EXPERIMENTAL STUDY OF PARTICULATE MATTER EMISSION FROM BATCH LOADED WOOD STOVES

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Introduction

The elaboration in design of smaller domestic installations as wood fired stoves have been increasing significantly for the last decades demonstrating high combustion efficiency. Particulate matter (PM) is one of constituent of the wood combustion smoke and pollution agent. The existing EU standards limit the particle emissions in terms of total mass concentrations of PM10 [1]. However, much interest now is dedicated worldwide as well as in the EU countries to extend this approach to number concentrations and size distributions of particles, because of their impact on the environment and the human health [2].

The regional measurements are important in the way of testing the models of combustion devices customary for the country or area [3].

The objective of this work is to characterize and quantify the PM emissions in terms of the number concentration and size distribution from the manually operated batch loaded log wood stoves typically used in houses in Belgium as well as some Northern areas of France, Germany and other countries.

Experimental

The experiments were performed on two commercially available manually operated logwood stoves of 10 and 20 kW nominal power output. Series of tests were run with the stoves during the routine product performance testing. The particulate matter emissions were measured in the stack during the combustion tests by means of the Electrical Low Pressure Impactor (ELPI+), from Dekati Ltd. By means of the 14 separating stages the device can measure particle mass and size concentrations as well as their size distributions in a range of aerodynamic diameters from 6 nm to 10 µm. The sample taken from the stack was conditioned by two stage dilutor consisted of the porous tube and ejector. The dilution ratio (DR) controlled by measuring CO_2 concentrations in the stack and in the diluted sample was varied between 31 and 42.

Results

Series of combustion cycles for both stoves were studied. Intermediate measurements of emission during the burnout phase were performed. The obtained results demonstrate quite significant variations of measured values over the time for different batches, which are usual for the combustion of log wood in small scale heating appliances. The average concentrations of the total PM emission from the batches corrected for dilution were between 2.7×10^7 and 5.0×10^7 and between 1.7×10^7 and 2.7×10^7 for burnout phases.

Conventionally the combustion cycle consists of the starting, nominal combustion and burnout phases. The starting phase usually took 5-7 minutes and demonstrated sharp increase of temperature and unprompted variations of the emission concentrations.

The nominal combustion lasted approximately 35-45 minutes with a relatively stable temperature in the stack. The example of particle number size distributions during the combustion phases are shown in Fig. 1 for the 10 kW stove. The distribution curves demonstrate the majority of particles in a range smaller than 1 µm and the highest maximum at 0.121 µm representative for all combustion phases.

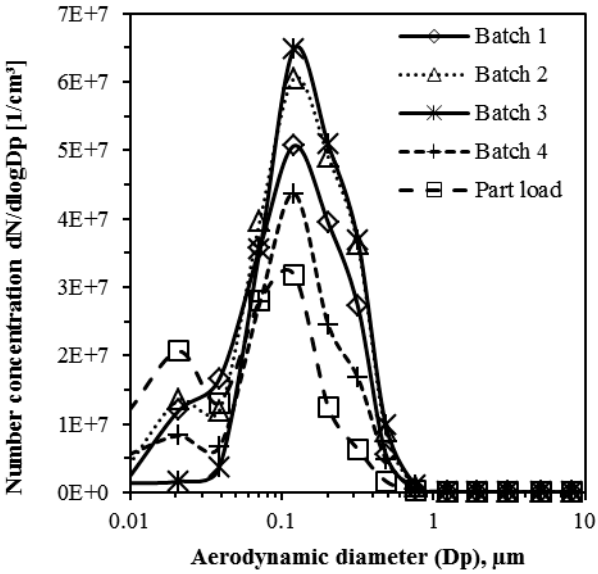

Fig.1. Particle number size distribution of different batches for the 10 kW stove.

The emitted particles, registered by the impactor, could be associated according to the usually multimodal character of their size distribution [4]. Apparently the particles generated by the similar formation mechanisms and of the similar origins could have certain range of size variation and be found and partly overlap on the different stages of impactor. Obviously the particle formation mechanisms depend on the

combustion and flue gas conditions resulting in altered distribution of PM during the different combustion periods.

To determine possible associations among the particles detected by the different stages of impactor the correlation coefficients for every pair of stages have been calculated. That was performed for the different phases of combustion for all test results by applying the Pierson formula. Rather typically the particles detected by the impactor can be differentiated in three groups. The first group is the finest particles of the first three impactor stages (aerodynamic diameters from 0.010 to 0.039 μm), the second group of particles between the stages 4 and 9 (0.072 - 0.764 μm) and the third group is the particles larger than 1 μm detected by the stages from 10 to 14.

In general, the approach of size groping could assist in applications of the appropriate methods to monitor the number concentrations characteristics for the regulation of the PM emission [2,5].

The inspection of the substrates after the measurements revealed that the collected PM forms the spots of the black and white colors representing perhaps the carbonaceous and inorganic matter. The spots of the black substance were observed only on the impactor stages up to stage number nine (0.764μm); stage one does not have a substrate plate; traces on the stage two were hardly visible. The distinguishable black spots replicate well images of riddle holes of the stages demonstrating the similarity of the trajectories and respectively densities of collected matter. They are spatially resolved on the subtract surface with white color depositions, those in turn are less compactly formed, perhaps revealing various substance composition and densities [6].

The levels of particle emission during the burnout phase are comparable to the levels of emission during the combustion phase. It was also observed that the number size distribution maximum is systematically reallocating toward smaller diameters when the wood combustion passes to the burnout phase.

The results of measurements of particle emission of burnout phases demonstrate two distinctive modes around 0.021 and 0.072 μm evolving in time indicating perhaps the dependence of PM formation regimes on the combustion conditions.

Conclusions

During the particles emission measurements from a small scale batch loaded logwood stoves of modern design the attention was paid to the different phases of combustion. The PM concentration levels measured at the burnout phase are quite comparable to those of the combustion phase. The number size distribution within the PM1 fraction changes in time with increasing of the concentration maximum at 0.021 μm. Correlation analysis applied to the measured PM emission by different impactor stages revealed three general size groups of particles emitted by the wood combustion probably related by the similar formation mechanisms and respectively the chemical composition. Size groping could be applied for selecting the measuring methods for the PM concentration detection.

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