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beReal – Development of a new testing method close to real-life for domestic biomass room heaters

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Abstract

Domestic biomass heating using firewood and wood pellets is one of the most important sources regarding air pollution, especially for particulate matter (PM). Current PM thresholds refer to standard type testing results, which are conducted under laboratory conditions and do not reflect real-life operation. Consequently the *beReal* project was initiated aiming at the development of a new testing method better reflecting real-life for firewood room heaters (acc. EN 13240) and pellet stoves (acc. EN 14785). At the end of the project the final *beReal* method should be implemented in a European quality label.

Keywords: Firewood/pellet combustion; Domestic heating; Standard type testing; Real-life performance

1. Introduction

Biomass combustion is a major source regarding air pollution in urban and rural areas. Especially particulate matter (PM) is one of the most critical parameters concerning emissions from biomass combustion. Currently, PM measurement at small scale biomass combustion systems is typically performed with gravimetric methods. PM emission thresholds are defined for standard type testing results under laboratory conditions. Emissions in the field are significantly higher than under standard type testing conditions (Reichert et al., 2014). Thus, it is useful to think about new testing methods for domestic

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biomass room heaters in order to better reflect real-life conditions. A new approach for a testing method regarding real-life conditions of biomass room heating appliances was investigated in the European FP7 project *beReal*.

This project aims at the development of new testing methods for firewood room heaters (acc. EN 13240) and pellet stoves (acc. EN 14785), and the implementation of this methods in a new European label. This *beReal* label should be an indicator for low emissions and high quality in real life operation.

2. Approach

2.1 Evaluation of user behavior and real-life operation

Real-life domestic biomass combustion operation and user behavior were assessed in a European wide survey. More than 2000 respondents gave feedback on questions regarding their biomass heating system and operational habits. Moreover, long term field measurements were performed in order to get additional information on user behavior, and to assess operating conditions regarding draught level and temperatures in the field. The results of those measurements and the questionnaire gave insight into real-life operation of firewood room heaters and pellet stoves.

2.2 Influence of different operation modes

Based on the findings of the survey and the long term field measurements, influences of different operation habits and conditions on gaseous and particulate emissions as well as on efficiency were determined. Table 1 gives an overview of some tested parameters including the most common survey answers. Additionally, the influence of different measurement procedures was evaluated. For example different temperature (thermocouple/pyrometer) and thermal efficiency (direct/indirect) measurements were compared.

Based on the results a draft version of the *beReal* testing method was defined.

Table 1. Tested parameters including the most common answer in the survey (Wöhler et al., 2016)

Parameter	Tested modes	Most common survey answer
Ignition mode	Bottom-up / top-down	Bottom-up ignition
Fuel type	Beech / Spruce	Hardwood
Draught conditions	12-24-48 Pa	Chimney high of 5-10m (in average higher draught than 12 Pa, used at type testing)
Recharging criteria	Quantitative criteria	Recharging when “flames are extinguished” or “when only small flames are visible”

2.3 Standardized data evaluation

An online web-based calculation tool was developed to guarantee a standardized data evaluation. After a login process, raw data can be uploaded and relevant measurement parameters can be entered. Then the calculation is done automatically. Finally a standardized report with all relevant results is generated automatically.

2.4 Method validation procedure

In order to validate the draft method and to identify optimization potential, seven firewood room heaters and five pellet stoves were tested. Thereby, the repeatability of the method was evaluated. For all appliances standard type tests were performed to allow for a comparison of the results. After optimization of the draft method the final *beReal* method was defined.

3. Highlights of the results

3.1 Evaluation of user behavior and real-life operation

The online survey identified parameters, which are important regarding the new testing method. For example, 90% of the respondents use hardwood as main fuel (Wöhler et al., 2016). Consequently, hardwood is used for the new testing method. Furthermore, 41% of respondents recharge their stoves *"when flames are extinguished"*, 37% *"when only small flames are visible"* (Wöhler et al., 2016). These qualitative results have been transferred to a quantitative criterion in the next step of method development (chapter 3.2).

3.2 Influence of different operation modes

The influence of different draught levels on gaseous and particulate emissions as well as on efficiency was evaluated for two firewood room heaters and one pellet stoves which were tested at draught levels of 12, 24 and 48 Pa. Figure 1 shows the results for particulate emissions (PM) and thermal efficiency (η) for one of the tested firewood room heaters. For PM no correlation of draught level and emissions is evident, whereas a trend for decreasing thermal efficiency with higher draught level was observed.

Further information on the influence of ignition mode and draught conditions can be found in Reichert et al. (2016). The comparison of direct and indirect thermal efficiency determination is published in Sturmlechner et al. (2016).

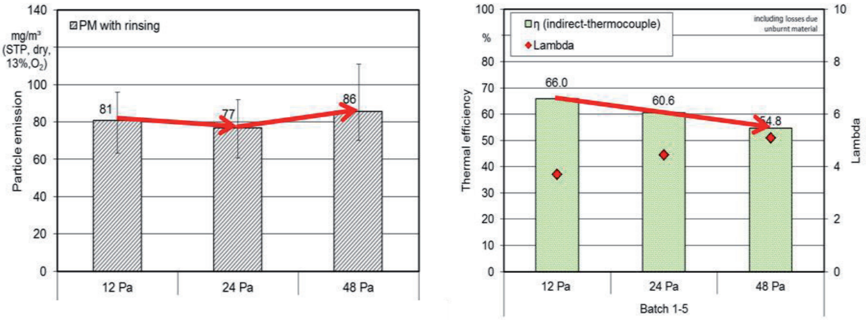

Fig. 1. Results of the influence of different draught levels on PM emissions and thermal efficiency

3.3 Method validation procedure

For evaluation purpose seven firewood room heaters and five pellet stoves were tested according to the draft method. Figure 2 (right) shows the repeatability of the measured parameters. All parameters have a good repeatability indicated by a low coefficient of variation (r<10%), except organic gaseous carbon (OGC).

The comparison of type testing results and *beReal* results shows significant differences. Figure 2 (left) for instance compares particle emissions for the three different test methods. However, stoves which performed best at type testing were not best at *beReal* and vice versa. This result shows the necessity of a new testing method regarding real-life operation.

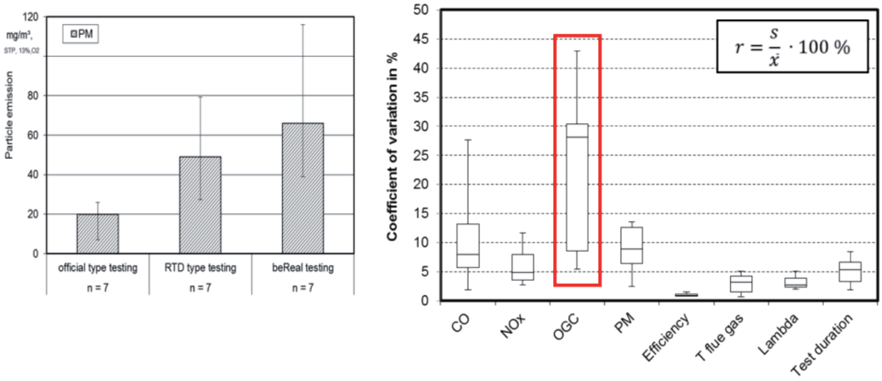

Fig. 2. Validation results for PM (left) and repeatability of the parameters of the *beReal* method (right)

4. Ongoing / upcoming work

4.1 Label development, field tests and a round robin test

The *beReal* method will be implemented in a European label, for which the organizational structure and the classification scheme is currently defined. The classification will be based on a *beReal* coefficient, which incorporates gaseous and particulate emissions as well as thermal efficiency.

The real-life relevance is confirmed by field tests. Eleven firewood room heaters and four pellet stoves are currently tested according to the final *beReal* method in the lab as well as in the field where users are asked to perform their heating operation as usual. Additionally, the effect of the Quick User Guide (QUG) will be evaluated.

The reproducibility of the *beReal* method is evaluated in a round robin test with one firewood room heater and one pellet stove. Both stoves will be tested at seven laboratories. Comparatively, the standard type testing method will be performed in order to compare reproducibility of the *beReal* method with the existing method.

5. Final *beReal* methods

The final *beReal* methods include defined heating operation cycles (Table 2). Table 3 gives an overview of the measured parameters and Figure 3 shows the test set up for pellet stoves and firewood room heaters. Data evaluation is done automatically by the web based evaluation tool. The test result for each parameter (CO, OGC, NOx, PM and efficiency) is volume weighted and is representing the whole beReal heating operation cycle.

Table 2. Defined *beReal* heating operation cycle for firewood room heaters (left) and pellet stoves (right)

Firewood room heaters (acc. EN 13240)	**Pellet stoves (acc. 14785)**
8 consecutive batches:	1a (50min): Cold start at maximum load
1-5: Nominal load (incl. ignition and preheating)	1b (90min): Minimum load
6-8: Part load	S1 (40min): Stand by
Followed by a cooling down phase (T = 50°C)	2 (50min): Warm start at maximum load
Air flap settings can only be adjusted immediately before 1st, 2nd, 6th batch and cooling down phase	S2 (40min): Stand by
	3 (180min): Warm start at medium load
	Followed by a cooling down phase (T = 50°C)

Table 3. Overview of measured parameters

Continuous (≤10s)	**Discontinuous measurement**
Carbon monoxide (CO), organic gaseous carbon (OGC), nitrogen oxide (NO_x), oxygen (O_2), carbon dioxide (CO_2), $T_{flue\ gas}$, $velocity_{flue\ gas}$	PM: gravimetric, recommended: acc. to EN-PME method
	Fuel properties, ambient air pressure, ambient air temperature

Furthermore, for firewood room heaters a Quick User Guide (QUG) is obligatory. This sheet is provided by the manufacturer and should include all relevant aspects for heating operation (e.g. ignition mode, fuel mass, air flap settings,…). Beech or birch firewood can be used as fuel. The recharging criterion, that defines the instant of time when a new batch should be refilled, is based on the CO_2 concentration in the flue gas. PM measurement is performed in batches 1, 3, 5 and 7 and lasts for the entire batch duration. For pellet stoves the PM measurement is performed isokinetically and also lasts for the entire phase (1a and 1b, 2 and 3, respectively).

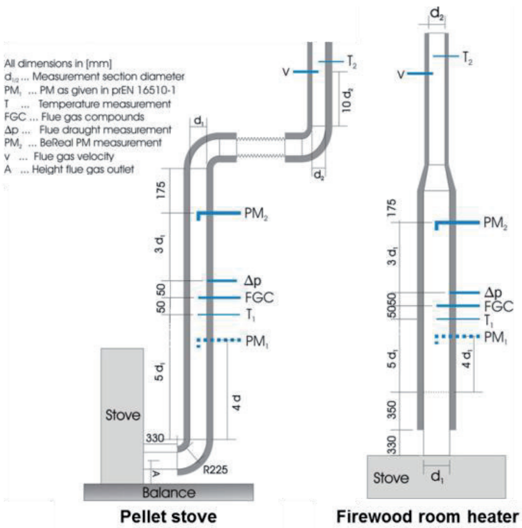

Fig. 3. *beReal* set-up scheme for pellet stoves (left) and firewood room heaters (right)

5.3 Most important differences to standard type testing method

The standard type testing method and the *beReal* method have many differences. The most important parameters are listed in Table 4.

Table 4. Most important differences between the *beReal* method and the standard type testing method

beReal	**EN 13240 (FW room heaters)**	**EN 14785 (pellet stoves)**
Defined heating cycle (no “failed” batches)	Average of best 2 batches (of undefined number of batches)	3h operation at nominal load, 6h at part load
Ignition, preheating and cooling down included	Ignition, preheating and cooling down not included	Steady state conditions
Serial appliance is required	No specification	No specification

6. Summary and conclusions

A new real-life oriented testing method for firewood room heaters (acc. EN 13240) and pellet stoves (acc. EN 14785) was developed within the project *beReal*. The results showed a good repeatability of the new testing method. Moreover, it leads to significantly different emissions and efficiency compared to the existing type testing method. This applies to absolute figures and ranking of appliances. A web based tool was established in order to guarantee standardized data evaluation. Finally, a label will be developed which highlights high quality products in real-life operation.

This label should trigger the development of new and improved technologies for a better real-life performance. This will be an important measure for emission reduction and consequently for better air quality. In a long term perspective the method could even become a harmonized testing standard allowing emission thresholds to be defined accordingly, which would have the biggest effect as all appliances would be covered.

7. Acknowledgements

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