Syngas production from re-gasified liquefied natural gas and its simulation using DWSIM

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Introduction

This aim of this project was to convert existing literature into a steady state simulation of Syngas production using liquefied natural gas (R-LNG) as a raw material. The simulation uses the provided data of mass flow rates, temperature and pressure obtained from Fertilizers and Chemicals Travancore Ltd (FACT), ammonia plant. The novelty of using R-LNG is that it has a lower carbon/hydrogen ratio, resulting in a total reduction of steam: carbon ratio and subsequently reduces CO_2 emissions and thus reduces the carbon footprint of the process.

Ammonia is produced from a gaseous mixture comprising of mainly N_2 and H_2 in a 1:3 ratio. Conventionally ammonia plants use naphtha as a feedstock for syngas production serving as a source for H_2 while the N_2 is obtained from the air. Using naphtha as a feed generates high amount of CO_2 due to higher carbon to hydrogen ratio. FACT wishes to upgrade its plant by introducing syngas production using R-LNG. This paper provides a simulation for the same.

Process Description

The ammonia production mainly consists of two steps:

(i) Syngas Production
(ii) Ammonia Synthesis

Part I will only be focused in this flow sheet. The unit operations included are steam reforming (primary reforming), air reforming (secondary reforming), CO shift reaction, CO_2 removal and finally methanation. 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. In secondary reformer, the nitrogen for ammonia synthesis is produced by air reforming. Here heat is supplied by combustion. Burning gas provides heat for the rest of the reforming process.

After the reforming section, the output stream contains H2, N2, CO, CO2 and along with minute presence of unreacted hydrocarbons. Removal of carbon oxides is carried out using shift convertors and CO2 absorber. In the CO shift conversion, the CO acts as reducing agent for water to yield H2 and CO2. Methanation is the simplest procedure to remove traces of carbon oxides from a stream. So using the above mentioned method, the concentration of carbon oxides is reduced.

Syngas production or feed preparation for ammonia synthesis has been modeled using three conversion reactors and two equilibrium reactors. In this particular work, desulphurized R-LNG acts as a hydrogen source. When this R-LNG is reacted with steam, it gets reformed in a primary reformer which is a conversion reactor. Air is added to the second conversion reactor (secondary reformer) to obtain the nitrogen. Shift conversion reactions take place in next two equilibrium reactors. It is followed by CO2 absorption, for the removal of CO2 from the feed. Later a methanator unit, which is a conversion reactor, is used to remove traces of carbon oxides from the stream.

Reactions

The following reactions take place in their respective reactors:

Primary reforming

(a) $CH_4 + H_2O \rightarrow CO + 3H_2$ (Conversion reaction)

(b) $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$ (Conversion reaction)

(c) $CO + H_2O \rightarrow CO_2 + H_2$ (Equilibrium)

Secondary reforming

(a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (Conversion reaction)
(b) $CH_4 + 1.5O_2 \rightarrow CO + 2H_2O$ (Conversion reaction)

Shift conversion
(a) $CO + H_2O \rightarrow CO_2 + H_2$ (Equilibrium reaction)

Methanation

(a) $CO + 3H_2 \rightarrow CH_4 + H_2O$ (Conversion reaction)
(b) $CO_2 + 3H_2 \rightarrow CH_4 + 2H_2O$ (Conversion reaction)

Flowsheet

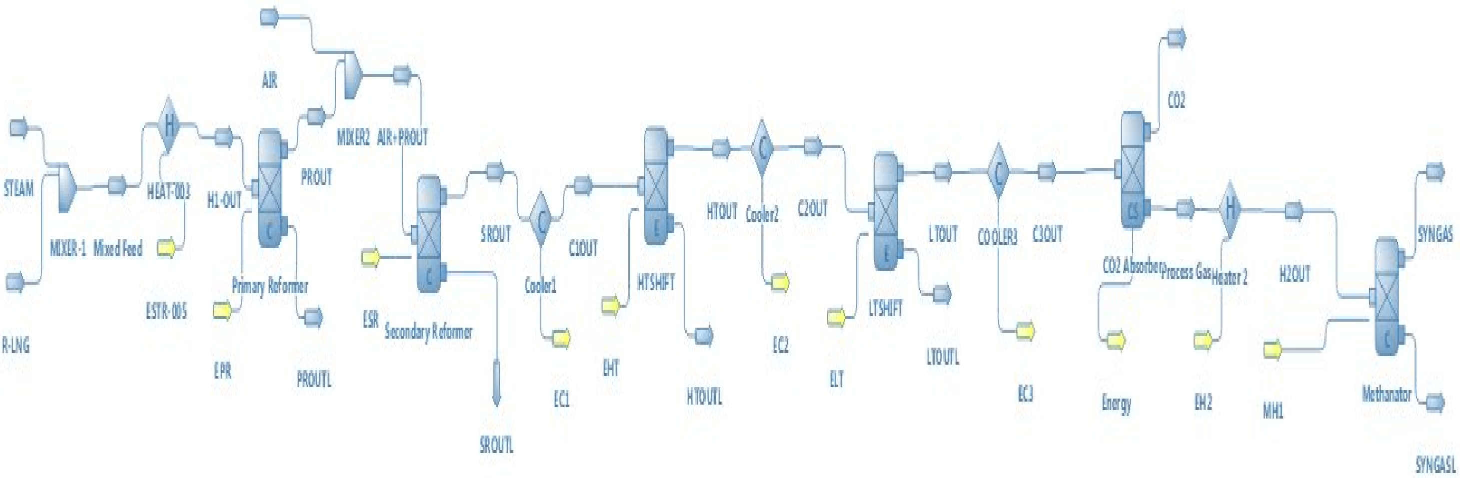

Fig 1. Syngas production from re-gasified liquefied natural gas in DWSIM

Results

Stream wise analysis of major material streams is given below.

Master Property Table					
Object	SYNGAS	STEAM	R-LNG	AIR	
Temperature	331	380	340	765	C
Pressure	30.4	30.4	37.3	31.1	bar
Mass Flow	46670.1	25221	8117.6	52678	kg/h
Vapor Phase Molar Weight	15.9325	18.0153	16.2325	28.8503	kg/kmol
Vapor Phase Mass Flow	46670.1	25221	8117.6	52678	kg/h
Vapor Phase Molar Flow	2929.25	1399.98	500.084	1825.91	kmol/h
Vapor Phase Molar Fraction	1	1	1	1	
Vapor Phase Mass Fraction	1	1	1	1	
Molar Fraction (Vapor Phase) / Water	0.00522838	1	0	0	
Molar Fraction (Mixture) / Methane	0.00180613	0	0.985197	0	
Molar Fraction (Vapor Phase) / Methane	0.00180613	0	0.985197	0	
Molar Fraction (Mixture) / Carbon monoxide	0	0	0	0	
Molar Fraction (Mixture) / Hydrogen	0.466676	0	0	0	
Molar Fraction (Mixture) / Carbon dioxide	0	0	0.00080016	0	
Molar Fraction (Mixture) / Oxygen	0.0314629	0	0	0.21	
Molar Fraction (Mixture) / Nitrogen	0.494827	0	0.0140028	0.79	