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Modelling and assessment of acid gas removal processes in coal-derived SNG production

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HIGHLIGHTS

- An integrated gasification – gas cleaning – synthesis system was modelled in AspenPlus™.
- A comparison of Rectisol™, Selexol™, K_2CO_3 and MDEA solvents.
- Rectisol had the highest power consumptions in a 50 MW_{th} coal-to-SNG plant.
- K_2CO_3 presented advantages over MDEA due to operating specifications.
- Optimization of gas conditioning is necessary for the coal-to-SNG configuration.

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ABSTRACT

Solid fuel conversion into Substitute Natural Gas (SNG) enables its use in remote heat and power applications via storage and transportation through the existing natural gas infrastructure. The product gas of an allothermal coal gasification process, requires cleaning and conditioning before the final methanation process. Catalysts' restrictions and grid requirements emerge the need of CO_2-and sulfur species removal before the methanator. This paper investigates the different acid gas removal processes through a comparison of their final integration on the coal-to-SNG production chain. Among these technologies, absorption with physical (i.e. Rectisol™, Selexol™) or chemical (K_2CO_3, MDEA) solvents which have been implemented in various clean syngas production applications are compared for their efficiency and feasibility. The paper presents conceptual designs comparison, mass and energy analyses of the four processes integrated in the coal-to-SNG system, based on AspenPlus™ modelling.

1. Introduction

Limited oil and gas resources in Europe have raised the role of solid fossil fuels (coal and lignite) in the future energy production, since their abundance also reduces the dependencies on energy imports. The production of Substitute Natural Gas (SNG) from solid fuels offers many advantages since solid carbon sources are upgraded into a methane rich gas which may be further transported via the existing pipelines infrastructure and be used in highly efficient and well-established heat and power systems (e.g. domestic heating systems and/or combined cycle plants) coupled with CO_2 sequestration technologies. The flexibility of different scale utilization of the produced SNG together with its feasibility of transportation addresses directly to the need for minimization of energy dependence, towards an enhancement of the fuel availability and security of supply. SNG can be used in power and chemical industry applications as well as in the transportation sector, ranging from industrial to domestic scale end-users. Large-scale methanation of coal is a mature technology and has been investigated for approximately 70 years particularly in Europe and in the US [1]. In the USA, a large commercial plant for the gasification of lignite – the Great Plains Synfuels Plant, Dakota Gas Company – is operating since 1984 [2] with syngas cleaning and methanation technology provided by Lurgi. Currently, large-scale SNG plants are under construction in USA, China, Ukraine and Republic of Korea, while feasibility studies have been

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conducted for Indonesia, Pakistan, Peru, India, Canada and Japan/Australia [3–6]. Moreover, coal-to SNG routes are considered for treating the coke oven gas from Steel industry coke plants [4]. Table 1 summarizes the worldwide projects of coal gasification to SNG production. European SNG research has been focused on the allothermal steam coal gasification [7,8] and as well as on several biomass projects (BioSNG and GoBiGas [3,9,10]). Furthermore, the methanation of carbon dioxide has recently received significant attention under "power-to-gas" concepts with thirty on-going European research projects [11].

In allothermal gasification, that is modelled in the present work, heat is provided to both, the reacting solid fuel and gasification agent, through an external source (usually a combustor chamber). Allothermal gasification offers a syngas-composition with high H_2 content that is required for the methanation process. The quality of produced syngas varies according to the geometrical design of the gasifier, its operating conditions (gasifying agent, solid fuel to agent ratios, temperature, pressure) and the downstream gas cleaning equipment. All these affect the subsequent methanation process. Apart from the main gases (CH_4, CO, CO_2, H_2), the syngas also contains undesired impurities such as particulates, tars, sulfur, halogens, nitrogen species and metal traces inherent in coal [12]. The removal of these traces, through proper gas cleaning steps requires an integration optimization and influence greatly the overall operation of the SNG plant because:

- the feasibility and the performance of the methanation reactor is highly influenced (poisoning and short life duration of catalysts [13–15])
- the subsequent injection of SNG to the grid and liquid methanation have strict specifications on contained traces
- heat utilization, water/steam requirements, optimum conditions for the system implementation to the methanation process, maximum exploitation of the syngas's energy content are of major importance for the total coal-to-SNG efficiency.

In the present work, several gas cleaning concepts of acid gas removal processes are assessed for integration to the coal-to-SNG production chain based on a syngas composition derived from steam gasification. The work focuses on small scale plants of 50 MW_{th}, and reports the internal consumptions gas cleaning technologies applied on such a plant.

2. Gas cleaning

2.1. Gas cleaning considerations

The gas cleaning system should be adjustable to the operating conditions of the gasifier and of the downstream equipment in respect to both the prerequisites for removal as well as for conditioning of the delivered gas. The operating conditions of gas

Table 1
Coal to SNG worldwide projects and plants [5,6].

Project name	Developer	City or county	State	Type	Size	Status
Great Plains Synfuels Plant	Dakota Gas Company	Beulah	North Dakota	SNG	Coal to 1.51 BSCM per year SNG	A
Cash Creek Generation	Erora Group	Henderson County	Kentucky	IGCC (via SNG)	1.7 million TPY coal to SNG and 720 MW electricity	A
Lake Charles Clean Energy	Leucadia National	Port of Lake Charles, Calcasieu Parish, USA	Louisiana	SNG, polygeneration	7.4 k TPD petcoke to 3.36 Million SCM per day SNG and 2 k TPD sulfuric acid	A
Indiana – Rockport SNG	Indiana Gasification, LLC (Leucadia National Corp.)	Rockport	Indiana	SNG	3.85 million TPY coal to 1.24 BSCM per year of SNG, 134 MW electricity,	A
Kentucky NewGas SNG	Peabody Energy, ConocoPhillips	Muhlenberg County, U.S.A	Kentucky	SNG	Coal and petcoke 3.5 million TPY to SNG 1.7 BSCM per year	D
Scriba Coal Gasification Plant (Empire State Project)	TransGas Development Systems (TGDS)	Scriba, USA	New York	SNG, polygeneration	20,000 TPD coal to SNG	D
Southern Illinois	Power Holdings of Illinois, LLC	Jefferson County, USA	Illinois	SNG	5 million TPY Illinois bituminous coal to 1.82 BSCM per year SNG	D
Taylorville Energy Center	Christian County Generation, LLC/Tenaska/Erora	Taylorville	Illinois	IGCC	High-sulfur, sub-bituminous IL coal to SNG which is then used to generate 602 MW in NG turbine power block	D
Chicago Clean Energy Project	Leucadia National Corp.	Chicago, USA	Illinois	SNG	Undefined high-sulfur Illinois coal to SNG	D
Southern Illinois Coal-to-SNG Project	Power Holdings of Illinois, LLC	Jefferson County	Illinois	SNG	5 million TPY Illinois bituminous coal to 1.82 BCM SNG per year	D
Datang	Datang	Chifeng	Inner Mongolia, China	SNG	Coal to 4 BSCM SNG per year	A
Datang	Datang	Fuxin	Liaoning, China	SNG	Coal to 4 BSCM SNG per year	A
Huineng	Huineng	Ordos	Inner Mongolia, China	SNG	Coal to 1.6 BSCM SNG per year	A
China Kingho Group	China Kingho Group	Ili	Xinjiang, China	SNG	Coal to 5.5 BSCM SNG per year	A
CPI Corporation	CPI Corporation	Ili	Xinjiang, China	SNG	Coal to 6 BSCM SNG per year	A
Xinwen Mining Group	Xinwen Mining Group	Ili	Xinjiang, China	SNG	Coal to 4 BSCM SNG per year	A
Guodian	Guodian	Hinggan League	Inner Mongolia, China	SNG	Coal to 4 BSCM SNG per year	A
Xinmeng Energy	Xinmeng Energy	Ordos	Inner Mongolia, China	SNG	Coal to 4 BSCM SNG per year	A
POSCO plant	POSCO	Gwangyang	Republic of South Korea	SNG	Coal to 0.7 BSCM SNG per year	A
Qinghua	Qinghua	Yili	China	SNG	Coal to 1.4 BSCM SNG per year	A
Ukraine SNG Project	Naftogaz	Lugansk	Ukraine,	SNG	Coal to 4 BSCM SNG per year	A

Many other proposed or active projects, which are summarized in Refs. [3–6] and turn to other fuels or use biomass or coke oven gas to SNG, are not included in the list.
A: active, D: delayed/cancelled, TPY = tons per year, TPD = tons per day, SCM = standard cubic meter, BSCM = billion SCM, k = kilo.

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