Electrostatic Precipitation in Small Scaled Biomass Boilers

Development of an Electrostatic Precipitator (ESP)

Funding Program
Biomass energy use

Project Frame

Since in Germany in 2010 a new regulation, which limits the maximum dust emission values for biomass boilers, was introduced, a huge demand for new secondary dust emission reduction measures was created. The IZES gGmbH works on the topic of electrostatic precipitation since 2007. In collaboration with the boiler manufacturer Hoval from Liechtenstein, an ESP prototype was developed. This ESP currently gets tested and further developed within the frame of a research and development project.

Approach

The aim of the project is to develop an economically feasible and commercially-ready product that can either be fully integrated or attached to small and medium biomass combustion systems. Fig. 1 pictures the possible and already realised installation types of the ESP.

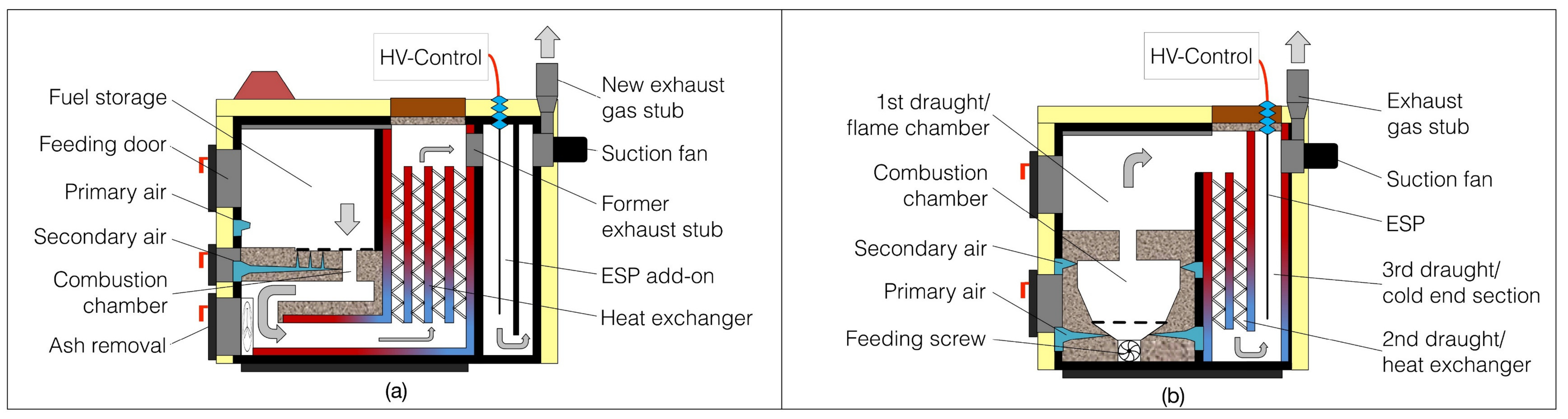

Fig.1: The attached solution (a) can be installed at the back of the boiler, between the suction fan and the exhaust gas stub or in the chimney. The integrated solution (b) directly gets installed in the cold end section of the boiler, but only if enough space is available.

Both solutions make the ESP an inseparable part of the boiler. This unique development feature also results in high requirements for the ESP components, since they have to be able to withstand the high temperatures and the rough conditions inside this early stage of the exhaust gas system.

Current ESP system

The ESP can be provided in three different sizes, dependent on the nominal heat output of the boiler: 50 kW_{th}, 100 kW_{th} and 300 kW_{th}. The ESP mainly consists of two components: The precipitation unit, which contains the discharge and the collecting electrode, the ash removal system and the insulators. The precipitation box provides up to 8 stubs to either install the chimney or the suction fan. The second part is represented by the high voltage supply- and control-unit, which gets installed at the covering of the precipitation box. The control unit contains all necessary ESP-management components, such as the HV-cascade, the control algorithm and the long-distance communication module, with which the operating status can be observed.

Fig.3: ESP for < 50kW_{th} boilers

The ESP is currently tested in up to 16 different test facilities. The test systems differ in the fuel type used, the nominal heat output, the feeding system and the installation type of the ESP. The operation of the test systems should evaluate the ESP performance. Therefore they can be equipped with special measurement devices in order to measure the dust concentration, CO-content and the electrical characteristics of the ESP.

Fig.3: Selected test sites (from top left): Pellet boiler with the large ESP, Woodchip boiler with the directly integrated ESP and logwood boiler with the small ESP

Recent Results

Standard fuel test results

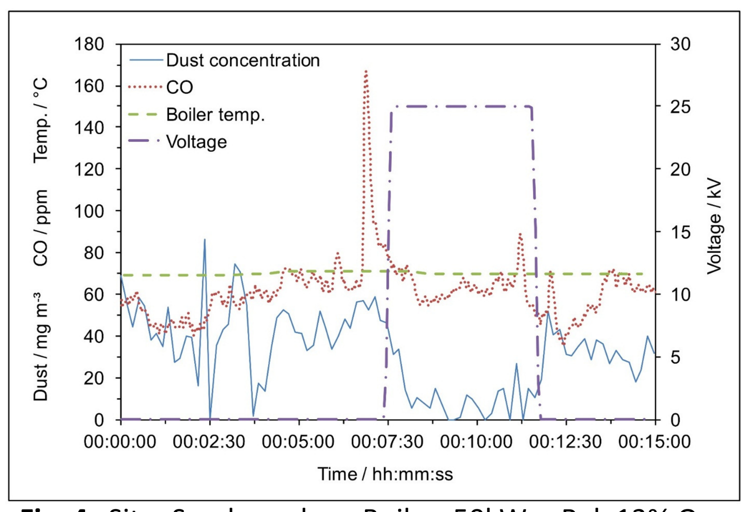

Fig. 4: Site: Saarbruecken; Boiler: 50kW_{th}; Rel. 13% O_2; Fuel: Logwood f<20%; Device: Afriso STM 225

The development of the ESP basically is carried out by using a modular and cyclic optimization methodology. The developed components are applied to field test systems and operated. The results are evaluated and the further steps are defined and tested again. Fig. 4 shows an example of a test at a 50 kW_{th} logwood boiler. As soon as the ESP is set on (indicated by the voltage), the dust concentration is decreased strongly.

Alternative fuel test results

But next to standard wooden fuels, the ESP should also be able to process dust emissions from the combustion of alternative fuels. Fig. 5 shows results from a test where cotton briquettes (5c) were burned. The ESP was able to process the dust emissions since they were lowered to approx. 25 mg/m³ when the ESP was set on (5a). The boiler was not able to completely burn down this high ash content fuel, as the grate was found to be clogged after the combustion (5b). Fig. 6 shows another example of a test of the ESP by using alternative fuels. A pomace-miscanthus mixture (6b) was pressed as briquettes (6d) and burned in the logwood boiler. Again the ESP was able to lower the dust emissions very effectively. A minimum of approx. 12 mg/m³ was reached (6a). The varying voltage height results from the regulation algorithm of the control unit, as it adjusts the voltage to an optimal value, considering the actual combustion state. Fig. 6 shows a slagged grate (6c), what indicates a too high combustion temperature as the ash sintering point of the fuel was exceeded.

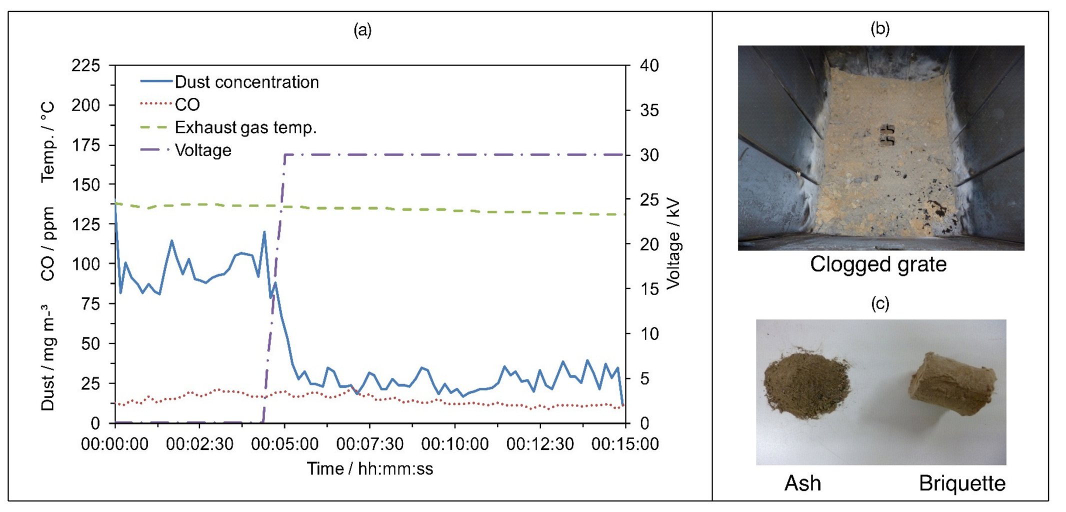

Fig. 5: 15 minute test with alternative fuels. Site: Saarbruecken; Boiler: 50kW_{th}; Rel. 13% O_2; Fuel: Cotton briquettes f<10%; Device: Wöhler SM 500

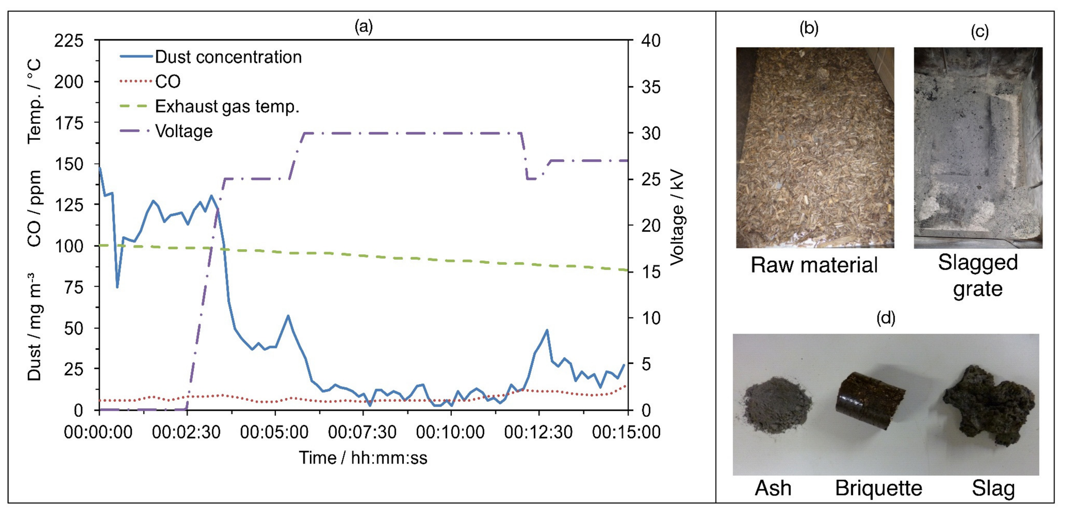

Fig. 6: 15 minute test with alternative fuels. Site: Saarbruecken; Boiler: 50kW_{th}; Rel. 13% O_2; Fuel: Pomace/Miscanthus f<10%; Device: Wöhler SM 500

Overall performance

Fig. 7 and 8 show a summary of selected test results for two test sites during winter 2015/16. The used pellet boiler was intentionally operated with bad combustion conditions in order to increase the dust emissions onto a usable height. The current ESP shows an overall precipitation efficiency of around 80%. Although the dust emission rates can be lowered to an acceptable minimum, the ESP performance has to be increased during future development steps.

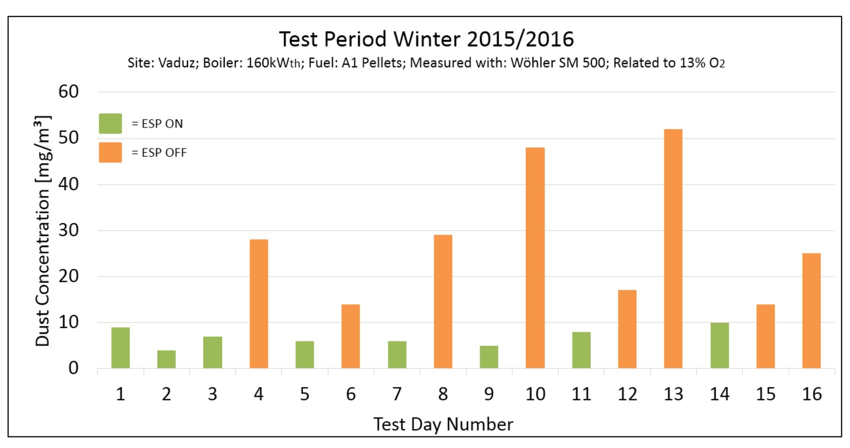

Fig.7: Summary of results for site „Vaduz", Winter 2015/2016

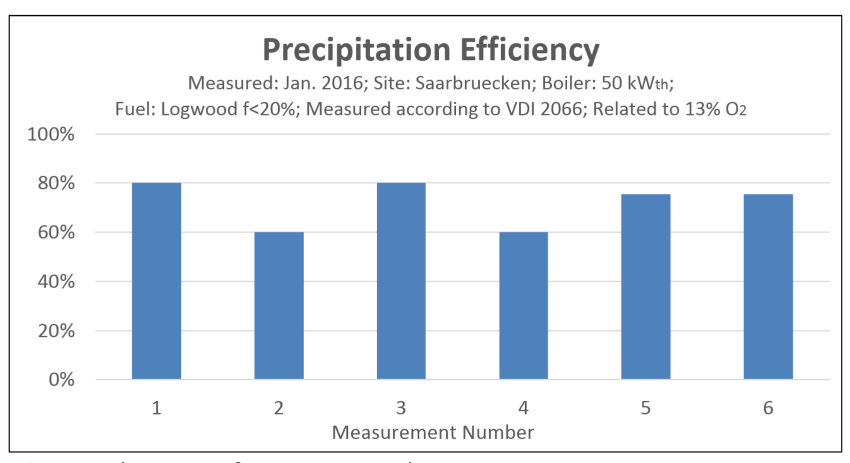

Fig.8: Selection of gravimetrical tests in January 2016

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Alexander Berhardt[1]

---Poster Summary---

Introduction and Background

The poster describes the gained results and experiences from the field development of a small scaled electrostatic precipitator. Electrostatic precipitators are widely used in the industrial sector to clean the exhaust gas of power plants since decades, but recently the application for small scaled combustion systems also became interesting. Electrostatic precipitators work with the principle of electrostatic forces between two oppositely charged electrodes. The particles first are charged, then transported through an electric field to the collecting electrode and then they are deposited and removed (Fig. 1).

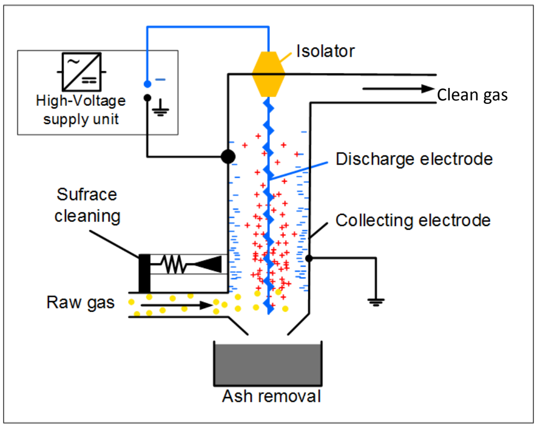

Fig. 1: Scheme of a pipe-type ESP and working principle

With the introduction of the revised German fine dust regulation (1st BImSchV) at the 22nd of March 2010, stricter requirements for the fine dust emissions of solid fuel combustion systems with a maximum nominal heat output of 1 MW_{th} were introduced. Especially biomass combustion systems, such as single room combustors, furnaces, fireplaces, stoves and boilers were predicted to have huge differences in keeping these limits. There are two possibilities to reduce the dust emissions of a combustion system: Either the combustion process and the system are optimized, what will be a primary measure, or a secondary emission reduction measure is applied. Therefore the presented work aimed the development of a secondary emission reduction system, in order to reduce the fine dust emissions and to be able to continue the operation of biomass combustors. The aimed scope of application of the presented electrostatic precipitator was defined for biomass boiler systems with a maximum nominal heat output of 150kW_{th}. Since the 1st January 2015 the stricter legal limits came into force, which is why the after this date newly installed biomass boilers, have to be able to meet these stricter limits. Especially concerning the legal limit for fine dust emissions, which allows just 20 mg/m^3 in the exhaust gas of the boiler, this aim is very ambitious and difficult to reach for some boiler systems. State of the art woodchip and logwood boiler systems for example, generally show higher dust emission rates in practice. Pellet boiler systems have a much better dust emission rate, but during their real-life practical usage, the legal limits also can be exceeded.

Direct integrated solution

The application of the ESP only for boiler systems and not for single room combustors was chosen, because with this application scope a possibility, which makes the development unique and new, could be reached.

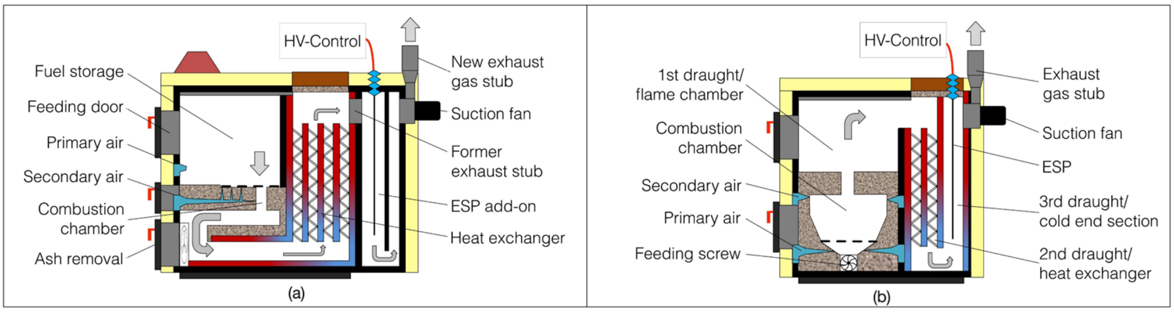

Fig.2: The attached solution (a) can be installed at the back of the boiler, between the suction fan and the exhaust gas stub or in the chimney. The integrated solution (b) directly gets installed in the cold end section of the boiler, but only if enough space is available.

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Compared to all other existing systems or developments, this work aimed a direct integration of the ESP into the boiler system, without attaching or installing parts inside of the chimney or downstream the boiler (Fig. 2 a). The direct integration represents a totally new approach of a secondary emission reduction system. Several benefits were realized, such as the connection of the control systems of the boiler and the ESP, with what an optimized operation of the ESP in relation to the actual state of combustion could be reached. Another main advantage of the direct integration is the less number of ESP components which are needed. The collecting electrode for example, already is represented by the walls of the cold end section. Also the existing ash removal system of the boiler could be used. But the direct integration also meant high requirements for the development, since very high temperatures and difficult conditions in this early stage of the exhaust drainage system in the cold end section of the boiler exist. Of course the direct integration into the cold end section of the boiler only is possible if enough space is provided. This decreases the possible usable scope of boiler systems to which the ESP can be applied to. Therefore a second development, which uses the same components of the integrated ESP, was defined.

Attached Solution / Precipitation box

An especially developed precipitation box (Fig. 3) was equipped with the ESP components from the direct integration, as they were the high-voltage supply and control unit, the insulators and the discharge electrodes (Fig 2 b). The collecting electrode, the ash removal system and the electrode cleaning system had to be developed as well. The precipitation box can be applied to the exhaust gas stub of the boiler, which makes it a stand-alone system. But the idea of the combination of both systems, also was followed during the development of the precipitation box. The suction fan, as the last constructional part of the boiler, can be installed at the end of the precipitation box, what makes it a constructional part of the boiler. Again several benefits could be realized, like the combined use of the exhaust gas guidance by the fans of the boiler. With the possibility to either directly integrate the ESP, to integrate the ESP into the boiler construction with the precipitation box, or by installing the ESP as a stand-alone system, a unique and completely new approach was aimed.


Fig.3: ESP for < 50kW$_{th}$ boilers

During the development of both solutions, a focus was set on the development of an intelligent and self-sufficient control algorithm inside of the completely new developed ESP control and supply unit. By knowing the actual state of the combustion due to the direct combination of the boiler and the ESP controls, the ESP control algorithm for example can adjust the voltage height onto the actual temperature or the expected dust amount.

Shown Results

Starting with a detailed description of the approach and the background, the current ESP configuration is presented on the poster. As a representative result of the field tests with standard wooden fuels, the poster then shows and discusses results of the ESP performance during a combustion at a logwood boiler, where the precipitation box was tested.

Another matchless feature of the development, that represents the individual character of the presented work, can be found in the aim of the possibility to process dust emissions from also alternative fuels. Standard wooden fuels, such as logwood, wood residue chips or industrial wood residue pellets show significant lower dust emission rates than alternative biomass fuels. The within the energy revolution very important increase of the competitive ability of the renewable share at the heat sector, becomes during times of low gas and oil prices more and more urgent. Therefore until now not used alternative resource paths have to be developed. The poster shows the results from field tests of the ESP where pomace-miscanthus and cotton residue briquettes were used.

Concluding that the ESP showed very good performance characteristics in separating the fine dust out of the exhaust gas of the biomass boilers, a summary of the newest results is presented. At the end it can be said that the development still needs some time to improve the ESP, especially considering the rough conditions for the integrated solution. But the very good precipitation efficiencies, especially during the combustion of the alternative fuels, create a high motivation to continue the development until a market-ready ESP can help to make the biomass combustion technique more competitive against fossil fired boilers, although now stricter emission limits exist.

Project Frame

The presented work gets carried out within the frame of a national research and development project. The project, which is named "IntEleKt" (Integrated electrostatic precipitator within a small series test), started in October 2014 and is planned to end in March 2018. The project aims the further development of the ESP until it is market ready and can be commercially available. Therefore a small series test where up to 16 test systems should be installed is planned.

In order to carry out the proposed tasks, a modular and cyclic optimization methodology has been used. The iterative and continuously ran cycle consists of five main steps: "build, test, evaluate, define and implement". The cyclic methodology is applied to the test phases during the winter seasons, that aim to individually evaluate the three crucial operational characteristics of the ESP: Long term operational stability of the ESP, mass suitability (applicable for different boiler types) and practical applicability (in terms of usage in households).

Within the small series test, a total of 16 test facilities have been planned. To examine the aimed mass suitability, the systems are installed in different biomass boilers. These systems mainly differ in: Used fuel (pellets, logwood or wood-chips), feeding system (manually or automatically) and nominal heat output. The test systems, which are spread across Germany (Fig. 4), are grouped into 3 clusters, based on regional focuses. Each cluster gets super-vised and operated by an associated project partner.

Fig. 4: Planned and already installed test systems

Key Facts Projekt:

Name: IntEleKt (Integrierter Elektrofilter im Kleinserientest)

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FKZ-Nb.: 03KB095A & B

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