Hans Hartmann and Paul Roßmann, Straubing, Stephan Ester, Bad Wünnenberg, and Michael Struschka, Stuttgart

Rapid Detection of Excessive Dust Emissions

In the future the chimney sweep may be able to determine excessive dust emissions from domestic wood boilers. For this purpose a rapid measuring method was developed and tested. A conventional filter measures the accumulating filter pollution during a 15 minute flue gas sampling period, which shows itself through an increase in pressure drop. A series of field tests and laboratory trials have shown that a differential pressure of 24 (36) hPa, respectively, only 47% (16)% of filters would still require a subsequent gravimetric test.

Dr. Hans Hartmann is the head of the department „Technology of Renewable Raw Materials" at the Technology and Support Centre in the Centre of Competence for Renewable Raw Materials; this is also the affiliation of Paul Roßmann; Schulgasse 18, 94315 Straubing;
e-mail: *hans.hartmann@tfz.bayern.de*.
Dr. Stephan Ester is the director of Wöhler MGKG GmbH, Bad Wünnenberg
Dr. Michael Struschka is member of the scientific staff at the Institute of Process Engineering and Power Plant Technology (IVD) of the University of Stuttgart

Keywords

Wood combustion, dust emissions, emission control

For domestic wood furnaces excessive dust emissions are the most frequent reason for objections in regular emission checks by the chimney sweepers. In the usually applied determination method the accumulated dust load of a pre-weighed filter cartridge is determined in a central laboratory. This means that the final weighing can only be made after considerable time and the furnace operator is thus informed about the diagnosis with a delay of several weeks.

Therefore a method for an instantaneous detection of a dust proof furnace operation was developed during the last years. The technological approach was made by Wöhler MGKG GmbH. It was based on an idea in the „wood combustion working group" of the TFZ.

The basic idea

In this method the accumulating filter pollution during a 15 minute flue gas sampling period is reflected by an increase of the pressure drop over a conventional filter, while the rate of exhausted gas volume is kept constant. The pressure drop over the filter is determined as the differential pressure (Delta-p) to the ambient pressure.

It was the goal to conclude on any excessive dust emissions by determining the differential pressure and thus to receive the relevant information already on the site and before any reweighing of the loaded filter cartridge (*Fig. 1*). This procedure would require the identification of a threshold value for Delta-p which would indicate that the dust emission boundary value (150 mg/Nm^3 in the German 1.BImSchV) is not exceeded at a sufficiently high probability. The Delta-p-function can be refit to any of today's measuring devices for chimney sweepers at additional cost of about 350 €.

Testing

A first prototype of the Delta-p-measuring principle had already been applied in 2001 on the combustion test stand of TFZ. In a series of 137 measurements at a conventional 50 kW-wood chip boiler a clear statistical correlation was found between the Delta-p value and the gravimetric dust determination. Therefore in 2002/2003 a broad field test was conducted using four improved prototypes, which were applied by 25 particularly trained chimney sweepers in a total of 363 measurements in Bavaria. This was done at randomly selected sites along with the regular inspections. The evaluation of these measurements had shown that an optimum level for the desired threshold value of the differential pressure could be around 24 hPa. In order to verify this threshold optimum for future inspection measurements, a third series of 135 dust emission determinations were made under both practise and test stand conditions involving a total of 18 furnaces. This time the IVD and the TFZ were the executing measuring institutes.

Results

Between the Delta-p values and the simultaneously determined dust emissions by the gravimetric method an improved statistical

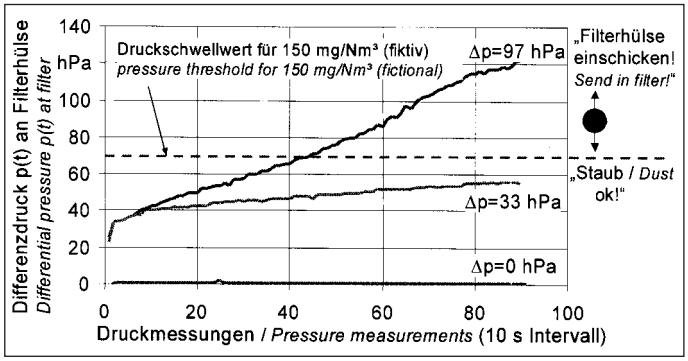

Fig. 1: Basic considerations for the application of the Delta-p-method for instantaneous dust emission evaluation

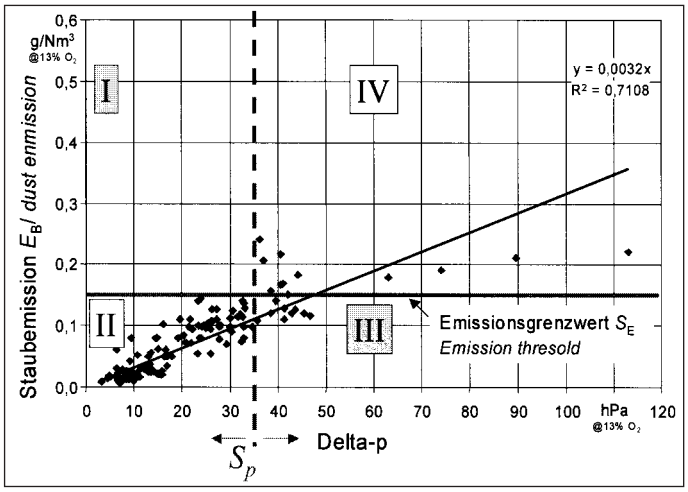

Fig. 2: Correlation of the gravimetric dust determination with the Delta-p-value

correlation was found in the described third test series using the improved devices (*Fig. 2*). The displayed residual variation can - among others - be explained by the fact that particle mass determination considers always the total mass on a filter while the differential pressure depends also on further dust properties such as the particle size, shape and density as well as the properties of the filter itself.

However, for the practical use of the Delta-p method it is not the final goal to achieve a perfect data correlation but it is rather important to identify a critical differential pressure which indicates excessive dust emissions. This threshold value S_p should be fixed on a level, where on the one hand the smallest possible error probability would be given, while on the other hand also a low number of filter cartridges would still have to be sent to the central laboratory for gravimetric determination. In order to find such a proper level, an analysis of probability for erroneous judgement was conducted for variable threshold values of Delta-p. This procedure is explained in *Figure 2*. In the displayed four quadrants (I to IV) the possible distribution of the dust emissions (E_B) and Delta-p values is demonstrated; S_p is the desired threshold value for inspection in practise and S_E is the corresponding current emission boundary for dust from domestic wood boilers (150 mg/Nm³ at 13 % O_2-concentration). If a pair of variates is located in Quadrant I (here for example below a threshold value S_p of 36 hPa), an excessive dust emission would not be identified by the Delta-p measurement. For this area the qualified probability P{EB>150 mg/Nm³ | delta-p≤S_p} must consequently be minimised by an appropriate fixation of S_p. The notation P{E_B>150 mg/Nm³ | delta-p≤?S_p} describes the probability for the event E_B>150mg/Nm³ when the event delta-p≤S_p occurs. Such a minimisation inevitably implicates, that the number of pairs of variates in the third quadrant (III) rises. They represent those measurements, for which at the respective threshold value the filter cartridge are unnecessarily sent to the laboratory for gravimetric determination.

Figure 3 shows the course of these two qualified probabilities P{A|B} and P{C|D} for increasing threshold values S_p in the area between 10 and 55 hPa. Apparently the optimum level for the threshold value can here be found around 36 hPa. The calculated „probability of error" P{A|B} for a furnace evaluation according to the Delta-p-method is here still zero while the probability for an unjustified gravimetric determination of dust P{C|D} is already quite low, too. For presented data this means that at a threshold value of 36 hPa 114 of 135 furnaces would be tested as „passed" on the site and in none of the determinations this would be a false diagnosis. Among the cases where the measurement was above the threshold value there would be 10 of 21 furnaces which would then unnecessarily have to be evaluated by gravimetrical determination. In *Fig. 3* this corresponds to a probability P{C|D} of 0,48 for the event P{EB≤150mg/Nm³|delta-p>S_p}.

In the previous field tests the optimum threshold value was found at a lower level than the above mentioned 36 hPa, it was around 24 hPa; this is mainly due to the largely higher variation of the field test data. As a conclusion from both test series the wanted optimum should now be found between these limits, if the current German dust emission threshold value of 150 mg/Nm³ (1.BImSchV) are to be applied. In case that this dust emission threshold value shall be modified someday, the threshold value S_p can easily be adjusted on the basis of the elaborated data base.

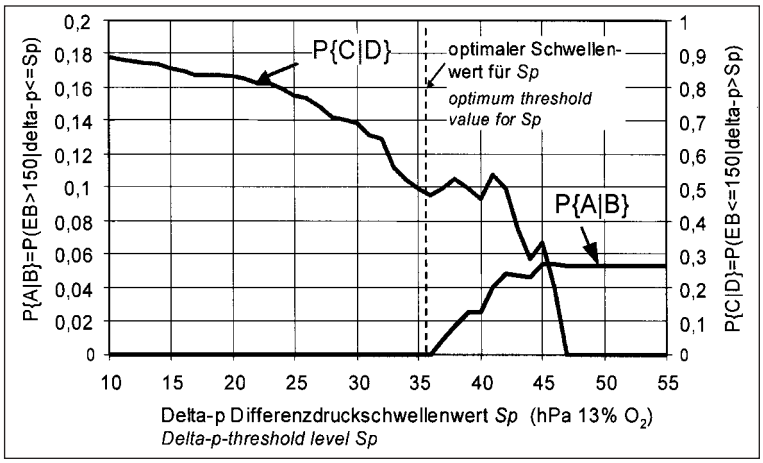

Fig. 3: Conditional probabilities P{A|B} and P{C|D}as a function of differential threshold level for S_p

Conclusion

The results show the high development status of the Delta-p method, which has in the meantime been achieved. They also suggest that an instantaneous identification of „dust proof" furnaces is possible by determining the differential pressure already on the site. Thus the number of filter cartridges, which would still have to be sent in for weighing could significantly be reduced. A high benefit could thus be achieved for wood combustion practise. A direct transformation of the determined differential pressure into a particle mass is, however, not possible with this rapid method, and it wasn't the goal of this method development either.

Acknowledgements

The research was conducted in several research projects funded by the Bayerisches Staatsministerium für Umwelt, Gesundheit und Verbraucherschutz (BayStMUGV) and by the Umweltbundesamt and it was conducted with the support of the Bayerisches Landesamt für Umweltschutz (LfU) and Bundesverband des Schornsteinfegerhandwerks (ZIV).

Literature

[1] *Hartmann, H., V. Schmid, H. Link, P. Roßmann, T. Decker, S. Ester, H. Wazula und G. Schmoeckel*: Vereinfachte Überwachung der Staubemissionen bei Holzkleinfeuerungsanlagen (Delta-p-Methode). Bayerisches Staatsministerium für Umwelt, Gesundheit und Verbraucherschutz (Hrsg.), München, 2005, Reihe „Materialien", Nr. 183, 90 S.