



Syngas production from regasified liquefied natural gas and its simulation using Aspen HYSYS



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ABSTRACT

This research was carried out to simulate the Syngas production unit using Aspen HYSYS with the aim of enabling regasified liquefied natural gas (R-LNG) as raw material. The simulation is based on conditions and parameters (mass flow rates, temperature and pressure readings) obtained from the Ammonia plant of the Fertilizers and Chemicals Travancore Limited (FACT). The simulation results showed that the resulting syngas composition indicated 0.2661, 0.7331, 0.0005 and 0.0003 mol fractions of N₂, H₂, CH₄ and H₂O respectively. The feed changeover from naphtha to R-LNG, which has a lower carbon/hydrogen ratio, results in the reduction of steam/carbon ratio and so reduces CO₂ emission.

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1. Introduction

Currently, the worldwide energy demand is continuously growing, and a significant percent of the primary energy demand is met by fossil fuels. Since their reserves will last only for the next few decades, alternative and sustainable raw material resources are being sought. Among different feed choices for ammonia production, R-LNG becomes a favorable option (Ding et al., 2013; Enger et al., 2008). Ammonia is produced from a gaseous mixture of N₂ and H₂ in a ratio of about 1:3 (Higman and van der Burgt, 2008). The Fertilizers and Chemicals Travancore Limited (FACT), Udyogamandal, Kochi, has an ammonia plant with an installed capacity of 900 MTPD (metric ton per day) of ammonia production. Here, the ammonia plant is designed for naphtha as feedstock, which acts as a source of H₂, and the required N₂ is obtained from air.

Now FACT is planning to revamp their existing Ammonia plant with Regasified Liquefied Natural Gas (R-LNG), which was originally designed for the naphtha feedstock. When working with naphtha feed, which has a higher Carbon to Hydrogen Ratio (CHR), the amount of CO₂ generated is high (Abbas and Wan Daud, 2010). While, in the case of R-LNG, which has a lower CHR than naphtha,

the amount of CO₂ generated gets reduced (Abdulrahman and Sebastine, 2013). Also, due to the lower sulphur content in the R-LNG, the pre-desulphurization (PDS) section where primary sulphur removal takes place can be eliminated from the operation. Thus, this scheme results in a reduction of thermal energy requirement for the feed treatment (Rafiqul et al., 2005). Hence, this paper aims at simulating the ammonia plant with R-LNG as feedstock.

Mingyue Ding et al. (Ding et al., 2013) reported a non-catalytic direct conversion of liquid natural gas (LNG) to ethylene and syngas using pulse discharge technology. In this case, the operational factors such as electric current, voltage, discharge distance and input power were found to affect strongly the LNG conversion and yield while, product distribution was only slightly affected. They also found that the CO₂ formation is suppressed due to the low temperature of LNG and the cage effect of high-density LNG. Our work deal with the indirect conversion of LNG includes the steam and dry reforming of hydrocarbons.

The simulation results focused on the energy consumption analysis, giving the best conditions to operate the plant. This approach decreases energy consumption in reforming section and reduces environmental impacts by reducing CO₂ emission while increasing profits. Accordingly, the obtained simulation results offer useful references for process operation optimization and equipment design. The process flow diagram was developed and simulated on the Aspen HYSYS platform. It is a primary tool designed to

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Nomenclature

E 207	Fuel Preheater
H 201	Primary Reformer
H 206	Natural Gas Preheater
R 201	Hydrogenator
R 202	Existing Sulphur Absorber
R 202 A	New Sulphur Absorber

Abbreviations

CHR	Carbon to Hydrogen Ratio
FACT	Fertilisers And Chemicals Travancore Limited
FDS	Final Desulphurisation

GHR	Gas Heated Reformers
HTS	High Temperature Shift
HTZ-3	Haldor Topsøe Zinc Oxide Absorbent – series 3
HYSYS	Hyprotech System
LNG	Liquefied Natural Gas
LTS	Low Temperature Shift
MDEA	Methyl-Di-Ethanol-Amine
MTPD	Metric Ton Per Day
PDS	Pre-desulphurization
PFD	Process Flow Diagram
PR	Peng-Robinson
R-LNG	Regasified Liquefied Natural Gas

provide numerous applications to the industries especially oil & gas refining, and these applications include the development of the steady state and dynamic models, process monitoring, troubleshooting, performance improvement, etc (AspenTech, 2011; Al-Lagtah et al., 2015).

2. Materials and methods

2.1. Process description

2.1.1. Present scheme in ammonia production

The entire ammonia production process can be divided into two main sections: (1) syngas production (preparation of feedstock) and (2) ammonia synthesis. The syngas production includes unit operations shown in Fig. 1, such as desulphurization, steam reforming (primary reforming), air reforming (secondary reforming), CO shift conversion, CO₂ removal and methanation (Ammonia principles and in, 2007; Holladay et al., 2009).

Desulfurization section has two parts; pre-desulphurization (PDS) and final desulphurization (FDS). In PDS, the organic

sulphur compounds are removed by catalytic conversion to hydrogen sulphide, which is then separated from the feed by distillation. In this section, the sulphur content in the raw feed is reduced from 1000 ppm–10 ppm. In FDS, a further catalytic hydrogenation of the residual organic sulphur compounds takes place followed by absorption of hydrogen sulphide on zinc oxide. After this process, the sulphur content in the feed is reduced to 0.05 ppm (Aghahosseini et al., 2011).

Ammonia synthesis section requires an input feed stream of N₂ and H₂ in the stoichiometric ratio of 1:3 referred to as synthesis gas (syngas). For that purpose, the reforming reaction is split into two sections; primary reforming and secondary reforming. In the primary reformer, hydrocarbon reforming takes place in the presence of steam. This reaction is controlled to maintain 10.5% of hydrocarbon in the output stream that is necessary to perform complete air reforming in secondary reformer (Giddey et al., 2013; Alves et al., 2013).

In secondary reformer, the nitrogen for ammonia synthesis is obtained by air reforming. Here heat is supplied by combustion of part of the air–gas mixture. Burning gas provides heat for the rest of the reforming process. After the reforming section, the output stream contains H₂, N₂, CO, CO₂ and 0.3 mol% of unreacted hydrocarbons (Giddey et al., 2013). Since ammonia synthesis requires only nitrogen and hydrogen, it is necessary to remove all the carbon oxides from the raw Syngas. Depending on feedstock and process technology, reformer output stream may contain 10–50 mol% CO and some varying amounts of CO₂ (Giddey et al., 2013). Removal of carbon oxides is carried out using shift converters and CO₂ absorber. In the CO shift conversion, the CO acts as reducing agent for water to yield H₂ and CO₂. Thus, CO is converted to readily removable CO₂. The gas leaving the CO conversion section has a CO₂ content of 21 mol%. The CO₂ is removed from the gas by absorption in 0.31 mol% MDEA (methyl di-ethanol-amine) solution (Giddey et al., 2013).

After shift reaction and CO₂ removal, the output stream still contains 0.2–0.5 mol % CO and 0.005–0.2 mol % CO₂ (Øi et al., 2014). Methanation is the simplest procedure to remove traces of carbon oxides from a stream. So using this method, the concentration of carbon oxides in the output stream reduces to well below 10 ppm (Giddey et al., 2013). The output stream from methanator having a composition of N₂ and H₂ in 1:3 ratio is referred to as syngas.

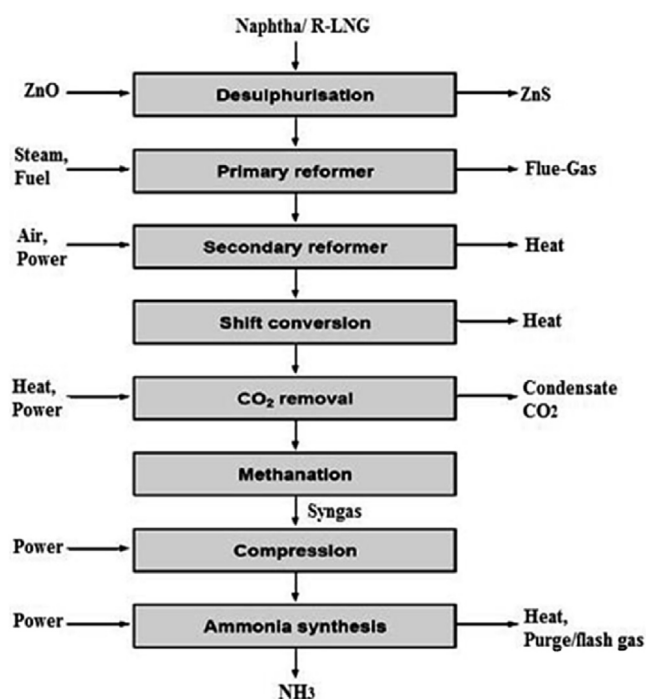


Fig. 1. Flow diagram for ammonia production.

2.2. Modifications required for feedstock conversion

The FACT Ammonia plant was originally designed based on steam reforming of naphtha and also using naphtha as fuel. The

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