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Study of Process Parameters and Optimization of Process Variables for the Production of Urea by Using Aspen HYSYS

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Abstract

Being easily acceptable in the soil, owning availability of raw materials and easy transportation made urea a unique fertilizer. Two main reasons are involved in urea fertilizer to be the best of all fertilizers. Firstly, about 46 percent nitrogen is contained in it. Secondly, it is a white crystalline organic chemical compound. Urea is formed naturally as a waste product by metabolizing protein in humans as well as other mammals, amphibians and some fish. Urea is widely used in the agriculture sector both as a fertilizer and animal feed additive having the chemical $CO(NH_2)_2$. In this paper, production of urea by the reaction of ammonia and carbon dioxide is simulated by the Simulator software Aspen HYSYS v.7.1. It is performed to investigate effect of few important parameters like temperature of carbon dioxide, temperature of HP (high pressure) steam and LP(low pressure) steam on the composition of urea. When temperature of HP steam varies from 357^0C to 365^0C, composition of urea varies from 0.055 to 0.08. When temperature of LP (low pressure) steam varies from 287^0C to 316^0C, composition of urea varies from 0.055 to 0.782. Being a typical Stamicarbon process, different process parameters are studied to understand the whole plant properly which are related with one another and the relation with several graphical representations are shown. By analyzing the process variables, the profit is optimized by using HYSYS Optimizer and found that $790.8.

Keywords: Biuret, Simulation, Stripping, Prilling, Granulation

1. Introduction

Maintenance of high temperature and pressure is needed for the production of urea [**1**]. Urea is formed through the heterogeneous reaction of carbon monoxide and ammonia [**2**]. Urea prills are produced in the prilling towers where a solidification-cooling process takes place and the ambient air is used as the cooling air stream for this process [**3**]. The temperature of produced prills and caking tendency of the prilled urea can be reduced by the increase in heat transfer from the particles by using installation of induced fans [**4**]. Granulation being the most fundamental operations in particulate processing, insight into the complex dynamic state behavior of these units is still needed [**5**]. Having similar chemical properties of both prills and granules and also distinguishable physical and mechanical properties, urea has been made suitable for different application either as fertilizer or raw materials for chemical industry **[6**]. Urea granulation is favored over prilling due to the problems associated with prilling [**7**]. In this paper, modeling and simulation of high-pressure and low urea synthesis loop has been studied [**8**] Due to well established global warming concerns, technological attempts have been made to decrease reactive nitrogen (N) species emitted from the application of urea fertilizer to agricultural soils [**9**]. HYSYS is applied to model the most significant aspects of the urea production processes by the availability of modern flow sheeting tools [**10**].

2. Process Description

The raw material composition used for this simulation is: CO_2 gas 20% and liquid NH_3 80% in mole fraction
The block diagram of Urea production according to Stamicarbon stripping processs from CO_2 gas and Liquid NH_3 is shown in Fig. 1.

2.1 Reactions Involved

$$2\ NH_3 + CO_2 \leftrightarrow H_2N\text{-}COONH_4$$
Ammonium Carbamate
$$H_2N\text{-}COONH_4 \leftrightarrow (NH_2)_2CO + H_2O$$
Urea
$$2NH_2CONH_2 \leftrightarrow NH_2CONHCONH_2 + NH_3$$
Biuret

2.2 Industrial Production Process

Urea is synthesized from ammonia and carbon dioxide. The urea plant has 5 sections excluding utility system:
1. Synthesis section
2. Purification section
3. Concentration and prilling system
4. Recovery system
5. Process and condensate treatment system

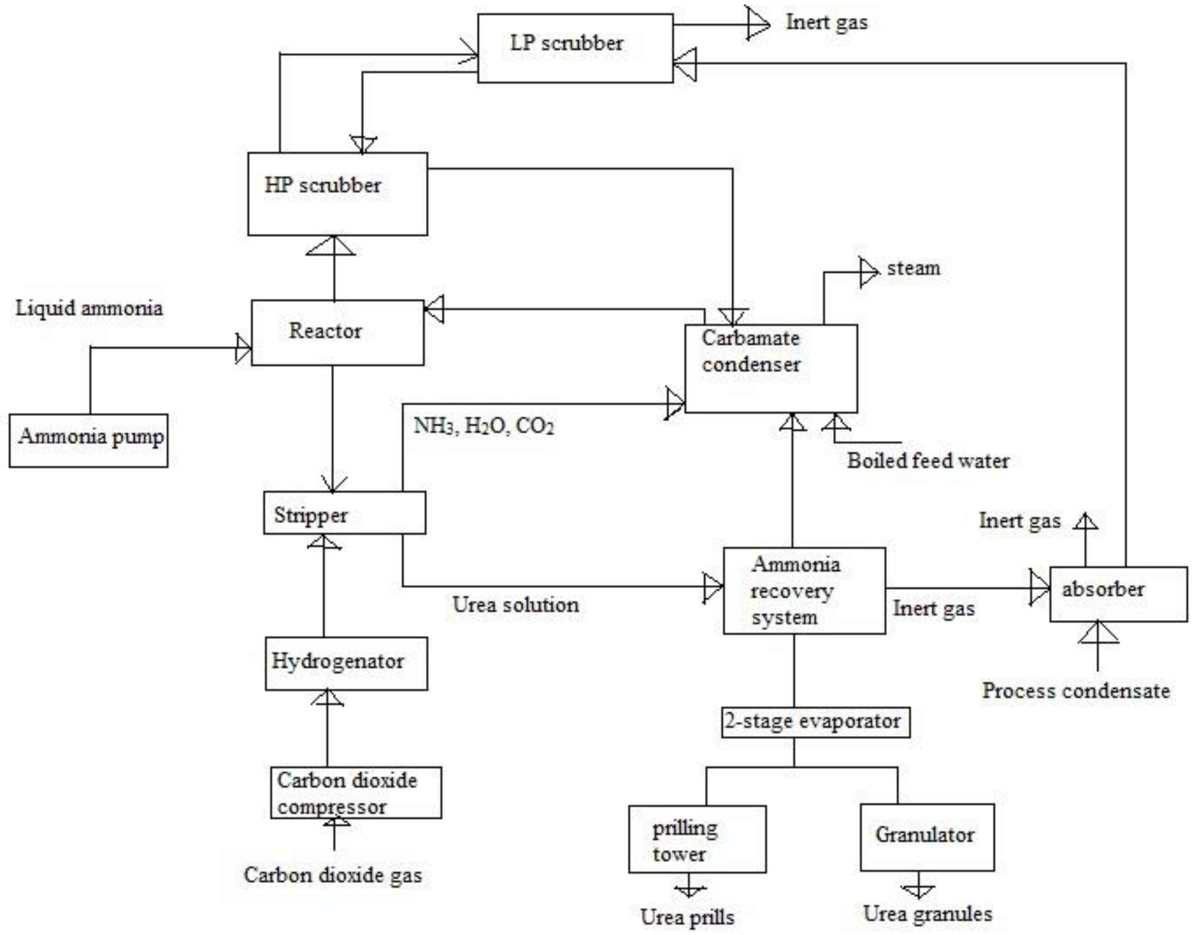

Fig. 1. Process block diagram of urea production.

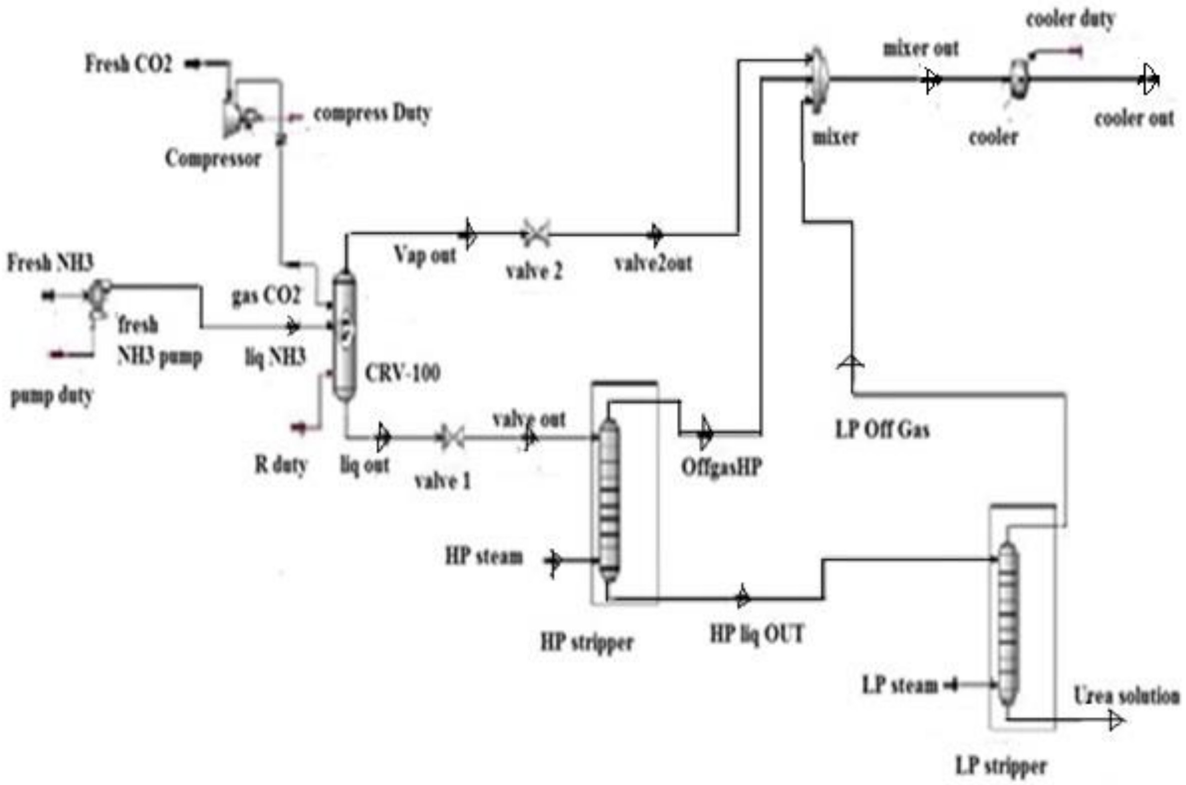

Fig. 2. Process flow diagram of urea production from ammonia and carbon dioxide.

2.3 Optimization

Table 1. Assumptions and data imported from HYSYS

Assumptions	Data imported from HYSYS
Selling Price of cooler Out product, Pcool = $0.471/kg	Mass of cooler out = M1= 3225 lb/hr
Selling Price of Urea solution, PU = $0.6/kg	Mass of urea solution out=M2= 200 lb/hr
Cost of HP steam Inlet, PHP = $ 0.20/kg	Mass of fresh CO2 = M3= 120 lb/hr
Cost of LP steam Inlet, PLP= $0.30/kg	Mass of NH3 = M4= 190 lb/hr
Cost of fresh CO2, Pco2 =$0.05/kg	Mass of HP steam= M5= 1250 lb/hr
Cost of fresh NH3, PNH3 = $ 0.06/kg	Mass of LP steam = M6= 1936 lb/hr
Cost of pump duty, Cp= $0.03/kg	Pump duty =Q1= 184.4 Btu/hr
Cost of Compressor duty, Cc = $0.02/kg	Compressor duty = Q2= -13.33 Btu/hr

Profit= (M1*Pcool) + (M2*PU)-(M3*Pco2)-(M4*PNH3)-(M5*PHP)-(M6*PLP) - (((Q1*Cp)+(Q2*Cc))/3600)
=790.8

3. Results and Analysis

By comparing the process parameters and calculating the profit of this typical Stamicarbon process, more profit can be made from the real plant. From optimization it was found that maximum profit was $790.8.The whole process can be understood very clearly.

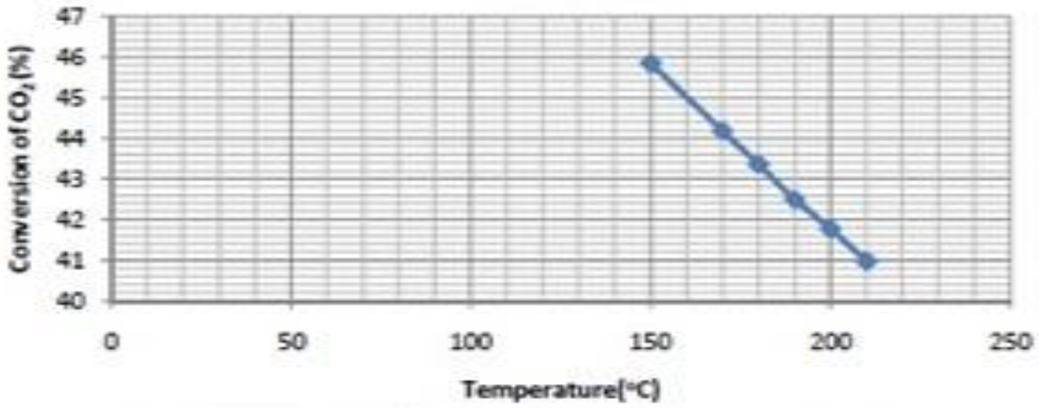

Fig. 3. Effect of temperature on CO_2 conversion.

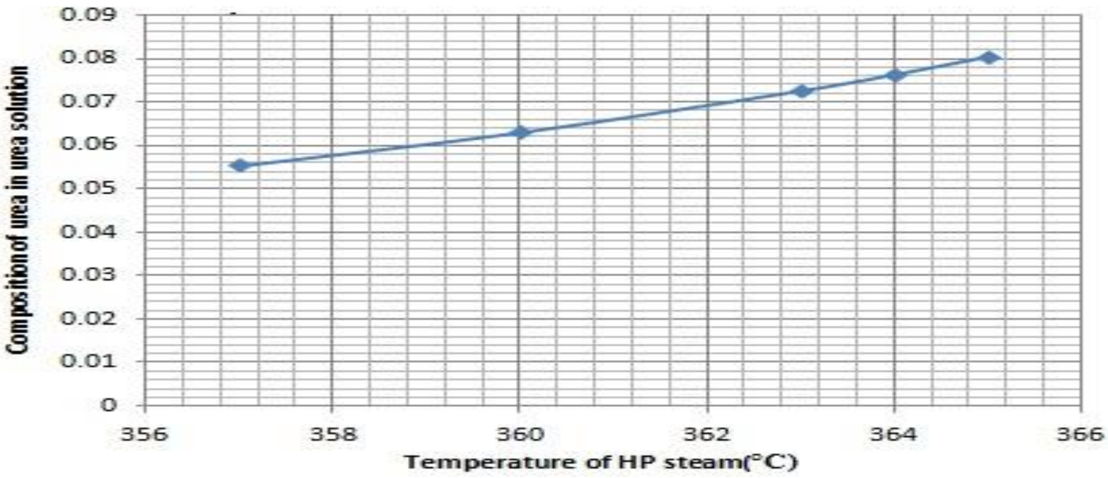

Fig. 4. Effect of HP steam temperature on composition of urea.

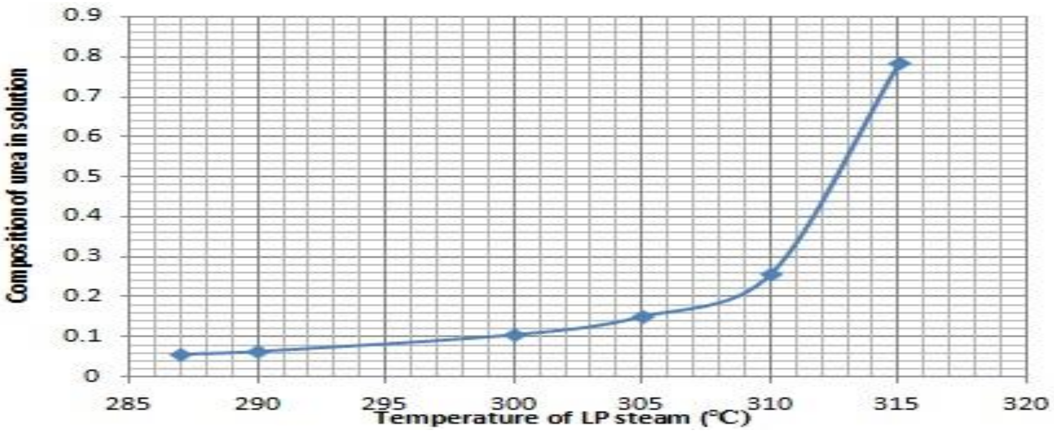

Fig. 5. Effect of LP steam temperature on composition of urea.

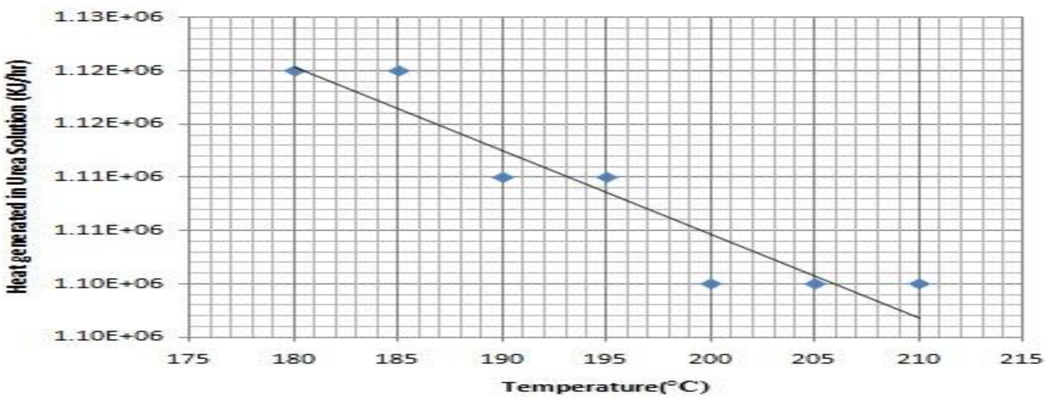

Fig. 6. Effect of CO_2 temperature on heat generated in urea solution.

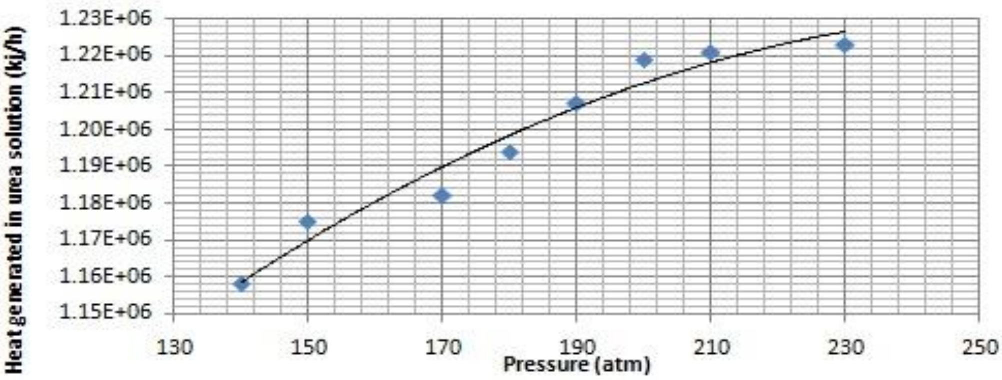

Fig. 7. Effect of pressure of CO_2 on heat generated in urea solution.

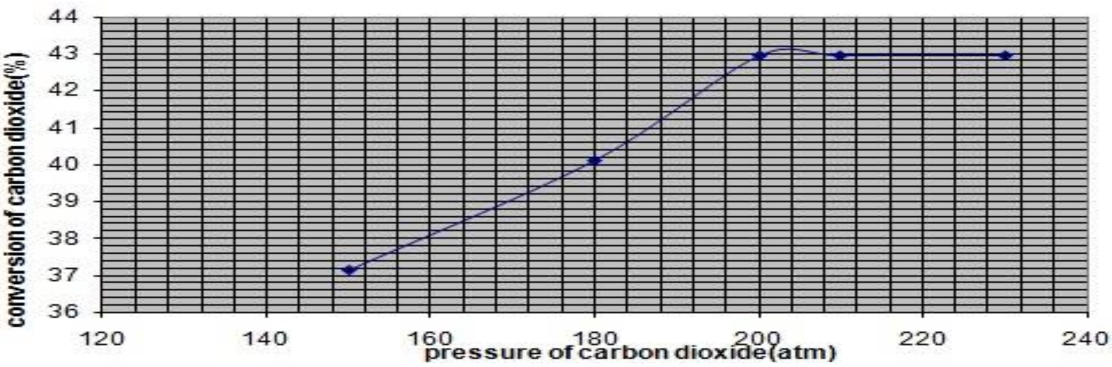

Fig. 8. Effect of pressure on CO_2 conversion.

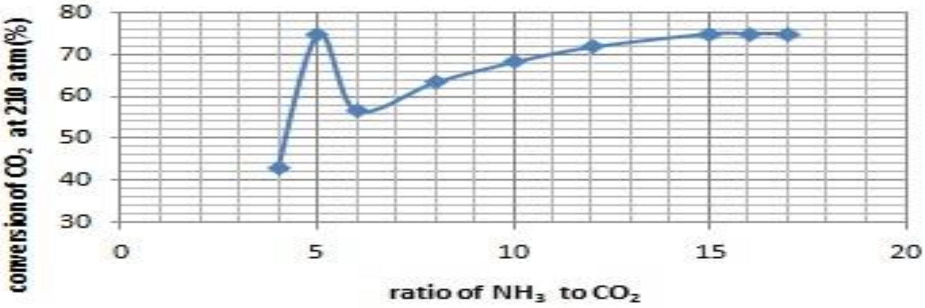

Fig. 9. Relation between rate of ammonia to carbon dioxide flow rate and conversion of carbon dioxide.

Fig. 3 shows the effect of temperature on the percentage conversion of CO_2 in the reactor (at 200 atm). As the temperature increases, the conversion of CO_2 decreases. Fig. 4 shows the effect of HP steam temperature on composition of urea (at 170 atm). As the HP steam temperature increases, the composition of urea also increases. Fig. 5 shows the effect of LP steam temperature on composition of urea. When the LP steam temperature reaches 310^0C, the composition of urea suddenly increases from 0.25 to 0.8. Fig. 6, shows the effect of temperature of CO_2 on heat generated in urea. Heat generated in urea solution decreases with the increase in temperature. Fig. 7, shows the effect of pressure of CO_2 on heat generated in urea solution. Generation of heat in urea solution is increased with the increase of CO_2 pressure. Fig. 8 shows the effect of pressure on the percentage conversion of CO_2 in the reactor. The conversion of CO_2 is seen constant after the pressure reaches 210 atm. Fig. 9 shows the effect of ammonia flowrate on composition of urea. Conversion of CO_2 at 210 atm is seen constant when the ratio of NH_3 to CO_2 is made 15.

4. Discussion

The reactor temperature and pressure are kept in the range 180^0C-190^0C and 120-150 bars respectively. So the fresh ammonia temperature and pressure should be chosen carefully. Similar process should also be maintained for fresh carbon dioxide. Production of urea and optimization is depended on the feed temperature and pressure. So feed temperature and pressure should be chosen cautiously.

5. Conclusion

Being an inexpensive and most concentrated nitrogenous fertilizer, urea is incorporated in mixed fertilizers as well as also used alone to the soil. Over 90% of the world's production of the substance is done for fertilizer related product. About 350 MMSCFD natural gas is required for the yearly production of about 3 million metric ton urea. A very competitive market has taken place due to the excessive use of urea. In order to produce urea at a low cost, Simulation analysis can be proved very handy in the optimization of urea production without conducting any real reactions or experiments. This job can be done pretty efficiently by optimizing several operating conditions.

6. Acknowledgement

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