Optimization of Methanol to Ethylene Process in Nigeria using Aspen HYSYS

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***Abstract*:-This aim of this study is to simulate a methanol-to-olefins (MTO) process plant that makes use of methanol as raw material for the production of ethylene. Nigeria has large gas reserve of methanol which makes MTO process viable in the country. Aspen HYSYS 7.1 was used in the modeling of the MTO process after which process variables were varied to optimize ethylene production. The major products of the MTO process were ethylene and propylene accompanied by other by-products like butene, di-methyl ether (DME) and C_5+ fractions. The process was optimized at various temperature and pressure to determine the optimum condition for maximizing product yield. It was observed that low pressure of 50kpa and temperatures between the ranges of 350-600°C lead to anincrease in the production of ethylene.**

Keywords: **Methanol, Ethanol, Temperature, Optimization, Ethylene, Pressure, Methanol-to-Olefins**

I. INTRODUCTION

The conversion of methanol to olefins (MTO) is a means to produce ethylene and propylene from feedstock derived sources other than crude oil or condensates. Methanol is mostly gotten from natural gas or coal abundant reserves. Nigeria has a lot of such reserves. MTO enables low costs of production for ethylene and propylene. MTO helps to fill the gap between ethylene and propylene demand and supply from steam crackers and refineries by producing olefins at high ratios of propylene to ethylene [1].The methanol to olefins (MTO) technology is a series of processes which converts methanol (obtained through a number of routes) into olefins such as ethylene (C_2H_4) and propylene (C_3H_6) along with other by-products in the presence of acidic zeolites which is the catalysts [2]. It is possible to generate olefins through petroleum refining processes but the quantity produced is not sufficient to meet the needs of industrial processes that require olefin hydrocarbons hence the search for a viable approach - the MTO process [3].

The process to convert methanol to olefins such as ethylene is not a new technology or development as it had been in operation since it was introduced by Mobil in 1977 [4], it is quite surprising that Nigeria with its natural gas potentials is not keying-into this technology given the key role ethylene hydrocarbons play in the petrochemical sectors.

A simplified process flow diagram for the MTO process as proposed by UOP is given in“Fig. 1” below.

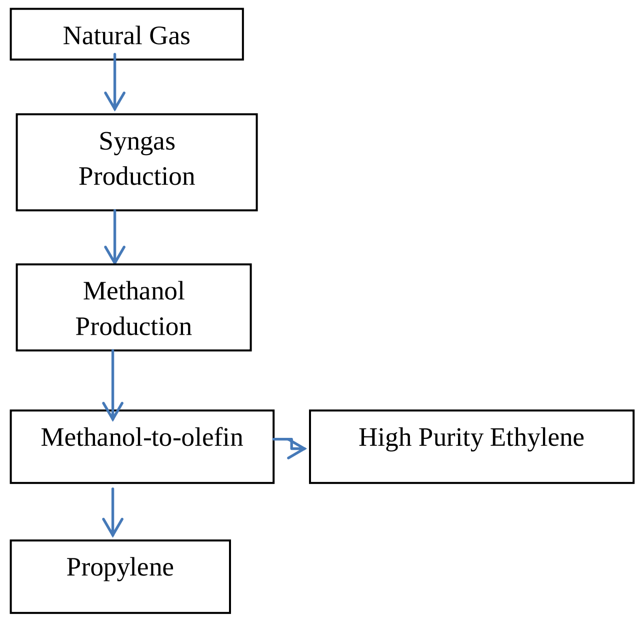

Figure 1: Simple UOP Methanol - to-Olefin Process flow diagram

There are various factors that affect the MTO process. The type of catalyst used affects ethylene production. The reaction process can also be influenced by varying the reaction temperature between 350 to 650°C [5].

II. METHODOLOGY

The feed (Methanol) at room temperature and a normal pressure is sent into the process through a pump which raises the pressure of the feed to the required pressure of the first reactor which is about 411.6kpa. The feed is heated to 450°C using a heater, then sent to the mixer where it is mixed with water. It then goes to the reactor where the reaction occurs at a high temperature with desired products occurring in vapour phase. The vapour products goes through the top to a cooler where it is cooled to about 70°C , water is liquid so water is knock out where as methanol and DME are all vapour. The water is cooled again then the little traces of methanol in the water is recycled back. The vapour is further heated to the temperature of the second reactor. The methanol/ DME in the second reactor reacts to form ethylene, propylene, butene and C_5+ which is cooled to 30^oC and sent to the three phase separator for removal of more water . At the top of the three phase separator, ethylene, propylene and C_5+ is sent to the component splitters where dry gases are separated based on their boiling point.

III. SIMULATION

The model of the fluidized bed reactor proposed in this work was developed by May [6]. It contains solid catalysts that behave as liquid which enable them to be transported freely. Since the solid catalysts circulate the bed, they can easily be regenerated by burning off coke. The raw material for the simulation is Methanol (Process feed) and the Catalyst. The equipment utilized for the simulation of the process includes Pump, Heater, Reactors, Mixers, and Splitter. The design specification for the modelled plant is given in Appendix A.

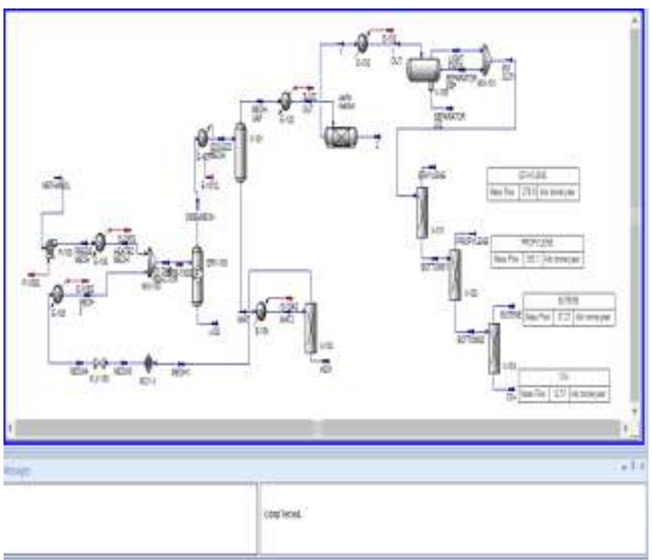

Figure 2: Process flow diagram as modelled in HYSYS

IV. SIMULATION RESULTS

The results obtained from the simulation and optimization process are presented below. The results obtained from various process parameters in the Methanol-to-Ethylene process are presented in Tables 1, 2 and 3 below.

Table 1: Effect of Varying Temperature at Constant Pressure

Temperature of feed (^oC)	Pressure of ethylene (kpa)	Ethylene (kt/yr)	Propylene (kt/yr)	Butene (kt/yr)	C_5+ (kt/yr)
150	411.6	109.1	431.9	99.67	40.13
200	411.6	131.1	430.3	87.50	32.06
250	411.6	156.0	423.6	75.75	25.72
300	411.6	183.5	412.1	64.70	20.66
350	411.6	213.5	396.2	54.53	17.21
400	411.6	245.5	376.2	45.37	14.52
450	411.6	278.9	353.1	37.27	12.57
500	411.6	313.1	327.5	30.24	11.20
550	411.6	347.4	300.2	24.24	10.26
600	411.6	381.3	272.2	19.20	9.544
650	411.6	414.0	244.2	15.05	9.253

Table 2: Effect of Varying Pressure at Constant Temperature

Temp. of feed (^oC)	Pressure of feed (kpa)	Ethylene (kt/yr)	Propylene (kt/yr)	Butene (kt/yr)	C_5+ (kt/yr)
500	50	419.6	242.6	11.47	8.795
500	100	385.2	271.9	16.10	9.149
500	150	364.7	288.6	19.44	9.507
500	200	350.0	300.2	22.14	9.855
500	250	338.6	308.9	24.43	10.19
500	300	329.3	315.8	26.44	10.52
500	350	321.4	321.6	26.24	10.83
500	400	314.5	326.4	29.88	11.13
500	450	308.5	330.6	31.39	11.43
500	500	303.1	334.3	32.78	11.72
500	550	298.2	337.6	34.08	12.00
500	600	293.5	340.5	36.31	12.27
500	650	289.7	343.1	36.46	12.54

Table 3: Effect of Varying Temperature at constant low pressure

Temperature of feed(^oC)	Pressure of feed (kpa)	Ethylene (kt/yr)	Propylene (kt/yr)	Butene (kt/yr)	C_5+ (kt/yr)
350	50	305.1	340.8	25.91	10.08
360	50	312.7	334.7	24.68	9.920
370	50	320.4	328.4	23.48	9.774
380	50	328.0	322.1	22.23	9.640
390	50	335.7	315.7	21.21	9.519
400	50	343.4	309.2	20.14	9.409
410	50	351.2	302.6	19.10	9.310
420	50	358.9	296.1	18.11	9.221
430	50	366.6	289.4	17.15	9.141
440	50	374.3	282.8	16.23	9.070
450	50	381.9	276.1	16.35	9.007
460	50	389.6	269.4	14.50	8.955
470	50	397.2	262.7	13.70	8.904
480	50	404.7	256.0	12.92	8.862
490	50	412.2	249.3	12.18	8.826
500	50	419.6	242.6	11.47	8.795

V. DISCUSION OF RESULTS

1. Effect of Change of Temperature (at Constant Pressure) on the Products Yields

"Fig.1" below shows the effect of temperature on the yields of the different products of the Methanol-to-Ethylene process. The major products from the process are ethylene and propylene, accompanied by other by-products like Butene and C_5+. As the temperature increases, the yield of Ethylene increases while those of Propylene, Butene and other C+ decreases as seen in the figure below. A maximum Ethylene yield was obtained at 650^{o}C.

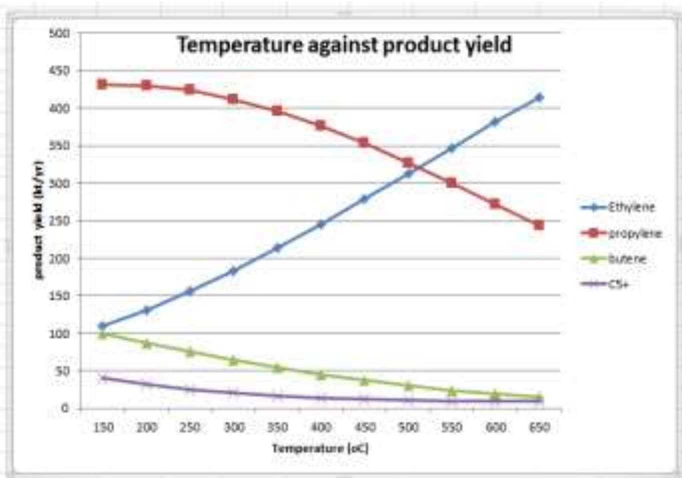

Figure 3: Effect of Feed temperature against product yield

The trend shown in "Fig. 3" above shows that as temperature increasesethylene production is increased while propylene, butane and C_5+ decreased.

2 Effect of Change of Pressure (at Constant Temperature) on the Products Yields:

The effect of pressure on the product yield at constant temperature of the process is shown in "Fig. 4" below:

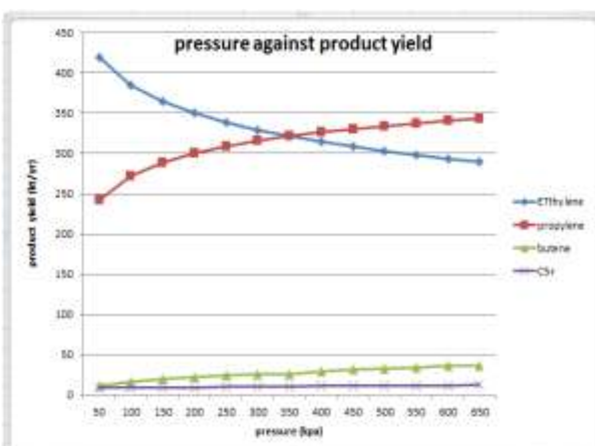

Figure 4: Effect of Pressure on product yield

From "Fig. 4", anincrease in pressure results in a drop in the amount of ethylene production. Thepressure increase leads to higher yield of propylene and other by-products. The trend depicted in "Fig. 3" shows decrease in Ethylene production as the pressure increases, increase in Propylene production, slight increase inButene production with very little of C_5+ production.

3 Effect of Changing Temperature (at a constant pressure of 50 kPa) on Product Yield

"Fig.5" below shows the effect of increasing temperature from 350^{o}C to 500^{o}C on the yield of ethylene and other products while pressure remains constant.

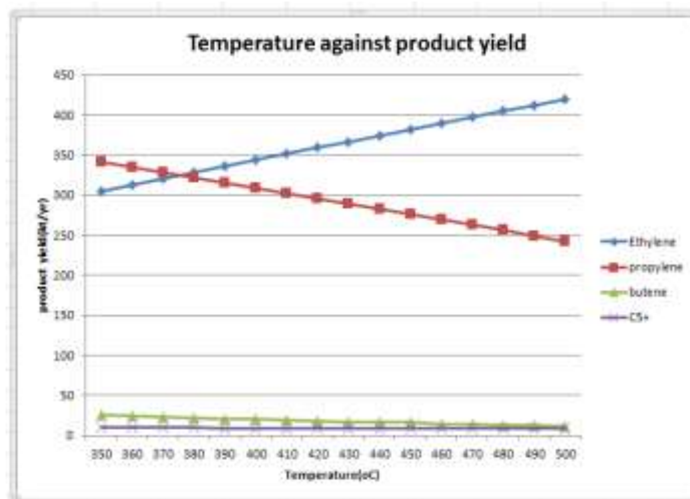

Figure 5: Product yield against Feed Temperature

From the graph above, there is increase in the level of ethylene production and a large drop in propylene yield. The pressure of 50kPa was chosen as a reference pressure because optimum yield of ethylene was obtained as shown in Table 2 above. The trend in "Fig. 3" above shows that Ethylene production increases while Butene and C_5+ production decreases.

VI. CONCLUSION

From the above results it is seen that an increase in temperature leads to an increase in Ethylene production. Therefore, to maximize Ethylene production of a plant the plant should be operated at a maximum temperature and minimum pressure.

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APPENDIX A

Information for HYSYS SIMULATION

Catalyst: SAPO-34

WHSV (Weight hour space velocity): 0.5 hr^{-1}

Temperature: 400°C

Reactor Temperature: 350-550°C;

Reactor Pressure: 45psig

Feed: Methanol (CH_3OH)

Reaction: $2CH_3OH \rightarrow CH_3OCH_3 + H_2O$

$CH_3OCH_3 \rightarrow C_2H_4 + H_20$

$3CH_3OCH_3 \rightarrow 2C_3H_6 + 2C_3H_6 + 3H_2O$

Reactor Type: Fluidized bed reactor

DeEthanizressure: 2.4-2.8 MPa

DeButanizer Pressure: 0.4-0.5 MPa

Input/Out flow rates				
Chsemical	**CH_3OH**	**C_3**	**C_2**	**Gasoline**
MTO (kt/a)	**1560**	**386**	**214**	**----**