IEA Bioenergy Agreement
Task 33: Thermal Gasification of Biomass
DRAFT
Work Shop 2: Gas Cleaning & Gas Engines for Small-scale Biomass Gasification Applications
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by
Martin Wittrup Hansen, Dong Energy
Copenhagen, Denmark
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Background

At the end of October, 2004, the IEA Task 33 :Thermal Gasification of Biomass held its semi-annual, Fall 2004 meeting in Copenhagen. The group comprises of representatives from ten countries. The Danish Energy Authority hosted the workshop (WS). Denmark also prepared the following summary of the on the status of gas cleaning and gas engines for small scale plants.

Introduction

Historically Denmark's research and development climate has facilitated the pursuit of a variety of biomass gasification (BMG) processes. The objective of the Danish RD&D program is to develop small-scale BMG coupled CHP plants both for domestic and export applications. The Danish RD&D organizations have demonstrated great creativity and persistence and have spearheaded several successful initiatives.

Even though it remains difficult to purchase biomass gasification plants on the market, the The Danish R&D pilot plants have displayed the ability to produce clean fuel gas with relatively simple gas cleaning that kept the gas engines running efficiently for many hours. The workshop included presentatios from several of the member countries who spoke of the latest developments.

BMG in Scandinavian Countries

There are some extremely large biomass industrial undertakings in the Nordic countries – for example, within the paper industry. In Sweden and Finland, large biomass energy plants, using waste biomass from the primary production process, were built as an integral part of the industrial activities. This also applies to gasification plants. In Denmark, by virtue of population density and population distribution, the application of biomass energy plants are relatively small in size and capacity and limited to CHP applications.

Finland: VTT, which is Finland's national research organization, has been developing the NOVEL gasification technology. Starting in the Winter of 2005, the 7.2 MWth capacity gasifier, built in the town of Kokemäki, is undergoing shakedown for demonstartion. The fixed-bed, updraft gasifier can be designed for 1-10 MWth range and handle biomass particles of 0-50 mm size and moisture contents of upto 30%. Such variability in fuel property requirements can result in fluctuations in the quality of the gas

produced. To manage this variation in gas quality, an advanced gas cleaning system is being developed for integrated operation of the gasifier with a gas engine for CHP applications. The tar in the gas is catalytically decomposed, after which it is cooled, filtered of particles and finally the chlorides, ammonia, and alakline compounds are removed in a wet-scrubber.

The Finnish, Carbona company has 25 years' experience developing gasification plants of both the fixed-bed and fluidized bed types. Carbona observed that there will always be tar in the gasification gas and that there is definite need for the development of gas cleaning technologies. Carbona pointed out the limitations of fixed bed gasifiers which includes fuel bridging leading to formation of "tar channels," the limits to scale-up, and the challenge of gas cleaning. Consequently, Carbona chose to license the RENUGAS process from GTI, develop and commercialize the fluidized bed gasification process, and develop a gas cleaning method to handle smaller quantities but still persisting presence of tars.

Carbona's objective is to produce a clean fuel gas for power generation. The gas must be clean so that the tar can neither be "smelled or seen". The tar is removed from the hot, raw gases by catalytic decomposition. A cleaning process of this type is at present being designed for the Carbona CHP demonstration in Skive, Denmark. The Carbona fluidized bed gasification plant will initially use wood pellets. The plant will have a capacity of 5.4 MW electricity and 11.5 MW district heat, and it is being supported by the Skive municipality(?), Danish Energy Authority, and the US Department of Energy (DOE).

Denmark: Benny Gøbel of the Technical University of Denmark (DTU) spoke of the successful efforts to overcome the problems to operate the 20KWe (~100 KWth) capacity Viking (2-stage) gasifier for on-site power generation. The automated pilot demonstraion has run for a total of 2220 hours with a gas engine. The gas contains small quantities of tar and dust particles which did not present any operating problems. The gas filters have lasted for long periods and the gas engine operated continuously for many hours. The fuel is gasified efficiently that only ash with some carbon dust, and waste water is left, which can be can be disposed in existing waste treatment facilities.

The DTU together with the Danish companies Weiss and COWI are now jointly scaling-up the Viking gasifier. No problems are expected in scaling-up the plant to 1-2 MWe capacity and in achieving an electrical efficiency of over 35%. The estimated cost of the gasifier and gas engine will be comparable to that of a normal wood chip boiler plant. Questions were raised with issues related to fuel bridging and the consequent fluctuations in gas production and quality.

In 2003, the Swiss equivalent of DANIDA approached the gasification group at DTU, for collaboration with an Indian organization to develop village-gasifiers for off-grid and on-site power.The first prototype has been set-up and it is being opertaed by local man-power in an India village; the system produces electricity in the evenings.

TK Energi (TKE) worked for several years with gasification technology developers and identified the major technical problems with biomass gasifiers. Based on this experience, TKE has developed a gasifier that is simple in geometry and design and without any movable mechanical parts in the high temperature zone. The TKE pilot gasifier in Denmark has demonstrated sustained integrated operation with a gas engine for 1200 hours operation, producing a fuel gas with low-tar content. TKE has also built a 250 KWth, three-stage down-draft BMG plant in Japan. This plant design is in compliance with stringent local regulations that provide protection for typhoons and earthquakes. At this time the plant has run for 200 hours.

Switzerland : In Switzerland, the Xylowatt company developed and commissioned the open-top Indian Institute of Science gasifier at a sawmill. The demonstration plant includes a simple sand filter that had persistant operational problems. In its latest configuration the gasification system, was equipped with a cyclone, three scrubbers, a drip catcher and a bag filter. With these modifications, the gasifier has run for 2000 hours with a naturally-aspirated gas engine and for 120 hours with a new turbo-charged engine. The gasifier is fed with wood chips containing upto 25% moisture and produces 50 kWe, at an efficiency of 22%. Gas cleaning produces 14 litres of wastewater per hour.

USA: Community Power Corporation (CPC) is continuing work with small open top fixed bed gasifiers. The company has been operating a few portable small-scale gasification plants. The first prototype plant has ben operated in Philippines and the next plant was built for operation at a high school in Colorado and in a furniture factory in New Mexico. These on-site power generation plants can produce 15 kWe and is intended for stand-alone operation independent of the power grid. The CPC gasifier employs a dry gas cleaning system to avoid handling waste water.

The ITN Energy System has successfully demonstarted the operation of a solid oxide fuel cell (SOFC) on CPC fuel gas produced from coconut shells, pecan, and pine. The SOFC, which produces 2.75 W with pure hydrogen, has shown it can generate almost 2 W on biomass fuel gas.

Choice of Gas Engines

In most countries gas engines are the natural choice for use with small-scale gasifiers. Some plants work with turbo-charged engines. However, turbo engines are more expensive to run and require a more expensive gas ramp than ordinary naturally aspirated engines. This is reinforced by the fact that naturally aspirated engines can run at a higher compression and thus with a richer mixture of gasification gas than natural gas without exceeding NOx emmission limits. In addition, the naturally aspirated engines are less sensitive to variations in gas quality and the overall efficiency is comparable to that of turbo-charged engines. The picture becomes even brighter considering that the smaller gasification plants can use industrial diesel engines which can be modified to operate on biomass fuel gas. Diesel engines of up to 400 to 500 kWe are mass produced and cost a third of custom designed gas engines which at present can only be produced in small batches. This will have a dramatically positive effect on the capital cost for small gasification plants of up to 1½ or 2 MW. The one concern is the difficulty in complying

with CO emission requirements when fuel-rich mixtures are employed in gas engines. Nevertheless, recent changes in rules by the Danish EPA have eased CO requirements.

UK: The Biomass Engineering company has recently tested a 30 KWe, Capstone micro-gas turbines for 350 hours on a synthetic LCV fuel gas. These tests have shown that output falls to about half LCV fuel gas compared to natural gas, but emissions comply with current statutory requirements. The Capstone micro-turbine is extremely sensitive to fluctuations in the power grid, which are common at many locations in the UK, and moreover turbines of this size are assessed as being not profitable at this time.
At the same time, the Biomass Engineering company has developed a catalytic converter and a parallel flow gasification plant with ceramic membrane gas filtration.

The background for the small scale plant initiative in the UK is a rapidly growing interest for biomass within energy provision combined with a number of physical and administrative barriers. The driving forces are:

- Rising prices of natural gas and oil
- Government incentives for sustainable energy program (Renewables Obligation), under which about 10 p is paid for every kWh electricity produced
- Landfill directives have increased the cost of depositing wood residues
- Royal commission recommendations to provide additional grants for producing power and heat from biomass

The cost of connecting an on-site electricity generating plant to the high voltage grid is high. Plants under 250 kW can be connected to the low voltage network much more economically, thus increasing commercial interest in small plants. According to Future Energy Solutions, several gasification projects have operated for many hours. However, it is not clear how many of these include integrated engine operation. Other UK R&D initiatives include the development of ceramic membrane gas filters.

Attachment

Pictures from Denmark BMG Plants

1. The updraft gasification plant in Harboøre is currently running on the 10th year of continous operation. The gasification plant is the only to have reached a full commercial level.

2. 500 kW Low Temperature CFB gasification plant at Technical Univeristy of Denmark.

3. The Three Leading Danish BMG Technology Developers: Thomas Koch, Henrik Houmann Jacobsen, and Ulrik Henriksen.