FCS Flow Chemistry CONGRESS 14 - 15 MAY 2013 BOSTON USA

Open your mind. LUT.
Lappeenranta University of Technology

Recycled Gas Flow Control to Optimize Reaction Conversion and the Accomplishment of Heat Integration in Benzene Production through Hydrodealkylation of Toluene

Afshin Abrishamkar[1], Saman Ahmadi Siahpoush[1], Yury Avramenko[2], Eiman Rahnema Falavarjani[3]

1. Master student, Department of Chemical and Process Engineering, Lappeenranta University of Technology, Finland.
2. Senior lecturer, Department of Chemical and Process Engineering, Lappeenranta University of Technology, Finland.
3. Master student, Department of Chemical and Petroleum Engineering, Sharif University of Technology, Iran.

Abstract

Benzene is largely used as an intermediate substance consumed in the production of chemicals, mainly ethylbenzene, cumene, and cyclohexane. In this work, a benzene production plant through hydrodealkylation process was investigated through a simulation by Aspen Plus V7.2® and run based on the real data obtained from a benzene production plant operating in the United States. The reaction takes place in a double-bed catalytic reactor which was assumed as two stoichiometric reactors in the simulation, each represents one compartment. The reaction conversion is decreased at high temperature therefore, the reactor temperature was controlled by specifying the flow of required recycle gas which enters in between of two reactor beds. The study was enriched with the improvement of thermal efficiency of the plant by heat integration. For this purpose, a heat exchanger network (HEN) was designed to reduce the utility consumption. Furthermore, the part of recycle gas flow was suggested to utilize as the fuel to the furnace. Such gas flow control allows supplying around 70% of the heat required for increasing the reactor feed temperature to the desire point. As the result, the overall efficiency of the plant is increased by the manipulations of gas flows in the process.

Introduction

The major processes for producing benzene include Catalytic Reforming, Toluene Hydrodealkylation, Pyrolysis Gasoline, and Production from Coal Tar [1, 2]. Toluene Hydrodealkylation reaction, which is the main objective of this study, is defined as follow:

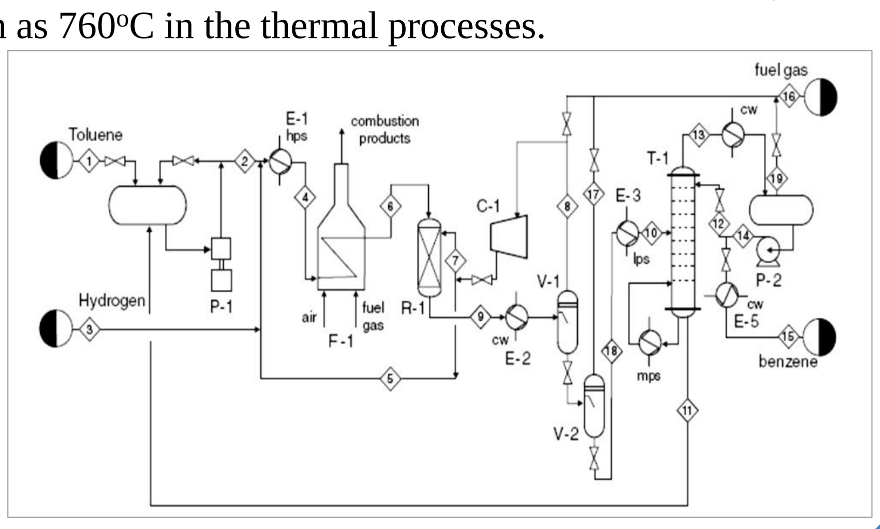
$$C_6H_5CH_3 + H_2 \longrightarrow C_6H_6 + CH_4$$

Hydrodealkylation of toluene can be operated under catalytic or thermal conditions. Toluene is mixed with heavier aromatics or paraffins from the benzene fractionation column; then heated with a gas containing hydrogen at a specific pressure. The stream then passes through a dealkylation catalyst bed in the reactor. Here, the toluene reacts with hydrogen, producing benzene and methane. Due to the high cost of energy, the safety of the process and the required higher yield of process, it is essential to optimize the conversion of reaction in the reactor. Furthermore, Heat integration within the plant is a crucial factor to improve the thermal efficiency of process.

Process Description

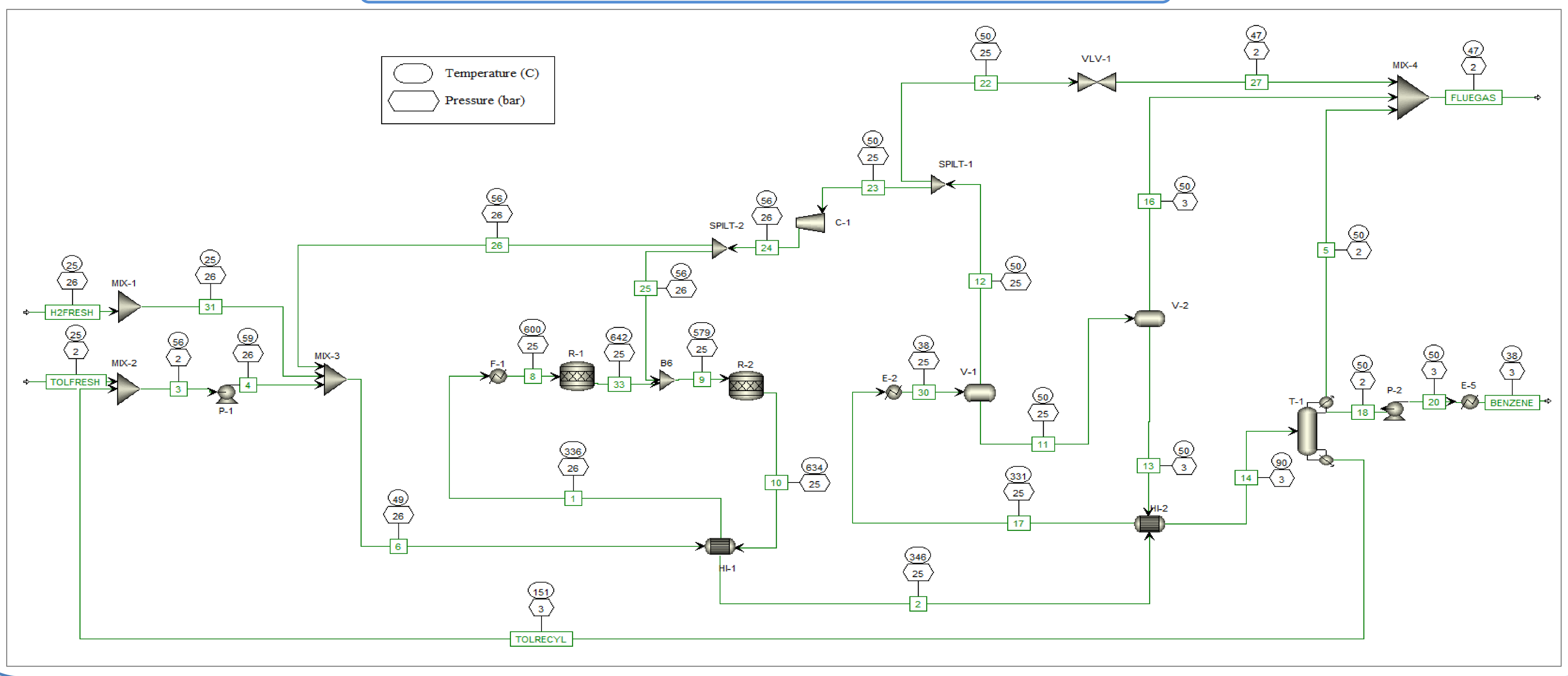
Toluene hydrodealkylation can be done by catalytic or thermal processes. Both are quite similar. Toluene is heated to 590-650°C and 25-40atm for catalytic hydrodealkylation or to as high as 760°C in the thermal processes.

The catalytic process has the advantage of lower heat loads but they have catalyst costs. Hence, here catalytic hydrodealkylation process is taken and platinum chloride is selected as the catalyst in order to make it more reasonable and to be used.

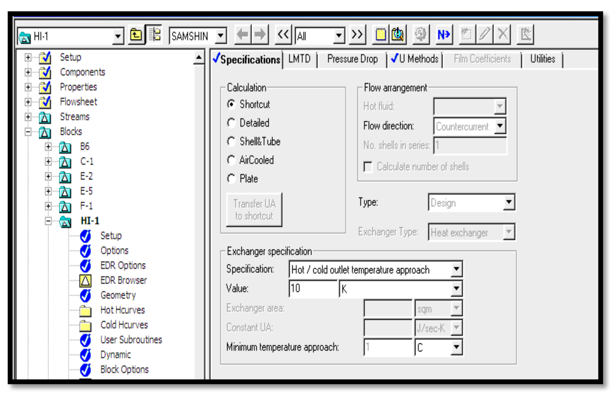


Results

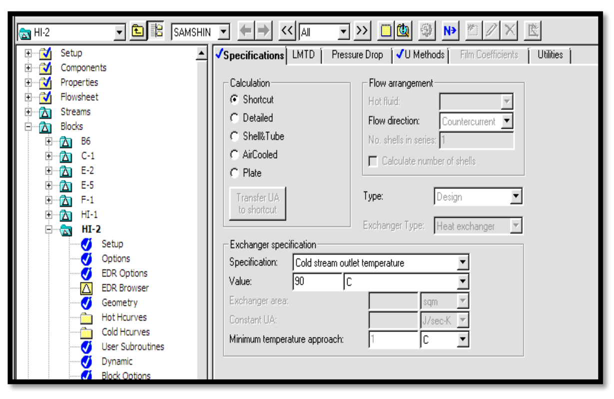
The Flow sheet of process drawn in Aspen Plus V7.2®



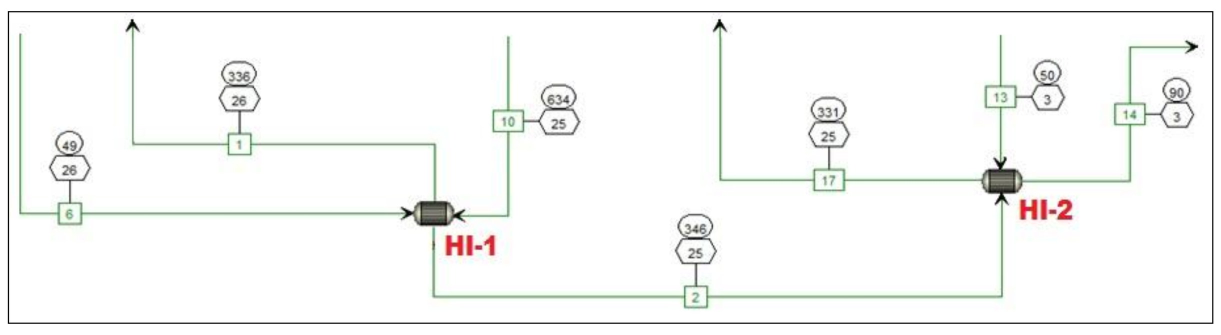
Heat Integration



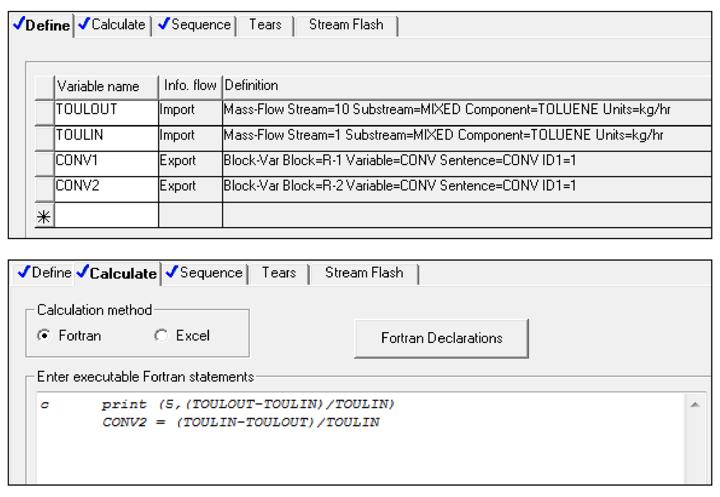
(HI-1)

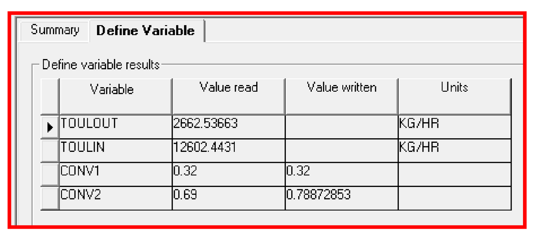


(HI-2)



Optimization of Reaction Conversion





Product and Recycle Streams Specifications

Recycled Toluene Stream		
Component	**Mass Fraction**	**Mass Flow (kg/hr)**
H_2	0.0	0
BENZENE	0.084	236.710
TOLUENE	0.916	2583.693
METHANE	0	0
Total Flow	--	2820.404

Recycled Hydrogen Stream		
Component	**Mass Fraction**	**Mass Flow (kg/hr)**
H_2	0.134	178.654
BENZENE	0.130	172.687
TOLUENE	0.014	18.923
METHANE	0.722	962.254
Total Flow	--	1332.518

Product Stream		
Component	**Mass Fraction**	**Mass Flow (kg/hr)**
H_2	1.44 E-06	0.012
BENZENE	0.999	8067
TOLUENE	2.19 E-05	0.177
METHANE	9.77 E-4	7.896
Total Flow	0	8075.085

Conclusion

In this work, utilizing Aspen Plus V7.2 a benzene production plant through hydrodealkylation process was simulated. The reactor temperature and the reaction conversion of reaction units were calculated and optimized. The recycle gas also contributed the safety of the operation. Then, the thermal efficiency of the plant was improved through a heat exchanger network design and heat integration. Heat integration was performed in two heat exchangers HI-1&2 reducing the thermal load of the fire heater by 58.8%. Applying these heat exchangers, the preheater and a heater were eliminated. Significant decrease in utility and fuel gas consumption were fulfilled through heat integration and by utilizing the flue gas as a fuel in the furnace. The flue gas supplied approximately 68% of the fuel requirement in the fired heater.

References

[1] Balonek, C. M., Colby, J. L., Schmidt, L. D., AIChE Journal, Vol. 56, No. 4, pp. 979-988, 1987.
[2] Kovash, S. M., Patrick, R. E., Kmecak, R. A., US Patent, US3700745, 1972.
[3] Patrick, R. E., Kmecak, R. A., Kovash, S. M., US Patent, US3686340, 1972.
[4] Meidanshahi, V., Bahmanpour, A. M., Iranshahi, D., Rahimpour, M. R., Chemical Engineering and Processing: Process Intensification, Vol. 50, No. 9, pp. 893-903, 2011.
[5] Grenoble, D.C., Journal of Catalysis, Vol. 56, No. 1, pp. 32-39, 1979.
[6] Jin, T., Xia, D. H., Xiang, Y. Z., Zhou, Y. L., Petroleum Science and Technology Journal, Vol. 27, No. 16, 2009.
[7] Turton, R., Bailie, R. C., Whiting, W. B., Shaeiwitz, J. A., "Analysis, Synthesis and Design of Chemical Processes", Pearson Education Publishing, 3rd Edition, 2009.