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ASPEN-HYSYS SIMULATION OF SULFURIC ACID PLANT

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Abstract

This work presents a theoretical investigation of the simulation of Sulfuric acid process plant. In the production of the acid in contact process liquid sulfur is sequentially oxidized to Sulfur tri oxide via an exothermic reaction which is absorbed by 98% Sulfuric acid in an absorption tower. In this research Aspen One V7.2 has been successfully used to design every sub-process of the sulfuric acid plant in one integrated environment. In order to simulate the process as accurately as possible COM thermo was selected as advanced thermodynamics. Electrolyte NRTL and Peng-Robinson were used for liquid and vapor phase respectively as fluid package and HYSYS properties were used for simulation. The simulation of sulfuric acid process included automatic chemistry generation and the capacity of handling electrolyte reactions for all unit models. Aspen-HYSYS provides specialized thermodynamics models and built-in data to represent the non-ideal behavior of liquid phase components in order to get accurate results. Material and energy flows, sized unit operations blocks can be used to conduct economic assessment of each process and optimize each of them for profit maximization. The simulation model developed can also be used as a guide for understanding the process and the economics, and also a starting point for more sophisticated models for plant designing and process equipment specifying.

Keywords

COM thermo, Fluid package, NRTL, Peng-Robinson, Simulation

Introduction

Aspen-HYSYS is a market-leading process modeling tool that uses best-in-class process technologies and has the ability to provide process design knowledge to improve the profitability and efficiency of the business. The purpose of this research is to develop and implement an effective knowledge on Simulation of process plant in Aspen-HYSYS [1]. Several works have been carried out on the dynamic simulation and optimization for an existing sulfuric acid plant. Operational problems may occur when the process is disturbed due to production rate changes or catalyst deactivation, the non linear response of the plant leading to sustained oscillations. Since the plant is operated near full capacity, only minor increases in energy production can be achieved. However, the SOx emissions can be significantly reduced by ~40% or more, by optimizing the operating parameters [3].

Most sulphuric acid plants are rather old and are facing now additional challenges that aim to maximize the amount of energy produced while reducing the environmental impact. Sulphuric acid is the chemical product manufactured in largest quantity in terms of mass, with about 40 million tons produced annually only in USA. It has a wide range of uses and plays an important role in the production of almost all manufactured goods. Approximately 65% of the H_2SO_4 produced is used in the production of agricultural fertilizers. AspenOne engineering enables engineers to model the sulfuric acid processes in one integrated environment. It has been successfully utilized by plant owners/ operators, engineering and construction companies, and technology providers to improve yields, increase plant efficiency and quality, and reduce capital and operating costs [4].

Existing situation necessitate restrictions to reduce the impact of process industry on environment. The high maintenance cost of sulfuric acid plants, stringent requirements on SO_2 emissions, importance of energy efficiency, and accurate equipment sizing and rating has made the simulation of the plant challenging [4].

There are a few sulfuric acid plants in Bangladesh and even those are rather old and are facing now additional challenges that aim to maximize the amount of energy produced while reducing the environmental impact. Almost all the existing processing plants are now operating beyond their capacities. In such a case the idea of optimization of the Sulfuric acid processing plant will surely pave a way to a sustainable solution. This project has the intention to carry out the simulation of the Sulfuric Acid processing plant (WATA Chemical Ltd. at Rupgonj, Bangladesh) using the Aspen-HYSYS process simulator. The steady state simulation of the processing plant shall be performed based on both the design and physical property data of the plant.

PROCESS SIMULATION

Components

In Aspen One V7.2 software HYSYS properties of the components were used for the simulation. The components used were:

a. Liquid Sulphur
b. Oxygen
c. Nitrogen
d. Sulphur Dioxide
e. Sulphur Trioxide
f. Sulphur Acid
g. Water

In the process the raw solid sulfur is melted to form liquid sulfur using steam heating, but because of limitatiot of solid handling in Aspen-HYSYS liquid sulfur was directly used as feed component for simulation.

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Reactions

$S + O_2 = SO_2$ ....(1)
$2SO_2 + O_2 = 2\ SO_3$ ....(2)
$SO_3 + H_2O = H_2SO_4$ ....(3)

Thermodynamically all reactions are exothermic. Reaction (2) is rate limiting step

Fluid package

In order to simulate the process as accurately as possible COM thermo was selected as advanced thermodynamics. In model phase selection NRTL was selected for liquid phase and Peng-Robinson was selected for vapor phase. The global property option used in this model is ELECNRTL. This option set is used for the simulations with non-ideal electrolyte solutions. ELECNRTL calculates liquid phase properties from the Electrolyte-NRTL activity coefficient model. Also, Henry's Law is used to calculate gas solubility in sulfuric acid. The ideal property option is used for vapor phase at high temperature in the converter and heater unit operation.

Process Description

To 0·1 – 1·0 mL of a neutral aqueous (pH – 6) solution Sulfuric acid is manufactured in plant with Sulfur burning. Moist air is dried in the drying tower using 98% H_2SO_4. The resulting dry air is used in a sulfur burner to burn Sulfur and produce sulfur dioxide. The principle steps in this process are to convert sulfur dioxide to sulfur trioxide and then combining it with water to form a solution containing 98-99%. This is conducted by passing sulfur dioxide through four converter beds. Because of the limitation of Aspen HYSYS software four individual converters were used as converter bed. The SO_2 from sulfur burner is passed through a waste heat boiler to lower the temperature before entering the 1st bed converter (Converter-1). For the same purpose an inter bed cooler is used between each of two consecutive beds. The final outlet from 4th bed (Converter - 4) is passed through a cooler to maintain temperature as too high or too low temperature may reduce the conversion rate.

The cooled outlet from Cooler1, containing Sulfur trioxide is passed to an absorption tower where it reacts with 98% H_2SO_4 to form 98.5% H_2SO_4. The stack gas is vented from absorption tower which consists predominantly of Nitrogen. Since the absorbing acid is continuously becoming concentrated, so it is necessary to provide some means of diluting the part of the acid which is discharged from absorbers and is to be re-circulated. Consequently the 98.5% H_2SO_4 is fed to circulation tank along with de-mineralized water and 97.5% H_2SO_4 that comes from the drying tower. The resulting concentration of the H_2SO_4 exiting from the circulation tank is to be 98.1%, which is split into two parts. One portion is cooled and recycled back to the absorption tower. The rest is also cooled and further split into another two portions. One of these portions is the final product containing 98% H_2SO_4. The other portion is recycled back to the drying tower.

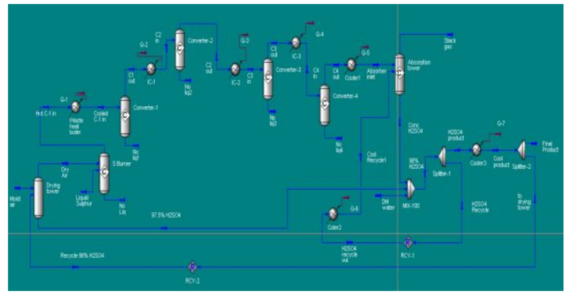

Fig 1. Simulation model of Sulfuric Acid Plant

SIMULATION RESULT

In this simulation Electrolyte NRTL and Peng-Robinson fluid packages were used. The Electrolyte NRTL was originally proposed for the aqueous system. It was later extended for mixed solvent electrolyte system [2]

From the simulation model different simulated process variables, energy streams for each unit were obtained. These can be used to compare the designed data with the simulated data and also can be applied for the better economic operation of sulfuric acid process plant.

Some of the key stream simulation results are given in Table1.

Table 1. Key stream Simulation Results

Feed	Air feed, kgmole/h	254.9
	Sulfur feed, kgmole/h	25.0
	Recycled 98% Sulfuric acid to absorption tower, kgmole/h	1572
	De-mineralized water feed, kgmole/h	30
Product	Sulphuric Acid, kgmole/h	27.32

Conclusion

In this work a simulation model of Sulfuric acid process plant was developed. Further material and energy flows, sized unit operations blocks can be used to conduct economic assessment of each process and optimize each of them for profit maximization. The simulation model developed can also be used as a guide for understanding the process and the economics, and also a starting point for more sophisticated models for plant designing and process equipment specifying.

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