HOT GAS CLEANUP IN BIOMASS GASIFICATION - REVIEW OF ACTIVITIES WITHIN EC SPONSORED R&D PROGRAMS

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INTRODUCTION

The use of biomass as an alternative fuel source attracts presently considerable interest in the European Community. A variety of R&D projects are currently active in investigating the prospects for biomass conversion processes in power and heat production.

Renewable energies in general are seen as one of the major options for energy supply, offering substantial advantages regarding environmental protection and CO_2 emissions. Because of their decentralize character they may also offer considerable potential in rural areas.

Within the European Commission (EC) research and technical development programs, several R&D and demonstration projects are being carried out reflecting issues in utilizing biomass or alternative solid fuels for power and heat production. Apart from being a potential environmental-friendly conversion route, the motives for introducing biomass in heat and power production is of course being able to replace the use of fossil fuels and to find alternative applications for existing agricultural areas.

One of the main technical issues is the gas cleanup process for clean gas utilizations and IGCC (Integrated Gasification Combined Cycle) concepts. Potential advantages are expected if the gas cleaning process can be accomplished at enhanced temperatures. Available options for integrated hot gas cleanup are being tested ranging from particulate removal to emission control. An overview of the ongoing projects in the area is presented in the following.

A new generation of gasifiers suitable for gasification of biomass and so called alternative solid fuels are under development. A PFB biomass gasifier test rig (Figure 2) has been installed at the Dept. of Chem. Eng. II (University of Lund). The system includes an integrated hot gas cleanup system that forms the basis for the activities at the department within two EC Joule II programs [1]. Progress from these efforts are presented and discussed.

PROSPECTS FOR BIOMASS UTILIZATION

At present about 80 % of the energy consumption within the European Union is from the use of fossil fuels. Within the power and heat production, some 40 % of the production is produced from coal utilization. These production systems have often modest efficiency and contribute to a large extent to the global emissions of nitrogen oxides, sulfur oxide, carbon oxide, and particulate matter [2]. Until today natural gas and fossil fuels have been regarded as the most economic and appropriate fuel for heat and power production where biofuels (biomass, agro- and forestry residues) may be believed to be the more environmental friendly alternative in the long run.

In many regions of Europe there is a steady and continuous production of biomass residues. The growing of biomass for energy production, combined with the utilization of agricultural and forestry residues, is an alternative energy resource in many areas that today is likely to be not too far from a commercial status. One driving force for this development is the tax structure including the exclusion of biomass from recently imposed CO_2 tax on fossil fuels. In some regions farmers may even be

encouraged to grow energy crops on land that during the last years has been taken out of production to balance the farming industry.

To meet the environmental challenges, improved technologies are needed. The current technologies involve combined cycle concepts where improved performances are needed. Novel solutions and continuous developments of integrated systems offer encouraging prospects for enhanced efficiency and more economical power generation. The improvements also have to involve fuel flexible systems accepting a broad variety of different solid fuels. Since the awareness of potential environmental-friendly alternatives has increased and the restrictions with respect to emissions has been reinforced, the interest for utilizing renewable fuels in heat and power production has correspondingly grown. With IGCC technology and renewable energy sources it is possible to get a both ecological acceptable and a highly efficient concept for heat and power production.

INTEGRATED HOT GAS CLEANING FOR IGCC PROCESSES

For a successful implementation of biomass gasification in commercial fuel gas production, the effluent gas must conform to allowable limits regarding particulate and other impurities. For IGCC applications there are potential advantages with gas cleanup at high temperatures and elevated pressures.

The fuel gas from gasification processes contains various amounts of impurities and particulate originating from the solid fuel and attrition products from the bed material. Advanced filtration technology today partially offers solutions to some of these problems. Especially the integration of these systems in larger scales has to be surveyed more carefully.

Hot gas cleaning also imply chemical manipulations of the product gas to meet environmental as well as technical standards. High molecular weight products, tars, and other components like alkali trace elements may cause in the condensed phase severe operational problems. These have to be removed before the gas product can qualify as fuel for gas engine or gas turbine purposes.

Within the so called JOULE II NON-NUCLEAR ENERGIES research framework several multi-partner projects have been drawn together embracing technical programs from a variety of R&D organizations, including industrial partners, from the current member states of the European Community. An unique opportunity is hereby given to establish expert networks designed to address key technical issues. Some of the networks are dealing with issues connected with particulate removal and emission control. A presentation of three projects working with biomass related hot gas cleanup is given below.

Current research projects in the EC Joule II Non-Nuclear Energy Program

- INTEGRATED HOT FUEL GAS CLEANING FOR ADVANCED COMBINED CYCLE PURPOSES (JOU2/CT93/0431) is a sub-project incorporated in a vast EC program project called CLEAN COAL TECHNOLOGY R&D. As the name implies, the project essentially deals with topics reflecting coal gasification and combustion. Likewise the sub-project is aimed to cover integrated gas cleanup issues in coal related advanced gasification systems. However, the need for fuel flexibility for such systems has been recognized and alternative solid fuels are considered and included in the studies.

The project organization and work, as for most EC project programs, is based on a close scientific and technical co-operation between the project partners organized in groups based on scientific areas. A typical project structure is shown in Figure 1. This project is one of the bigger projects within the Joule II program and the activities comprise a broad range of research tasks within hot gas cleaning. From techno-economic modeling studies via cycle control studies to fundamental and applied emission control investigations, the project has a total budget of close to 8 million ECU, an equivalent of 6 million USD. The grant from the European Commission is here about 3.5 million USD. The project is co-ordinated by CRE (Coal Research Establishment) in England.

- COMPARISONS OF ENTRAINED PHASE AND FLUIDIZED BED GASIFICATION OF BIOMASS WITH RESPECT

TO PROBLEMS RELATED TO FEEDING AND HOT GAS CLEANING (JOU2/CT93/0347) is another Joule II project focusing on integrated gas cleanup for advanced gasification systems. The project work is a co-operation between Coal Research Establishment (CRE) in the UK, Deutsche Montan Technologie (DMT) in Germany, and LIT in Sweden. The objective with the project is to collect end-user-oriented information for process development in advanced thermochemical conversion of biomass. Integrated pressurized hot gas cleansing units at DMT and LIT have been provided with different filters (filter types; materials) to find the most suitable filtering system for biomass gasification purposes. The project is co-ordinated by DMT and has a total budget of 1 million ECU (750.000 USD).

- ADVANCED AND INTEGRATED BIOMASS GASIFICATION WITH HOT AND CATALYTIC FLUE GAS CLEANING FOR ELECTRICITY PRODUCTION AND OTHER END PRODUCTS (JOU2/CT93/0399) is a project coordinated by the University of Madrid (Spain) dealing with catalytic reforming and optimization of the gas product. Specific focus is put upon catalytic methane steam reforming, hydrocracking, and the use of water-gas shift catalysis. Together with Danish Technical Institute (DTI) in Denmark cereal straw is converted in a fluidized bed gasifier with a down stream catalytic reformer. The total budget for a 36 months work period is 300.000 ECU (225.000 USD).

The above mentioned project are being carried out during 1994-96. Periodically, technical meetings as well as progress meetings are held through out the course of the projects to monitor and to assess the project progress. Apart from the Joule II program other EC sponsored research programs as well as various national research programs are undertaken within the individual countries in the European Community.

Project work at Lund Institute of Technology (LIT)

LIT takes part in two of the above mentioned projects with studies investigating the influence of different bed materials, the effect from biomass ash on the bed behavior in PCFB gasification of biomass, and hot gas particulate removal. The distribution of alkali species in the gasification products is additionally studied including an assessment for their reduction or removal [3].

Vapor-phase alkali metals (Na, K) may form condensed compounds in the temperature interval 400-550 °C. These alkali compounds are capable of drastically enhance hot corrosion on metallic surfaces in the process system, cementing deposited particulate, and support agglomeration tendencies of the bed material in a fluidized bed gasifier. Enhanced tendency for agglomerations in the bed, due to sticky layers of alkali condensations on the particle surfaces, has been found in systems utilizing biomass.

Specifically of interest is to what extent the alkali compounds in the fuel are converted into the gas phase and how to reduce the alkali concentration. At equibrillium the alkali content in the gas phase is strongly influenced by the temperature as well as by the pressure. At increasing pressures in the system the alkali content in the gas phase is reduced largely due to condensation mechanisms. The temperature in certain parts of the conversion system must be kept high enough to suppress such condensation mechanisms. Consequently, to reach efficient reduction this suggests that gas phase alkali capture must take place at temperatures above 600 °C that put distinct requirements on adequate on-line monitoring.

At LIT sorbents for hot gas alkali removal are studied and the efficiency of these sorbents are being evaluated. Routine on-line methods for monitoring alkali components directly in the hot gas phase are very scarcely reported in the literature. Current alkali measurements techniques are mainly based on batch sampling and laser spectroscopy, methods that both are being tested and evaluated within the Joule II program.

An instrument for plasma assisted alkali monitoring in the gas phase, developed by the University of Tampere (Finland), will be tested with the test rig at LIT. The method is based on optical spectroscopy of alkali metals heated by a thermal plasma at process temperature.

In addition, another novel device for on-line measuring of alkali metals in the gas phase will be used at LIT. The device and method, developed by Chalmers Technical University in Gothenburg

(Sweden), is suitable for determinations of trace alkali components in hot fuel gas. The technique is based on surface ionization of the alkali components and has been tested with pure alkali sources as well as with different biofuel with very encouraging results. Alkali concentrations in the range of 0.1 ppb to well above 1 ppm have been detected and measured. A setup was designed and constructed for the LIT test rig and preparation for measurement campaigns is presently in progress.

As a second main part of the EC project work at LIT, hot gas particulate removal is being studied in the LIT gasification test rig. The primary solid phase separation step is achieved by an internal axial cyclone that has shown a separation efficiency between 96-98% on a solid/gas phase ratio basis. A secondary step is performed by means of a single SiC-based candle filter with effluent gas dust concentration lower than 10 mg/Nm^3. However, the operational time on the candle filter has so far been short to make adequate predictions regarding the suitability in biomass gasification.

Comparable filter test are additionally being carried out together with DMT in Germany where metallic filter are tested and evaluated for biomass gasification purposes. Advanced ceramic candle filters offer promising solutions and have good filtration efficiency but integrated in biomass gasification specific issues have to be covered before the technology can be fully accepted for biofuel based IGCC applications.

CONCLUSIONS

A growing interest in utilizing biomass and other so called alternative solid fuels is today seen among various countries in the European Community. Alternative solid fuels as a domestic resource for energy production is important not only for the energy supply but also for the potential benefits regarding the environment and rural and regional development[4].

Key issues in implementing the technology associated with sustainable biomass utilization for both power and heat production have been identified and are emphasized in different R&D programs sponsored by the European Commission. An important area is the integration of gas cleaning systems for IGCC and similar applications.

Dept. of Chem. Eng. II at LIT is involved in two so called Joule II research projects studying hot gas particulate removal and alkali reduction. In these studies particular interest is in hot gas solid phase separation including filtering systems suitable for biomass gasification processes. Additionally, research efforts have been made in investigating the effects from fuel alkali in the fluidized bed gasification process and studies including an assessment for the reduction or removal of alkali components in the gas phase. So far the preliminary results indicate that most of the alkali in the LIT test rig is adsorbed on the surface of the ash collected in the filter unit. Two individually developed systems for monitoring alkali species in hot fuel gas will be tested and evaluated.

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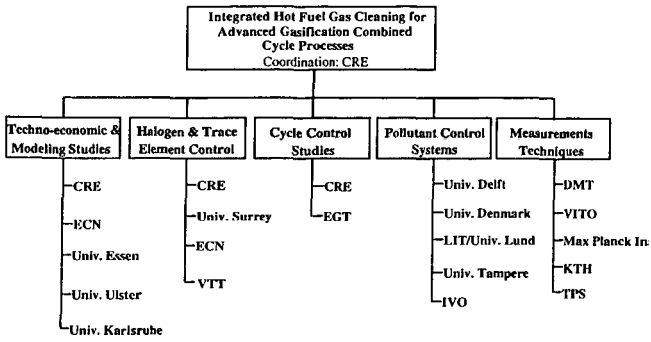

Figure 1. Project organization and activities

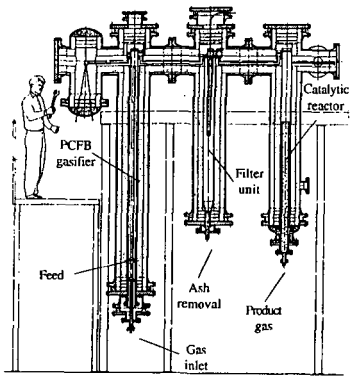

Figure 2. The PCFB biomass gasification test rig at LIT