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Innovative high efficiency filtration device for particulate matter from biomass combustion in small size boilers

Introduction

Biomass is considered a valid alternative to traditional fossil fuels due to its easy availability, the low cost and the CO_2 neutral balance during biomass growing and combustion.

Biomass can lead technical, economical and environmental benefits, consequently the use of biomass boilers for domestic heating have significantly grown in many countries in the last years.

Nevertheless, biomass spreading in **residential sector** has been limited by **high particulate matter (PM) emissions** due to unfavourable combustion conditions:

- low mixing of fuel and air, residence time, combustion temperature and excess air;
- low biomass quality: chemical composition, humidity.

Domestic and industrial biomass plants comparison

Urban area (high pollution): Bologna (474 biomass boilers per km²)

Single boiler power	12 kW
Single boiler flue gas flow rate	29 Nm³/h
Total installed power	5 700 kW/km²
Total flue gas flow rate	13 700 Nm³/h km²
PM filtration devices	**NONE**
PM10 emission (200 mg/Nm³)	**2740 g/h km²**

Industrial area: 5,7 MW biomass heating plant

Polluted area: 1 km²

Plant power	5700 kW/km²
Flue gas flow rate	10 830 Nm³/h
PM filtration devices	**High efficiency filters (η>95% on fine particles)**
PM10 emissions (20 mg/Nm³)	**217 g/h km²**

Objectives

In order to limit PM emissions from domestic biomass boilers, the Department of Industrial Engineering (DIN) of University of Bologna is developing an innovative high efficiency PM filtration device. The filter, applied on residential plants, must have the same characteristics of industrial PM separation device:

1. **PM removal efficiency greater than 99.9%;**
2. **specific energy consumption lower than 10 Wh/Nm³.**

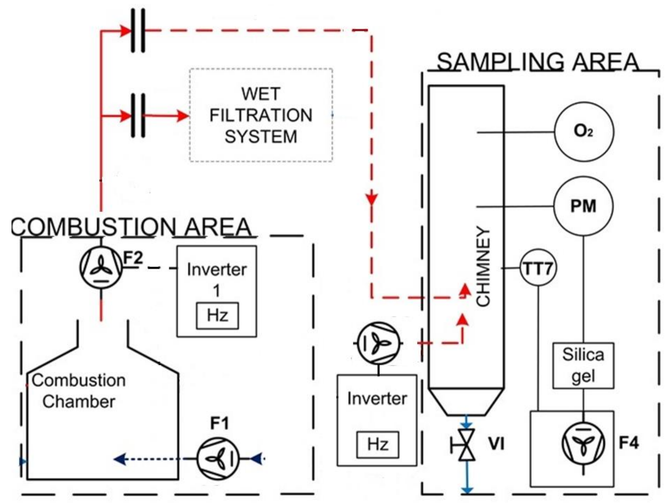
Methodology

Different configuration of **wet scrubber** were designed using and improving a consolidated mathematical model to evaluate the expected PM removal efficiency.

The main design parameters which influence the PM removal efficiency of wet scrubber are:

1) PM mass load and size distribution; 2) liquid flow rate; 3) void fraction.

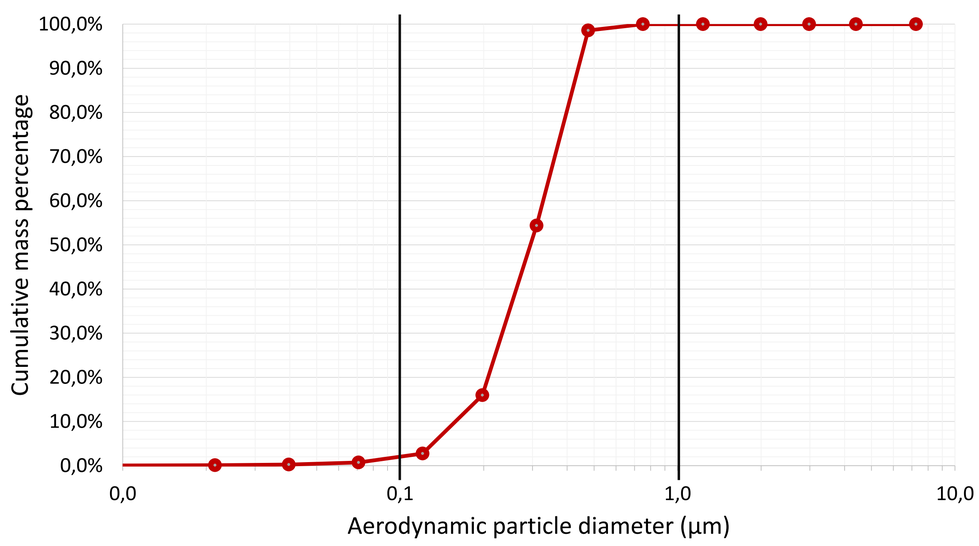
The configuration with the optimal design parameters was realized and tested on a 25 kW biomass boiler, installed at DIN laboratory. Numerous tests were conducted, varying liquid flow rate and void fraction.



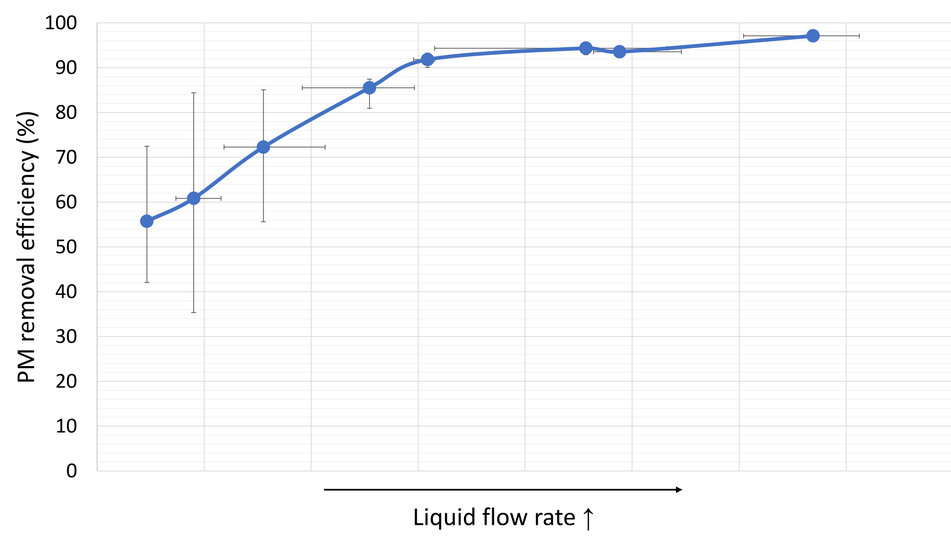
***Experimental test plant** – The plant consists of a 25 kW biomass boiler, fed by flint corn. The plant is provided by the instrumentation to maintain stable operating conditions and to evaluate PM concentration in the flue gases.*

Results

- **PM mass load and size distribution -** The experimental test plant produces 200-300 mg/Nm³ of PM10. The particles produced in the experimental test plant have a diameter between 0.1 and 1 µm, with a distribution peak at 0.3 µm.
- **PM removal efficiency and energy consumption** - The higher PM removal efficiency reached with the innovative scrubber is **97,1%**, with a specific energy consumption of **18.6 Wh/Nm³**.
- Increasing the liquid flow rate produces a lower void fraction. Consequently the PM removal efficiency increases, but also water consumption.
- The results confirmed the PM removal efficiency estimated with the mathematical model. Nevertheless, some adjustments for the equations were assumed in order to considered the real parameters which influence the filter performance.



PM mass size distribution.



PM removal efficiency trend according to liquid flow rate, in relation with 2 different resident times.

Conclusion

- The innovative high efficiency filter can make biomass a real alternative of traditional fossil fuels, also for domestic heating.
- With a proper parameter design, wet scrubber can reach the same performance (efficiency and energy consumption) of typical industrial PM separation devices.
- Developing an improved mathematical model makes it possible to define the values of scrubber parameters in order to obtain a desired PM removal efficiency with the desired specific energy consumption, in relation to PM load and size distribution.
- In this way, new configurations of scrubber can be adapted to other applications also in industrial sector (e.g. biomass gasification, incineration…).

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