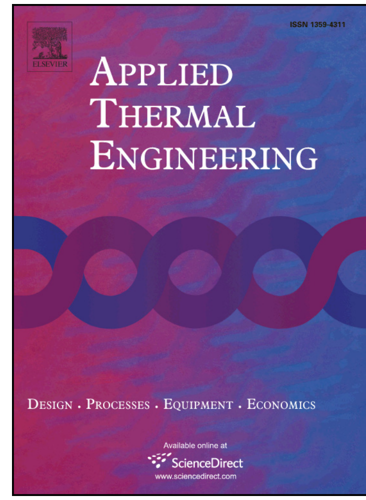

The small-scale production of hydrogen, with the co-production of electricity and district heat, by means of the gasification of municipal solid waste

Johannes Hognert, Lars Nilsson

PII: S1359-4311(16)30864-X
DOI: http://dx.doi.org/10.1016/j.applthermaleng.2016.05.185
Reference: ATE 8401

To appear in: *Applied Thermal Engineering*

Received Date: 15 February 2016
Revised Date: 29 May 2016
Accepted Date: 30 May 2016

Please cite this article as: J. Hognert, L. Nilsson, The small-scale production of hydrogen, with the co-production of electricity and district heat, by means of the gasification of municipal solid waste, *Applied Thermal Engineering* (2016), doi: http://dx.doi.org/10.1016/j.applthermaleng.2016.05.185

The small-scale production of hydrogen, with the co-production of electricity and district heat, by means of the gasification of municipal solid waste

Johannes Hognert & Lars Nilsson*

Department of Engineering and Chemical Sciences, Karlstad University, SE-651 88 Karlstad, Sweden

*Corresponding author
Environmental and Energy systems, Karlstad University, SE-651 88, Karlstad, Sweden
E-mail: lars.nilsson@kau.se
Tel: +46 54 700 2099

Abstract

Reducing the use of fossil fuels and increasing the recycling of waste are two important challenges for a sustainable society. Fossil fuels contribute to global warming whilst waste causes the pollution of land, water and air. Alternative fuels and innovative waste management systems are needed to address these issues. In this study a gasification process, fuelled with municipal solid waste, was assumed to be integrated into a heat plant to produce hydrogen, electricity and district heat. A whole system, which includes a gasification reactor, heat plant, steam cycle, pressure swing adsorption, gas turbine and compressors was modelled in Microsoft Excel and an energy balance of the system was solved. Data from the scientific literature were used when setting up the heat and mass balances of the gasification process as well as for assessment of the composition of the syngas. The allocation of energy of the products obtained in the process is 29% hydrogen, 26% electricity and 45% district heat. A significant result of the study is the high energy efficiency (88%) during the cold period of the year when the produced heat in the system is utilized for district heat. The system also shows a competitive energy efficiency (56.5%) all year round.

Keywords: hydrogen, gasification, waste, district heat.

1. Introduction

Reducing the use of fossil fuels and increasing the recycling of waste are two great challenges facing society today. Ever since the industrial revolution, the requirement of energy and waste levels have both increased rapidly. Lately, general awareness has been raised regarding the environmental issues caused by these matters, and has resulted in the emergence of an increased demand for alternative fuels as well as for more sophisticated methods for treating waste. In this study, a process is investigated in which both of these matters are addressed. A gasification unit for gasifying municipal solid waste (MSW) to produce hydrogen, electricity and district heat is integrated into a heat plant run on bio fuel.

1.1 Producing hydrogen by gasification

Gasification is a thermal treatment method in which a carbon-based material is heated in an oxygen-free or limited environment. The gasified fuel is transformed into three phases: liquid (tar), solid (char) and gaseous (syngas) and, depending on the gasification parameters, their proportions vary.

A process that utilizes gasification is the Integrated Gasification Combined Cycle (IGCC) in power plants comprising of a gas turbine and a steam turbine. The former is fuelled by the gas created in the gasification process and the steam for the latter is generated by the extensive heat that is produced during the process. Coal is often used as the fuel and IGCC is a well-established technology that also allows for Carbon Capture Storage (CCS) via the separation of carbon dioxide from the syngas.

Several studies have been carried out where the production of hydrogen is integrated in IGCC plants (Chiesa *et al.* 2005; Abu-Zahra *et al.* 2009; Cormos 2010; Cormos & Agachi 2010; Chen *et al.* 2014; Verma & Kumar 2015), some of which also investigate the possibility of CCS. There is also literature that investigates the prospect of using waste (Baggio *et al.* 2008; Byun *et al.* 2011) or mixtures of biomass and coal (Chen *et al.* 2014) as the fuel for producing energy via gasification processes. The result obtained by Baggio *et al.* (2008), who fuels a modified IGCC plant with MSW, is of particular interest for the present study. If this could be combined with a co-production of hydrogen, it would be possible to address both of the issues at hand.

He *et al.* (2009) carried out a study in which MSW was gasified with steam, using calcined dolomite as the catalytic bed material, the result of which was a hydrogen-rich syngas with no or low tar content. Also, Luo *et al.* (2012) reported that using steam as the oxidizer and calcined dolomite as the bed material produces a syngas with a high hydrogen content and a low tar content.

Most of the hydrogen produced today comes from the reformation of natural gas (steam methane reforming) which, due to the low cost of natural gas, is the cheapest production method (Navarro *et al.* 2007). The costs of methods based on sources of renewable energy, such as the electrolysis of water coupled with wind turbines or the solar