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Research paper

Development of a new micro CHP pellet stove technology

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ABSTRACT

BIOS and RIKA developed within the ERA-NET-project "Small-scale BM based CHP" a new micro CHP technology based on a wood pellet stove (thermal capacity 10.5 kW) with a thermoelectric generator (TEG), that enables the operation of the stove without electric grid connection. Thereby, the wear- and maintenance-free and also noiseless TEG system is cooled by a water circuit which makes it possible to supply an additional room with heat. To achieve a self-sustaining operation of the pellet stove a TEG with an electric power of up to 50 W was installed into the casing of the pellet stove and the electricity consumption has been reduced significantly by an optimization of the control system and the selection of appropriate low voltage components. Based on transient system calculations and CFD simulations as well as test runs with two testing plants the system has been optimized. To demonstrate the practical suitability of the new technology in real life, 8 h load cycle tests were carried out. At these tests overall efficiencies up to 92.6% were achieved and in addition to the coverage of the own electricity consumption of the stove, 50 W h surplus electricity were produced which can be used to charge mobile phones or other small consumers.

1. Introduction and objectives

Biomass based room heating systems are very common for space heating throughout Europe. In Austria, biomass stoves represent about 50% of the total number of installed single room heaters [1]. In the recent 15 years pellet stoves became more and more popular due to their advantages regarding automatic control, user friendliness (automated ignition, easy and clean fuel handling) and their low emissions in comparison to logwood stoves. The current market for pellet stoves in Europe is in the range of 200,000 units per year whereby the markets with the highest volumes are Italy and France [2–4]. However, the need of an external electric power supply to provide electricity for the start-up and operation is a disadvantage of pellet stoves especially with regard to fail-proof and independent heating systems. Thus, new and innovative solutions to overcome this deficiency of pellet stoves are required to further support room heating technologies with high efficiencies and low emissions.

The implementation of TEG systems in logwood stoves has already been successfully realised [5,6]. In order to enable the operation of an automatically controlled pellet stove without electric grid connection, a new micro CHP technology based on a wood pellet stove with a thermoelectric generator (TEG) and appropriate power electronics was developed. A TEG consists of several thermoelectric modules (TEM) connected in series. In this paper TEM refers to the single TEM unit, while TEG refers to the electricity generating system. The work was done in close cooperation of BIOS and RIKA within the ERA-NET-project "Small-scale BM based CHP", funded by the Austrian Climate and Energy Fund.

RIKA has worked in former projects on the development of a TEG to cover the own-electricity consumption of a pellet stove [7]. Thereby, the general applicability of the TEG technology for stoves was proven and a pre-selection of suitable TEMs took place. However, several key-issues remained unsolved:

- Number of TEMs needed to guarantee a sufficient power production
- Positioning of the TEMs to get high and homogenous hot side temperatures as constant temperature differences between the hot and the cold side at all TEMs implemented increase the achievable electricity output of the system
- Selection of an appropriate cooling system for the TEG as the cold side temperature of the TEM has a considerable impact on the electric efficiency
- Design of the pellet stove to guarantee a complete burnout of the flue gas before it is cooled by the TEG in order to minimise deposit formation on the surface of the TEMs (deposits hamper the heat transfer and thus reduce the temperature difference between hot and cold side)
- Development of appropriate power electronics for the TEG system

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- Optimization of the power consumption of the pellet stove
- Minimum additional costs for the TEG integration in order to make the grid independent system economically interesting

The goal of the project was to address the issues listed above and to develop the new technology towards commercialisation. Within this paper the new pellet stove technology with TEG is described and an overview regarding the development and optimization of the new technology and the results achieved is given.

2. Methodology

In order to ensure an efficient and target oriented development during the project, the following methodological approach was chosen.

2.1. Technical approach

The new CHP technology is based on an automatically controlled pellet stove with a thermal capacity of 10.5 kW which is coupled with a TEG and equipped with appropriate power electronics. The cooling of the TEG is done by a cooling device for the TEG which supplies thermal power to room heaters. Additionally, an accumulator and appropriate power electronics are considered for the new technology (see Fig. 1).

During operation of the pellet stove the TEG supplies the stove with electricity. Surplus electricity is stored in an accumulator. The accumulator supplies electricity during the next start-up for the ignition and other power consumers (fan, fuel feeding, and control system) until the TEG starts the electricity production.

Thermoelectric generators enable a maintenance-free and silent electric power generation from heat. Thus, this technology is particularly suitable to realise a grid-independent operation of stoves, which are usually installed in residential areas (e.g. for heating of the living room). The principle of the TEG is based on the Seebeck effect, in which heat is directly converted into electricity by two connected and differently doped semiconductors placed at different temperatures (Fig. 2).

The electric output of the TEMs and thus the TEG is influenced by the type of the TEM, the number of TEMs used, the temperature difference between the cold and hot side of the TEMs/TEG (with rising temperature difference the electric output is increasing) and the TEM/TEG cold side temperature (with rising cold side temperature the efficiency is decreasing). Thus, a high temperature difference between the cold and hot side combined with a low cold side temperature of the TEMs/TEG is the aim in order to achieve a high electric output of the TEG. In Fig. 3 a cross section of the new pellet stove micro CHP technology shows the position of the TEG in the flue gas path. It is located

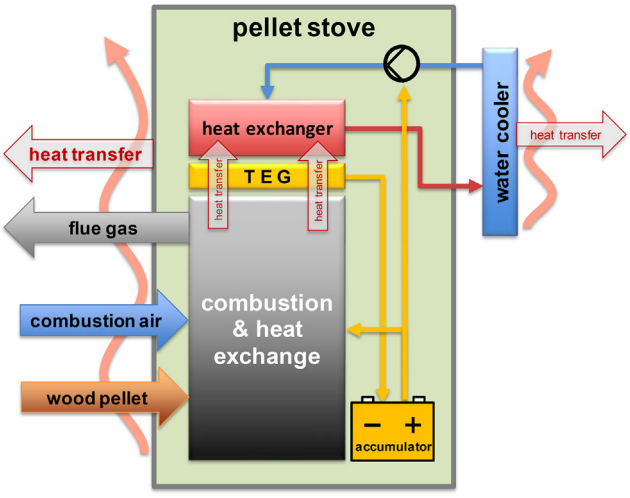

Fig. 1. General approach of the new pellet stove micro CHP technology.

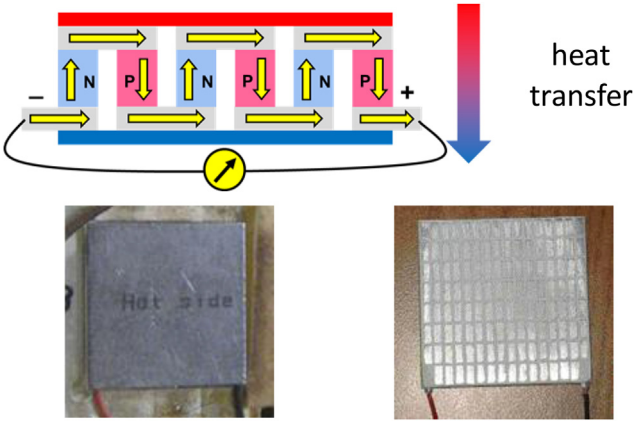

Fig. 2. General structure of a TEM (top) and photographs of the TEM with and without ceramic substrate (N … n-doped semiconductor; P … p-doped semiconductor).

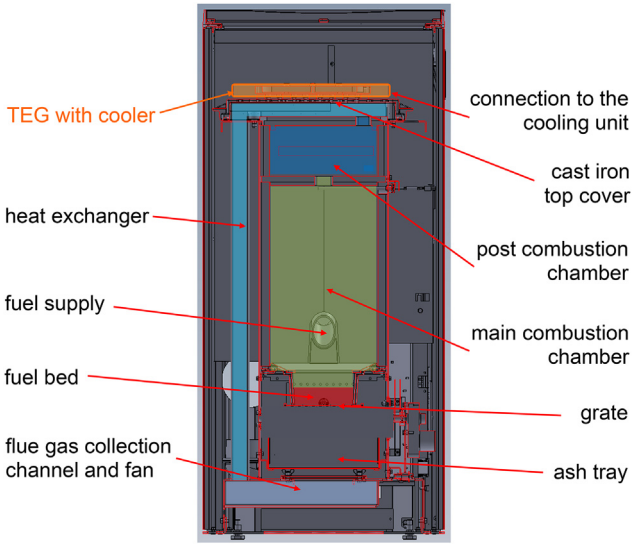

Fig. 3. Cross section of the new pellet stove CHP technology.

downstream the post combustion chamber where the flue gas temperatures are high and flue gas burn-out is already completed.

The electricity produced is stored in the accumulator for the next start-up of the pellet stove. The surplus electricity produced, when the accumulator is fully charged, can be used to charge external devices via USB port implemented in the new power electronics.

2.2. Transient system calculations

For the definition of the number of TEMs needed to provide electricity sufficient for the operation of the pellet stove and to evaluate different cooling options for the TEG system, transient system calculations were performed based on an in-house developed Microsoft Excel™ spread sheet considering the heat-up, stable operation, load changes and cooldown phases of the system. These calculations enabled a realistic overall dynamic system modelling based on the given boundary conditions regarding pellet stove operation, TEG and ambient. Thereby, different cooling options such as air cooling (II), heat storage (I) and cooling with a water circuit (III) were modelled and evaluated (see Fig. 4).

2.3. Selection of appropriate system components

As a first step towards a self-sustaining operation, the own