APPLIKATIONS- UND TECHNIKZENTRUM

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DECENTRALIZED BIOMASS POWER PLANT BASED ON PEBBLE-HEATER TECHNOLOGY AND HOT AIR TURBINE (SiPeb®)

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ABSTRACT: The principle objective of the proposed concept is to develop a cheap biomass CHP plant for small capacities (less than 5 MW_e). It would enable a decentralised usage of biomass, by locating small units directly at places where biomass originates. To lower the specific investment costs, just proven, cheap and/or standardised components has to be used, like: biomass combustor, radial gas-turbine and Pebble-Heaters with radial fluid flow (regenerative heat exchangers). Those components are arranged in a gas cycle with indirect combustion. The main novelty comparing to some previous projects dealing with the same cycle lies in the heat exchanger: instead of a recuperator here is proposed to use a new developed regenerator, the so-called Pebble-Heater with radial flow. That will result in the power generation efficiency in the range of 30% (depending on the required heat output and fuel quality). That concept is suitable for the electricity production from the high quality wood, as well as from low quality biomass (high water content, high ash content) of different origins. The first results from the erected test facility have shown, as foreseen, that dust and alkali can be removed very effectively inside the Pebble-Heaters, causing no problems for the gas turbine operation.

Keywords: biomass conversion, de-centralised energy generation, combined heat and power generation (CHP)

1 INTRODUCTION

Very few biomass power plants are really competitive to the classical power plants. There are two main obstacles for a higher competitiveness:

- specific investment costs
- expenditure for the logistics of biomass collection and transportation.

In fact, those two are reversely connected: by decreasing the plant capacity the cost of logistics decrease, but the specific investment costs increase and vice versa. Thus, the most successful biomass power plants are usually located near a big wood industry. The large amount of waste wood is locally available, so that it is possible to realize a high plant capacity without any additional logistics problems. However, such locations are more or less exhausted. Just with such leftover locations it is surely not possible to achieve the targets posed in the EU and worldwide.

For new biomass projects it is necessary to overcome the two obstacles mentioned. The principal objective is to develop a low cost (low specific investment) biomass power plant for small capacities. Such a facility has to have low operation costs, but at the same time a high power to heat ratio and a high thermal efficiency of power production, with the aim of reaching a good economic efficiency. For small plants those goals cannot be achieved with classical technology based on steam cycles. The efficiency of such plants is low at small capacities, so that they cannot be economic.

This paper deals with an innovative biomass power plant [1] based on Pebble-Heater technology and hot air turbine, suitable especially for small capacities (e.g. 100 kW_e – 5 MW_e). Such a facility should enable an economical exploitation of locally available biomass, without a need for expensive collection and transportation logistics.

By using cheap and proven components such as

- Pebble-Heaters as regenerative heat exchangers
- gas turbine in radial design for low pressures and temperatures (e.g. 4 bar, 850°C), and
- classical biomass combustor,

connected in an indirectly fired gas cycle, it would be possible not only to achieve low investment costs, but also a high efficiency of power production (approx. 30%). It would enable the economical operation of a plant located directly at the place where the biomass originates (smaller forest regions, wood industry, fast rotation crops, agricultural waste, food industry waste etc.).

ATZ-EVUS (know-how carrier of the Pebble-Heater technology and proposer of this innovative cycle) and SIEMENS (licensee of this new technology with the registered name SiPeb®) have made a partnership in order to investigate remained technical questions and to accelerate the market penetration of this innovative technology.

2 COMPONENTS OF THE INNOVATIVE BIOMASS PLANT

The main novelty compared to some previous projects dealing with a similar cycle lies in the heat exchanger. Instead of a recuperator, it is proposed to use a newly developed regenerator, the so-called Pebble-Heater with radial fluid flow [2], shown in *Figure 1*. The main obstacle to the use of a recuperator were the too high investment costs for a high temperature device. Moreover, biomass combustion gases always contain more or less dust alkali and tar residues (due to the non-homogeneous temperature field). Their deposition in the tubes of a recuperator drastically decrease their efficiency. Due to the required regular cleaning campaigns, the maintenance costs are very high, while the plant operation has to be interrupted.

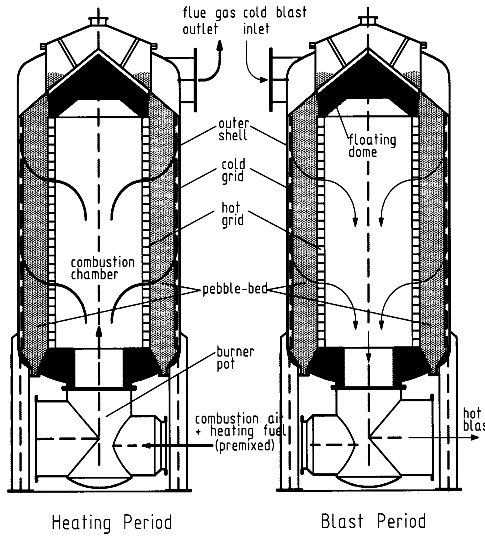


Figure 1: Pebble-Heater with radial fluid flow

Beside lower investment costs (bulk material is used as a heat storage mass), this new type of Pebble-Heater enables higher temperatures (800°C – 1,000°C) without any additional costs. The most important advantage of the new Pebble-Heater technology is its very high recuperation efficiency. For the proposed biomass plant it is expected to reach the recuperation efficiency of 95%. In some other applications of the Pebble-Heater technology, extremely high values of up to 98% have been measured [3]. Another important advantage of the Pebble-Heater is that bulk material (i.e. heat storage mass) may be taken out easily and cleaned if necessary. Partial recirculation and cleaning may be done pneumatically (with conveying air) even without interrupting the plant operation.

Figure 2: Basic flow-sheet of the innovative biomass CHP plant

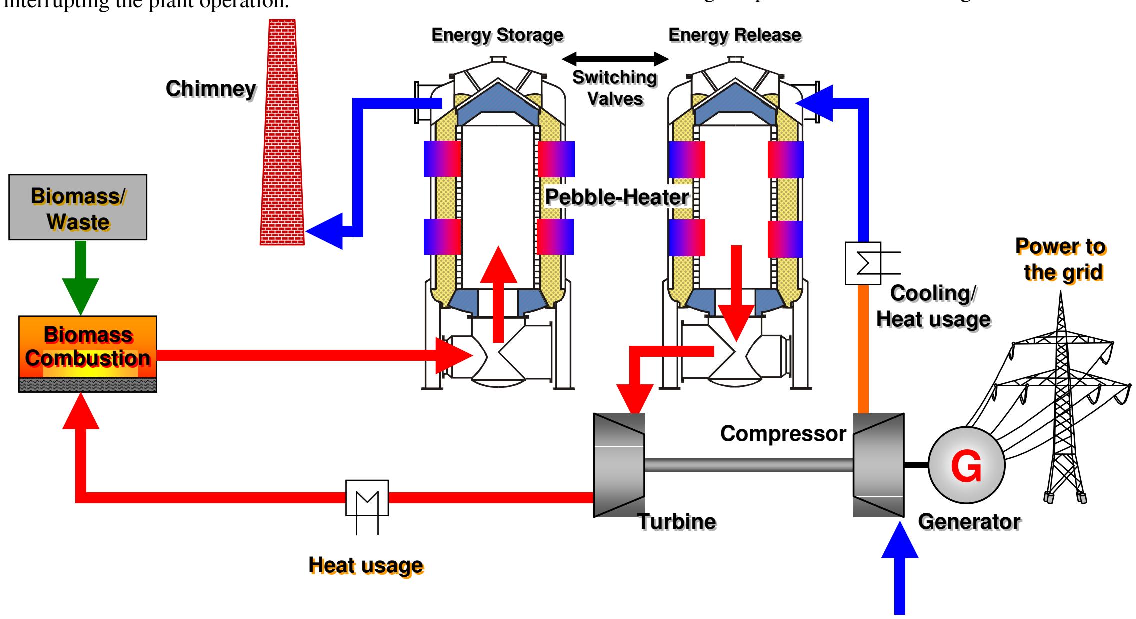
The best solution for optimal operational conditions of the proposed cycle is to use gas turbine sets in radial design. They are very robust, with low sensitivity towards dust and other impurities. There is no need for fine and cooled blades, as it is the case with modern gas turbines for high operational parameters. As a result, they are very robust with low maintenance required. The thermal efficiency in an open non-recuperated cycle is pretty low, usually less than 16%. Due to the very high recuperation efficiency of the Pebble-Heater and the usage of the turbine outlet air as preheated combustion air, the plant efficiency of power production is over 30%.

For the proposed cycle a more or less standard biomass combustor may be used. The only big difference to the common designs lies in a much higher air factor, which in this case is between 6 and 8 (depending on the type of biomass and the required output temperature). It is planned to first have a more or less common combustion process (with air factor 1.5 – 3) at elevated temperature, and afterwards to mix the combustion gases with the rest of the preheated air. That way the outlet temperature may be controlled (to avoid sintering of fly ash, as well as to control the amount of alkali aerosols). Moreover, all impurities (dust, aerosols, tars) will be diluted by a factor of two to four compared to the common biomass combustion.

3 DESCRIPTION OF THE PLANT LAYOUT

All the main components are well known, with proven reliability, robustness and low maintenance requirements. They are arranged in a gas cycle with indirect combustion, as presented in *Figure 2*.

The ambient air (15°C) is first compressed to 4.50 bar in a compressor driven by a gas turbine. Due to compression its temperature rises to 200°C. In an after-cooler it is cooled down to 90°C in a recuperative heat exchanger. The available heat may be used for a heat consumer, e.g. as hot water or low temperature steam. Decreasing temperature before entering the first Pebble-



Heater (PH1) is important for lowering the stack losses. Lower input temperature at PH1 enables lower outlet temperature at PH2.

After the cooler, the compressed air enters the first Pebble-Heater, where it is heated to 830°C. With that temperature the hot air enters the gas turbine, where it is expanded to almost ambient pressure (1.03 bar) and to a temperature of 540°C. The released expansion work is used for compressor and generator drive.

The most part of the expanded air is used as preheated combustion air for the biomass combustor. The rest may be used for another heat consumer, at a higher temperature level. As it is pure air, it may very well be used for drying processes, even in the food industry. Of course it may be used for drying the input biomass fuel, thus increasing the efficiency of the power production.

Biomass is fueled into the combustion chamber and burnt with preheated combustion air (from the gas turbine exhaust). Due to a high air factor, combustion gases have a relatively low temperature of 870°C. That prevents the sintering of flying ash. Depending on the kind of biomass and on its ash characteristics, that temperature may be further decreased (or increased as well). Depending on the ash content, it may be necessary to include a hot gas cleaning system (e.g. a hot gas cyclone or a filter bed) before entering the Pebble-Heater from the hot side (the so-called hot grid), where there is a homogeneous temperature field (870°C). If there are still some tar particles in the gas stream, they will at least be extracted there and certainly burnt. The combustion gases are cooled down to 100°C and exhausted through the stack. This temperature may be controlled (e.g. by the cooled compressed air temperature at PH1 inlet) and adjusted to the type of biomass used, i.e. to the actual sulfur and moisture content, in order to avoid cold-end corrosion.

The cycle with such parameters will result in an electric efficiency above 30%. In case the heat from the air after-cooler and from the hot air at the turbine outlet may be used, the total efficiency of the CHP plant will be about 71%.

It is clear that a high efficiency of power production is an outstanding characteristic for such small units. The power to heat ratio is also very high, above 80%, which is important for a better economy of the plant. The thermodynamical background for such good performances is given in [4].

4 TEST FACILITY

A joint test facility built by ATZ-EVUS and SIEMENS (see *Figure 3*) is in operation since October 2001. The main components are a biomass combustor (440 kW_{th}) and a Pebble-Heater (1.200m^3_{STP}/h) heated directly by combustion gases. On that way it was possible to investigate:

- dust separation in the pebble-bed
- separation of aerosols
- cleaning the pebble-bed during the operation
- control of pressure drop through the bed
- dust concentration in the hot air for the turbine drive.

Figure 3: Test facility in Sulzbach-Rosenberg

The achieved results are very promising so that after some small improvements the first industrial facility will be built. In fact, even during the test, the dust deposition in the pebble-bed was managed very well.

5 FURTHER STEPS

The commercial facility is offered by SIEMENS under the trade name SiPeb®. In the first phase a gas turbine with an output of 2,2 MW_e is available. *Figure 4* shows a 3D view of such facility. By integrating an ORC or steam cycle, it is possible to achieve capacities up to 5 MW_e. Later on some other gas turbines will be developed, in order to achieve a wider range of capacities.

ATZ-EVUS has the intention to continue the development of this technology towards less than 500 kW_e. The usage of micro-turbines, which have to be slightly adapted, is planned. The aim is to achieve low specific costs through the serial production of standardized components.

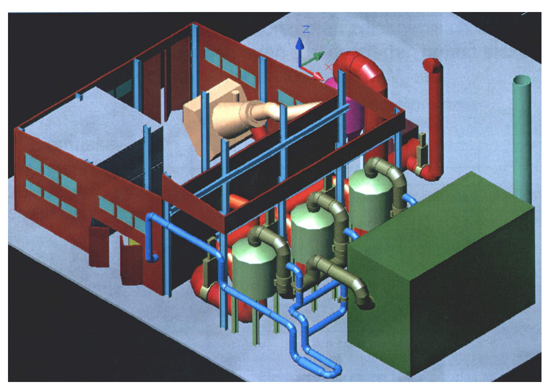


Figure 4: 3-D View of the biomass CHP plant of 2 MWe (SiPeb®)

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