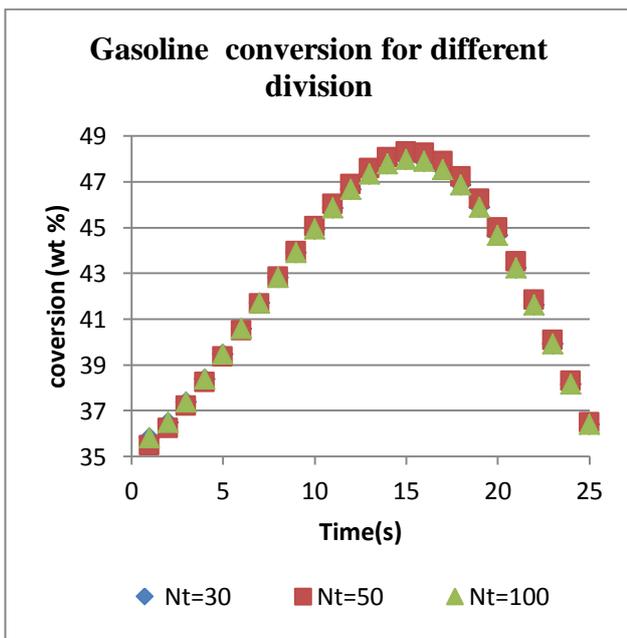
Fig. 6 Gasoline conversion for 30,50 and 100divisions

3.2.2. Variation of coke on catalyst, velocity, activity and flow rate along the length at different time
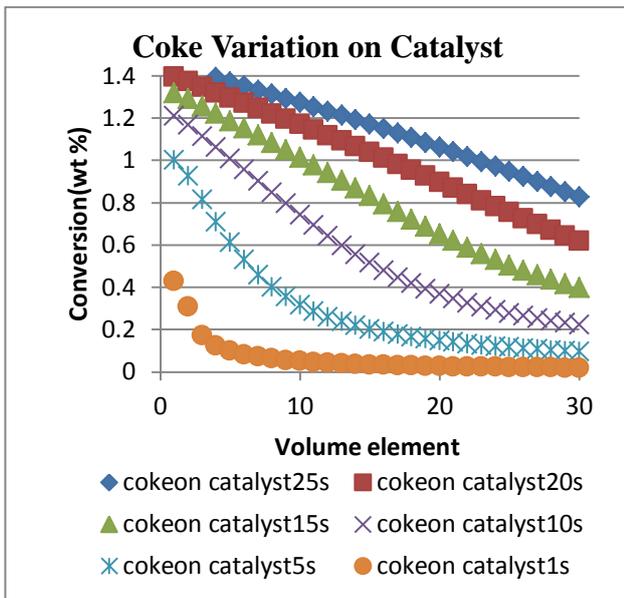
Fig.7Graph of Coke variation on catalyst

Fig.7,shows variation of coke on catalyst .Initially the coke formation in first few second of reaction is almost zero .Later on ,with the progress of reaction , formation of coke on each volume element start increasing.Coke formation is more in the beginning after that it starts decreasing.
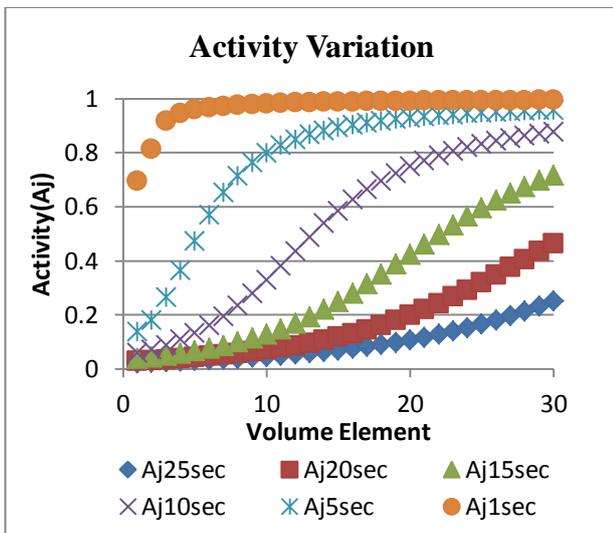
Fig.8 Graph of catalyst activity along the length

Catalyst activity along the length is shown in Fig 8. From figure it is observed that activity of catalyst decreases with the progress of reaction.It is almost one as coke formation is negligible initially,but the deposition of coke accumulation increases for particular volume element with progress of reaction and it decreases activity of catalyst .
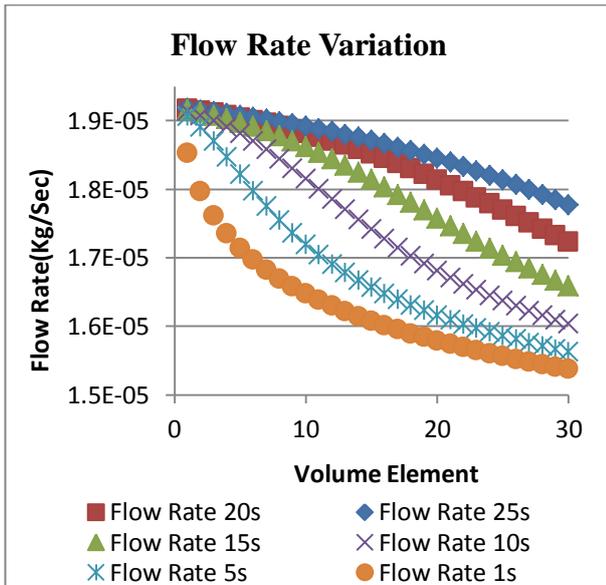
Fig.9 Flow Rate Variation
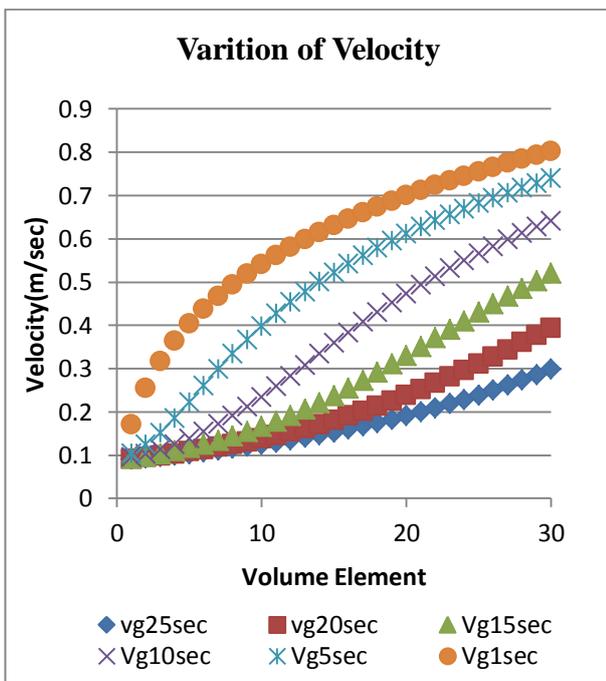
Fig.10 Gas Velocity Variation

Mass flow rate increases with the passage of time inside the reactor (Fig.9) ,whereas gas velocity of gas phases (Fig.10) decreases. This is observed due to the fact that ,due to high activity of catalyst initially , rate of reaction is high , so there will be more amount of coke deposition in specific volume element. After few second for same volume element due to decrease in activity, reaction rate will decrease therefore less amount of coke deposited compared to first time and mass flow rate is more .

For gas phase velocity(Fig.10),it is observedthat initially in a specific volume element there will be higher reaction rate due to high activity of catalyst ,there will be high molar expansion leading to increase in volume and thus increase in velocity. After some time , for same volume element reaction rate decreases, due to decrease in activity of catalyst thus molar expansion and volume expansion decreases , therefore velocity also decreases with time.

3.3 Effect of Catalyst to oil Ratio

The effect of catalyst to oil ratio on the performance of products yield has been studied in this section. The (Fig. 11) shows the effect of catalyst to oil ratio on the yield of various products. The yield of gasoline increases with increase in catalyst to oil ratioup to 12,thereafter the gasoline yield decreases . Flow rate of catalyst in the reactor increases with increase in catalyst to oil ratio. Due to more catalyst flow rate ,thenumber of active sites increases, cause more cracking , increases conversion of gas oil and yield of fuel gases and coke increases .Higher   rate of reaction by increase of catalyst to oil ration also produces more coke

Table : 8 Effect of Catalyst to oil ratio on product yield

Sr no	Catalyst Amount (g)	Feed (g)	Cat/oil ratio	Fuel Gas Yield (wt %)	Gasoline Yield (wt %)	LCO Yield (wt %)	HCO Yield (wt %)	Coke Yield (wt %)
1	6	1.5	4	9.6811	23.0089	14.1437	47.6779	5.4897
2	6	1.0	6	15.5676	29.7598	13.8631	32.8575	7.9556
3	6	0.75	8	21.5057	34.1284	12.2253	21.9161	10.2270
4	6	0.5	12	32.6417	37.0781	7.5962	8.5548	14.1449
5	6	0.4	15	39.7579	35.5715	4.4775	3.7221	16.4893
6	6	0.3	20	48.5331	29.8508	1.4651	0.8038	19.3685

Table :8 (a) Effect of Catalyst to oil ratio on product yield

Sr no	Catalyst Amount (g)	Feed (g)	Cat/oil ratio	Fuel Gas Yield (wt %)	Gasoline Yield (wt %)	LCO Yield (wt %)	HCO Yield (wt %)	Coke Yield (wt %)
1	3	0.167	18	45.3283	32.4429	2.4011	1.5458	18.3307
2	3	0.2	15	39.7841	35.5588	4.4671	3.7105	16.4977
3	3	0.25	12	32.6617	37.0726	7.5874	8.5426	14.1513
4	3	0.3	10	27.2600	36.4496	9.9719	14.0300	12.3021
5	3	0.375	8	21.5013	34.1134	12.2240	21.9393	10.2335

The activity of the catalyst decreases due to deactivation of catalyst by deposition of coke and drop in gasoline yield occur. At high catalyst to oil ratio, the catalyst spends less time in the reactor than low catalyst tocracking of gas oil. The optimum value of catalyst to oil ratio of 12 is more favorable for the catalytic cracking process for considered condition.With increase feed conversion by increasing CTO ratio, cause cracking of large molecules to smaller molecules ,velocities of gas and catalyst will increase and catalyst residence time will decrease.
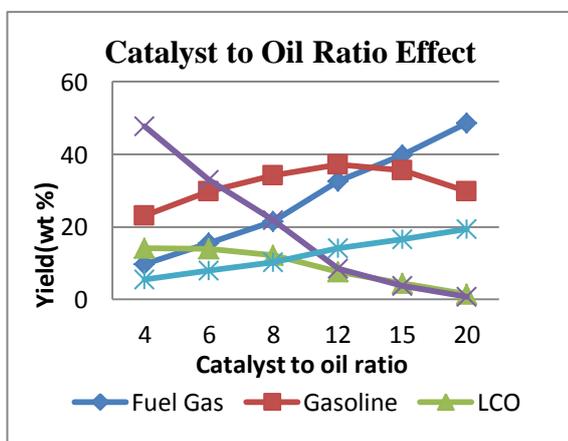
Fig:11 Effect of Catalyst to oil ratio.

4.Conclusion:

In the proposed model the cracking reaction mechanismhas been considered.The tuning parameters considered in the model have eliminated the need for consideration of large number of rate constant from literature for different combination of feedstock andcatalyst.Tuning parameters introduced in the relation have been used for calculating the rate constant. These parameters have been tuned to match the MAT experimental results and product yield obtained from model simulation.The four parameters E_0,k_0, ν and $\tau_2$wererequired to be adjustedto compare the model predicted results with MAT experimental results.The proposed model is capable for calculating conversion, product yields, catalyst activity, gas velocity, coke content on catalyst ,flow rate variation. The effect of catalyst to oil ratio has also been studied .The model results have been validated with MAT experimental results as reported in the literature.

5. Recommendations

The consider model and kinetic approach can be used for advance studies of FCC modeling.The modeling approach can be used for two dimensional hydrodynamic model.

Acknowledgement :

Notation

Aj=Catalyst activity
Ar=Area of cross section
Ci,j=concentration of ith Pseudo component in the jth volume element.
Cc, j=Concentration of coke on catalyst surface.
Eo=Activation Energy
fg=Blasius friction factor
ΔH=Heat of reaction
ki,m,n=Kinetic Rate constant for the cracking of ith pseudo component to produce mth and nth pseudo components
ko=frequency for cracking of Pseudo components
MWi=molecular weight of ith component
M=mass of catalyst
MCAT=Mass of Catalyst present in each volume element
Nt=Number of volume element
Pscompi,j=molar flow rate ith component ,PCi, through jth volume element.
PC=Pseudocomponent
p=Pressure
Pj=Pressure generated in jth volume element
$\left(\dfrac{dP}{dz}\right)_{fg}$ The pressure drop due to gas friction between gas and solid
Re=Reynold Number
R=Gas constant
ri,m,n=rate of disappearance of ith pseudo component giving mth, and nth pseudocomponent .
t=Catalyst time on stream
T=temperature of reaction mixture
Tj=temperature of reaction mixture leaving jth volume element
ug=gas velocity
$u_{g,j}$=Gas velocity in jth element
VE =Volume Element
Z=Length of catalyst bed
i,m,n =Name of Components

j=Name of jth volume element
φ=Decay of catalyst activity
n=rate constant of catalyst decay function
$τ_1 \& τ_2$=Tuning parameter
ρg=Density of gas
ρg,j=density of gas phase in jth volume element
αi,m,n=mass of coke formed
α=Catalyst decay coefficient
μ=exponent of molecular weight for activation energy
δc=Cluster volume fraction
δg=volume fraction of gas phase

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