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Optimizing The Production Of Benzene, Toluene And Xylene (Btx) From Nigerian Treated Heavy Naphthene Samples

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-ABSTRACT-

This work investigated the effect of temperature variation on the catalytic reforming process as it relates to the yields of Benzene Toluene Xylene (BTX). There is need to increase the level of Benzene, Toluene and Xylene (BTX) yield produced in the refinery and also made available for other industrial applications. The BTX are obtained froma continuous catalytic reforming process of treated heavy Naphtha samples obtained from Nigerian crude(Qua Iboe and Forcados) which are readily available in large quantities.The catalytic reforming process was simulated using Aspen Hysyswhile varying the temperatureof thereactors between 430 – 520^{o}C while the outlet concentrations of BTX (Vol.%) produced were measured. An increase in temperature led to an increase in the concentration of BTX produced. The volume of BTX at 430^{o}C for both samples was (0.81, 6.37, 5.78: 0.16, 5.82, 4.91 %vol.)while at 520^{o}C was (2.26, 9.85, 18.43: 2.26, 10.06, 17.20 %vol.) showing a significant increase in the level of BTX produced. The results also showed that the naphthene content of feed affects the volume of BTX produced which made Forcados crude a better source for BTX when compared with Qua Iboecrude.

KEYWORDS: *Benzene,Continuous Catalytic Reforming,Forcados Blend, Qua Iboe, Temperature, Toluene, Xylene,*

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I. INTRODUCTION:

About 70% of the global production of benzene, Toluene and Xylene (BTX) are produced in the catalytic reforming of naphtha, a technology primarily directed at the production of high octane gasoline components. The composition of BTX (benzene, toluene and xylenes) depends on the source as xylenes and toluene are the main components of reformate[1]. Aromatics are amongst the most important bulk feedstocks for the chemical industry, various downstream operations are often carried out on the BTX product to produce products in proportions to fit the market demand. Benzene and p-xylene are generally in higher demand than toluene, o-xylene, and m-xylene [2].

Continuous Catalytic Regeneration (CCR) is a process in which "catalyst is regenerated in one of the reactors at a time without disrupting the operation of the unit" [3]. It involves the conversion of low octane hydrocarbons such as paraffin and naphthene into to octane aromatics, Hydrogen and other liquid light gases[4]. The Continuous Catalytic Regeneration (CCR) unit consists of three or four adiabatic reactors in series with fired heaters installed between each reactor and recycle stream in other to achieve better reformate.

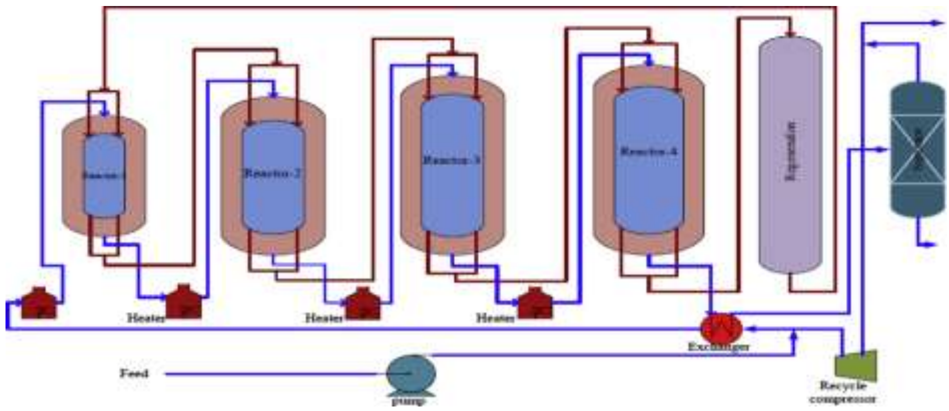


Figure 1: Schematic representation of Continuous CatalyticRegeneration

(Mohammad et al. [5])

Temperature is an important operating parameter in the catalytic reforming process. By raising or reducing reactor inlet temperature, reactions can either raise or lower the product. According to [6]since the inlet temperatures of reactor are not the same, it is common to consider the Weighted Average Inlet Temperature (WAIT) which is between 430^{o}C to 540^{o}C depending on the catalyst and material of reacting vessel.

For this study, treated heavy Naphthene samples from Forcados Crude and Qua Iboe crude are used.Forcados Blend: Forcados Blend is an average gravity, low sulphur, naphthenic crude. It is similar to Bonga rude in both quality and yield pattern but relatively heavier [7].

Qua Iboe: Qua Iboe crude is a crude gotten from a mixture of numerous offshore fields in the Bight of Biafra in south-eastern part of Nigeria. It is the most difficult crude to treat [7].

The assay of the Naphthene samples is shown in Table 1 and 2 below.

Table 1: FORCADOS ASSAY

Crude	Heavy Naptha
Density at 15^{O}C: 867.5kg/m^{3}	Density at 15^{O}C: 761kg/m^{3}
Nitrogrenwt% 0.220	Cut 80-150^{o}C
Sulphur wt% 0.094	Yield 12.99 Vol.%
	Napthene 53.8 Vol.%
	Paraffin 38.3 Vol.%
	Aromatics 9.9 Vol.%

Source: Total [8]

Table 2: QUA IBOE ASSAY

Crude	Heavy Naphtha
Density at 15^{O}C: 840.75kg/m3	Density at 15^{O}C: 760kg/m3
Nitrogen ppm900.95	Cut 90-160^{o}C
Sulphur wt% 0.094	Yield 12.99 Vol.%
API	Napthene 57.24 Vol.%
	Paraffin 33.08 Vol.%
	Aromatics 9.68 Vol.%

Source: ExxonMobil [7]

II THE CATALYTIC REFORMER TEMPLATE

The catalytic reformer template was configured for this research. It was used to allow the easy access of temperature change for the reactor and setting of the reaction kinetic parameters. Fig. 2 shows the window environment of the catalytic reformer template.

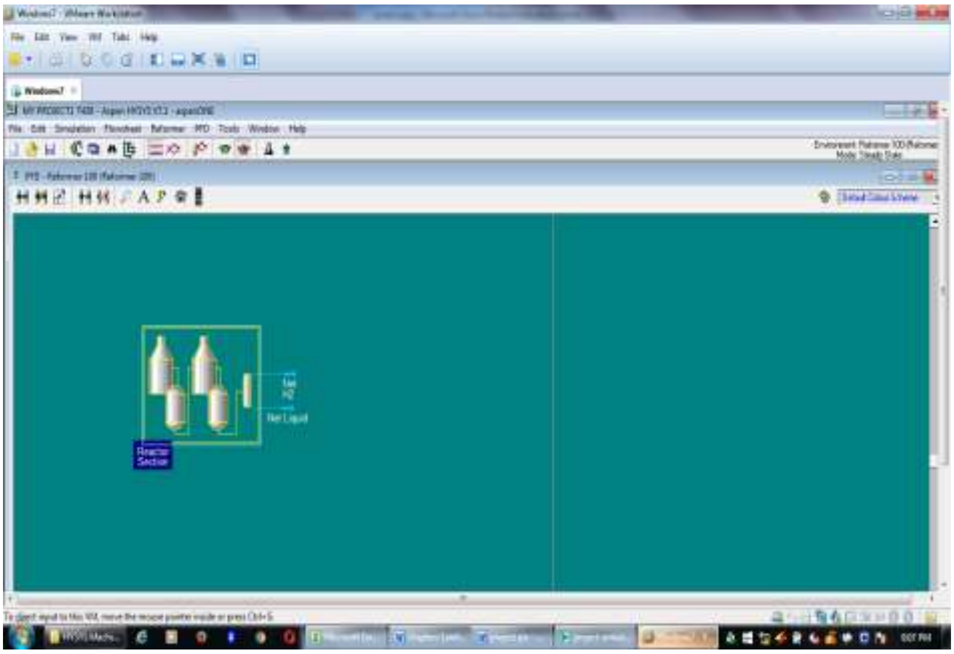


Figure 2: Window showing catalytic reformer template

Fig. 3 below shows the configuration page of the catalytic reformer, in this research it is configured as 4 beds and as a continuous catalytic reformer.

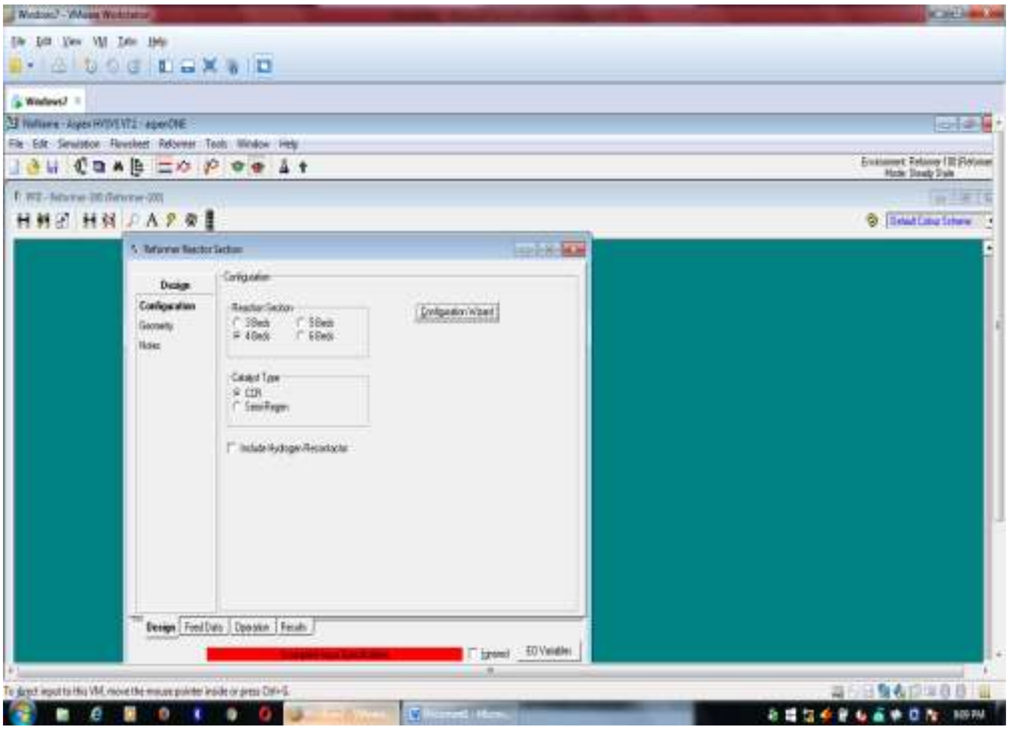


Figure 3: Window showing catalytic reformer configuration

Fig. 4 below shows the parameter page of the catalytic reformer template, this is the page where input of parameters is fixed for the configuration.

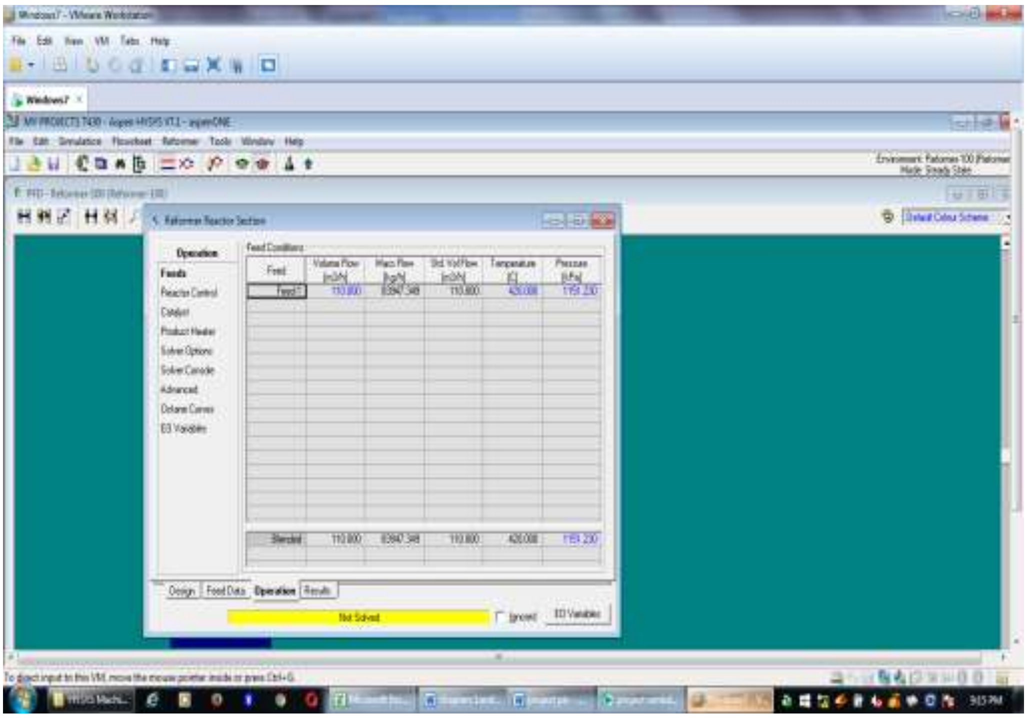


Figure 4: Window showing feed parameters in the reformer template

The temperature for the simulated catalytic reactor was varied within a temperature range of 430 to 520°C to determine its effect on the properties of the various samples of treated heavy Naphthene.

III KINETIC MODEL

The kinetic model used in the catalytic reformer template was that of Smith's which considers the following reaction:

1. Dehydrogenation of naphthenes to aromatics
2. Dehydrocyclization of paraffins to naphthenes
3. Hydrocracking of naphthenes to light ends
4. Hydrocracking of paraffins to light ends

The simplified naphtha reforming kinetics, as described in [9], are written as:

$$N \xleftrightarrow{r1} A + 3H_2 \quad (3.1)$$

$$P \xleftrightarrow{r2} N + H_2 \quad (3.2)$$

$$N + 2H_2 \xleftrightarrow{r3} 2G \quad (3.3)$$

$$P + H_2 \xleftrightarrow{r4} 2G \quad (3.4)$$

Where N, A, G, H and P; are Naphthenes, Aromatics, Gases, Hydrogen and Paraffin respectively.

The reaction rates are,

$$r1 = k_{f1}pN - k_{r1}pAp^3H_2 \quad (3.5)$$

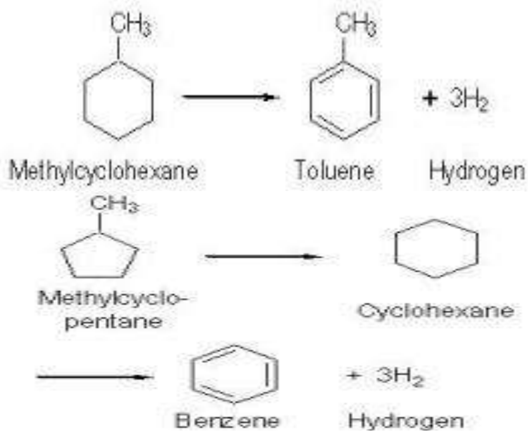
$$r2 = k_{f2}pNpH_2 - k_{r2}pP \quad (3.6)$$

$$r3 = k_{f3}pN/p \quad (3.7)$$

$$r4 = k_{f4}pP/p \quad (3.8)$$

Dehydrogenation reaction which is endothermic dominates the entire reactions thereby causing significant change in the temperature of the reactant [10].

The maximum yields of aromatics (BTX) could be obtained from naphthenes and paraffins if hydrocracking could be suppressed as shown in the reactions above.Aromatic yields increases with the number of carbon atoms per molecule; benzene from C_6 paraffin has a lower yield than toluene from C_7 paraffin [1].



IV RESULTS AND DISCUSSION

The samples were labeled as follows for easy identification and interpretation:

Forcados Blend (Sample 1)

Qua Iboe (Sample 2)

Table 3: BTX Yield for Samples

Temperature x 100 °C	Sample 1			Sample 2		
	Benzene (%vol)	Toluene (% vol)	Xylene (%vol)	Benzene 2 (%vol)	Toluene 2 (% vol)	Xylene 2 (%vol)
4.3	0.81	6.37	5.78	0.61	5.82	4.91
4.4	0.86	6.95	6.79	0.88	6.42	5.81
4.5	0.94	7.53	7.94	0.97	7.09	6.88
4.6	1.03	8.12	9.24	1.07	7.80	8.15
4.7	1.13	8.66	10.68	1.20	8.53	9.71
4.8	1.26	9.12	12.88	1.37	9.20	11.55
4.9	1.43	9.46	14.00	1.61	9.69	13.65
5.0	1.68	9.65	15.47	1.95	9.90	15.63
5.1	2.04	9.76	17.44	1.98	9.96	16.05
5.2	2.26	9.85	18.43	2.26	10.06	17.20

The volume of BTX yield of the samples at various temperature changes is shown in Table 3 above. It is seen that an increase in temperature leads to an increase in BTX yield. Sample 1 is seen to give the highest yield of xylene at any temperature rise which confirms to literature that the higher the aromatic content the higher the aromatic yield [11].

Also, it is seen that the catalytic reforming process favours the production of Toluene and Xylene when compared to the volume of Benzene produced. Both samples had similar behaviour in Benzene yield with respect to temperature changes.

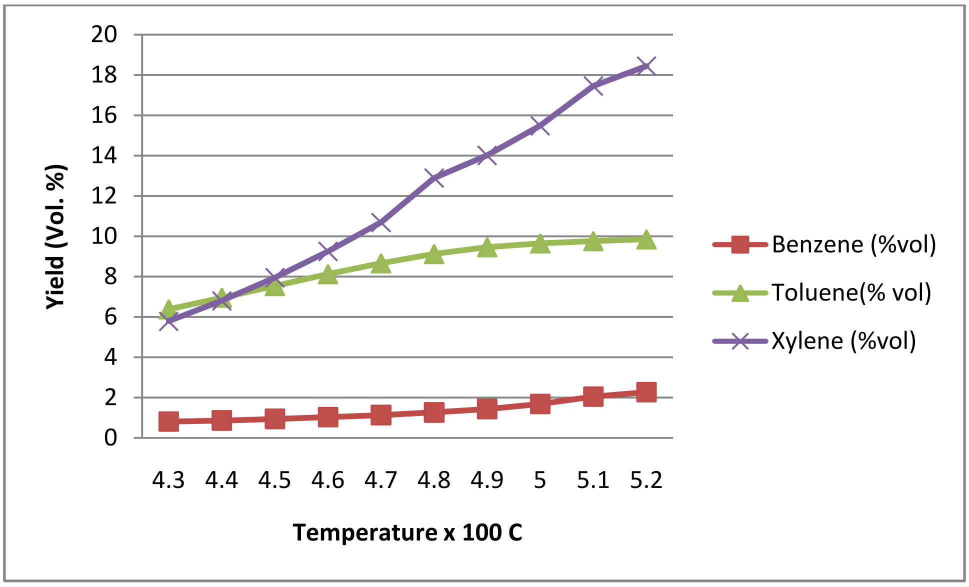


Figure 5: Effect of Temperature on BTX yield (sample 1)

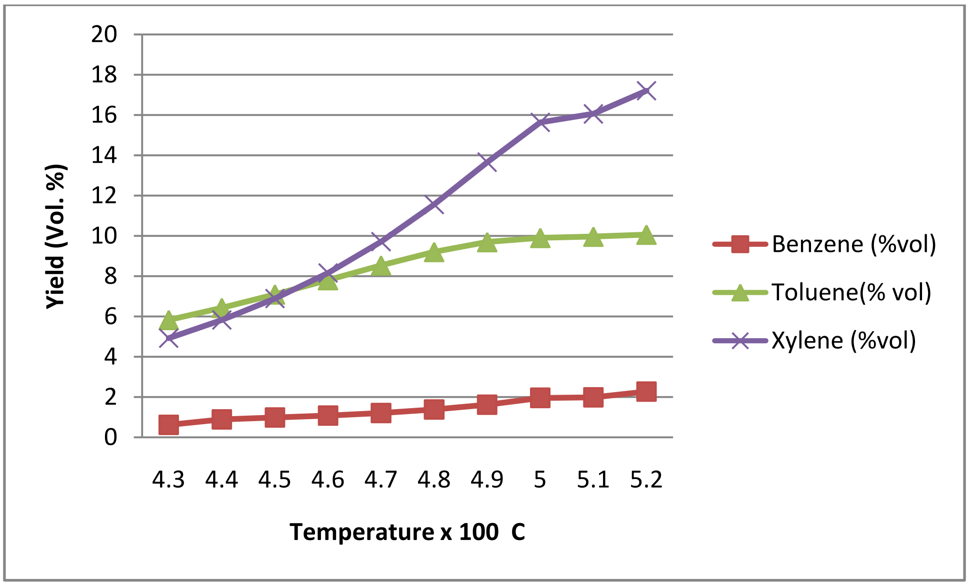


Figure 6: Effect of Temperature on BTX yield (sample 2)

From Fig. 5 and 6, it is seen that the curves are linear; showing that as the temperature increases the Benzene, Toluene and Xylene yield increases, showing a linear dependence relationship of temperature and BTX yield. It is seen that an increase in temperature leads to a drastic increase in the volume of Xylene produced at a particular time.

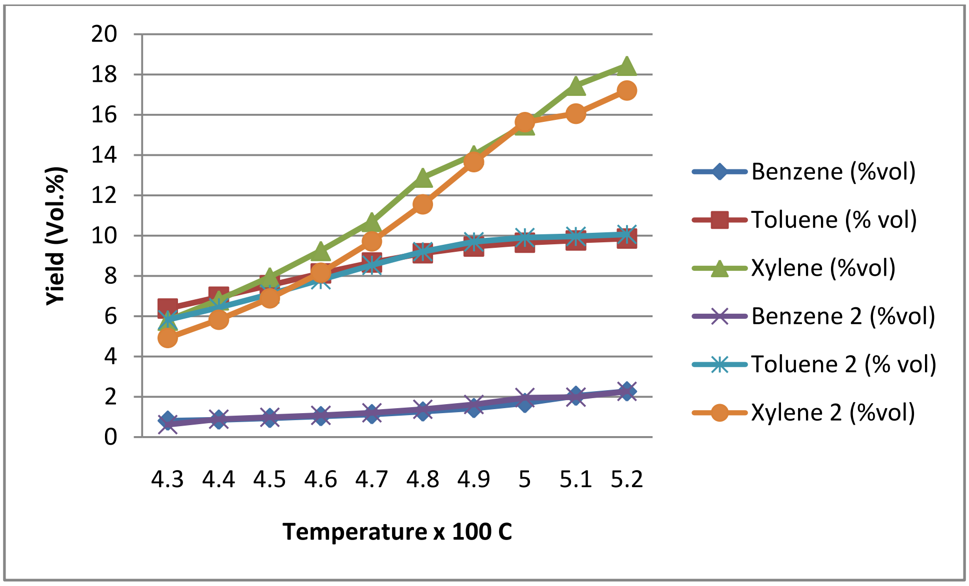


Figure 7: Effect of Temperature on BTX yield (bothsamples)

It is seen from Fig. 7, that there exist a significant difference in the volume of Xylene yield between samples 1 and 2. While Toluene and Benzene yield showed a low significant difference at various temperatures. It is also seen that as the temperature of reactor increased the aromatic yield increased confirming to literature that a sample with high N + 2A (N = Naphthenes %, A = Aromatics %) will yield a better quality of high aromatics [3].

From Fig. 5, 6 and 7, it is seen that the curves are linear, showing that as the temperature increases the volume of BTX increases. Both samples were seen to be increasing in yield quantity as the temperature increased; this is due to the disappearance of paraffins [12].

V CONCLUSION

The nature of treated heavy Naphthene affects the BTX yield. Reactor temperature has an effect on the volume of BTX produced and there exist a linear relationship between temperature increase and BTX volume produced. To increase the amount of BTX available for process industries, the feed stream to the catalytic reactor should be rich in its Aromatic content.

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