Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

Micro-scale Biomass Combustion System with Very Low Emission

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Micro-scale combustion

- Heat output 1-2 kW
- Downdraught combustion with special developed grate zone
- Primary and secondary air supply
- Continuous fuel dosage with comminuted wood pellets
- Integrated catalyst for low emissions during all combustion phases

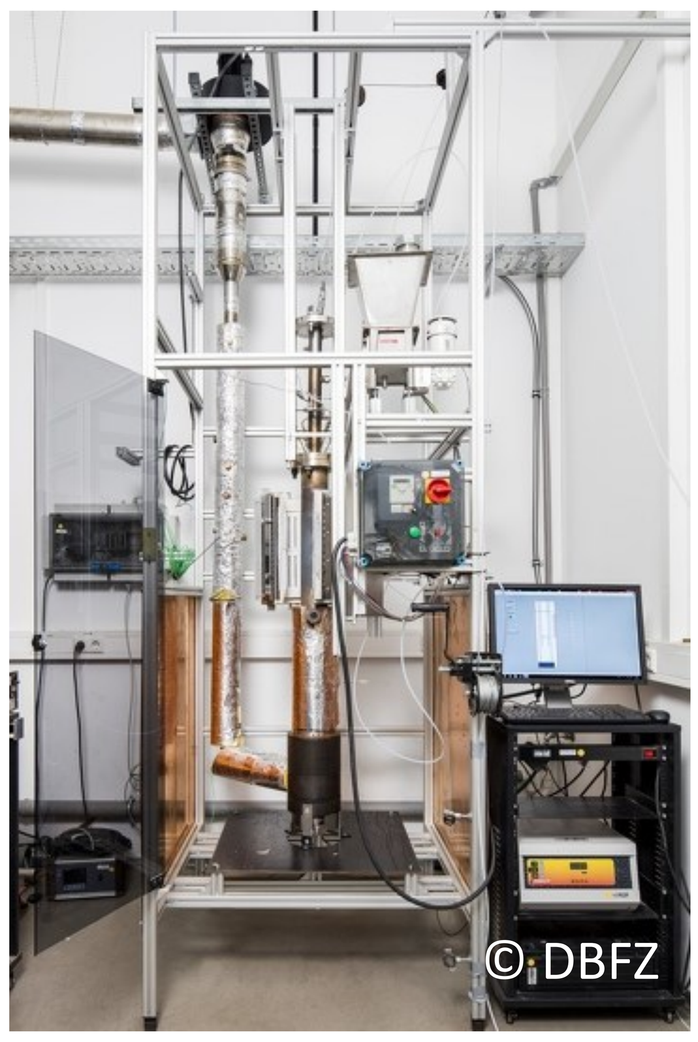

Fig.3: Micro-scale combustion system

Analysis

- Defined ignition procedure and characterization of four sequenced operation phases (1-optimal conditions, 2-lack of oxygen, 3-optimal condition, 4-oxygen excess)
- Measurement methods: Gaseous Compounds by FTIR and paramagnetic oxygen analyzer, Particulate matter by gravimetric measurement and SMPS

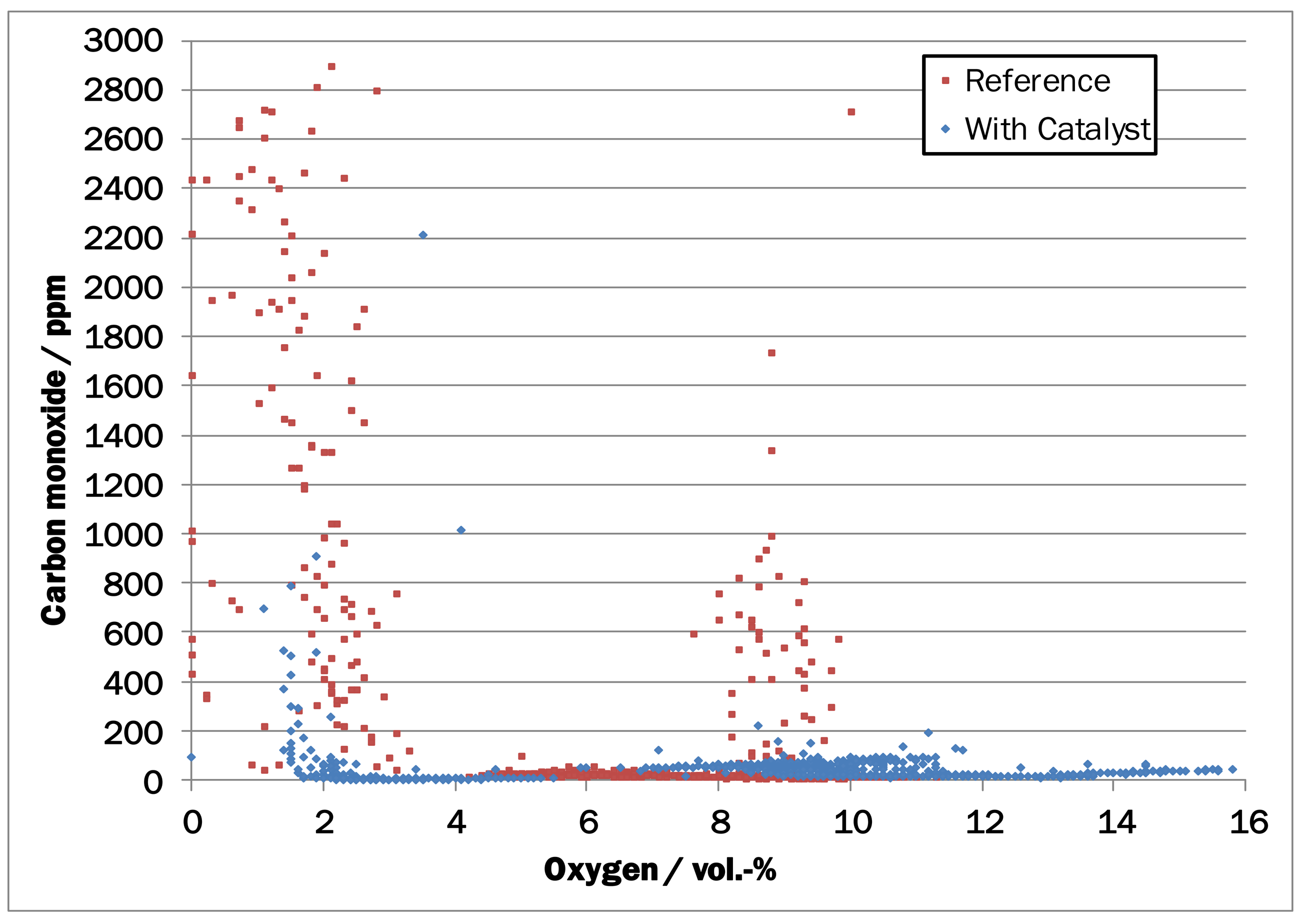

Fig.1: Oxygen dependent CO concentration measured in the flue gas

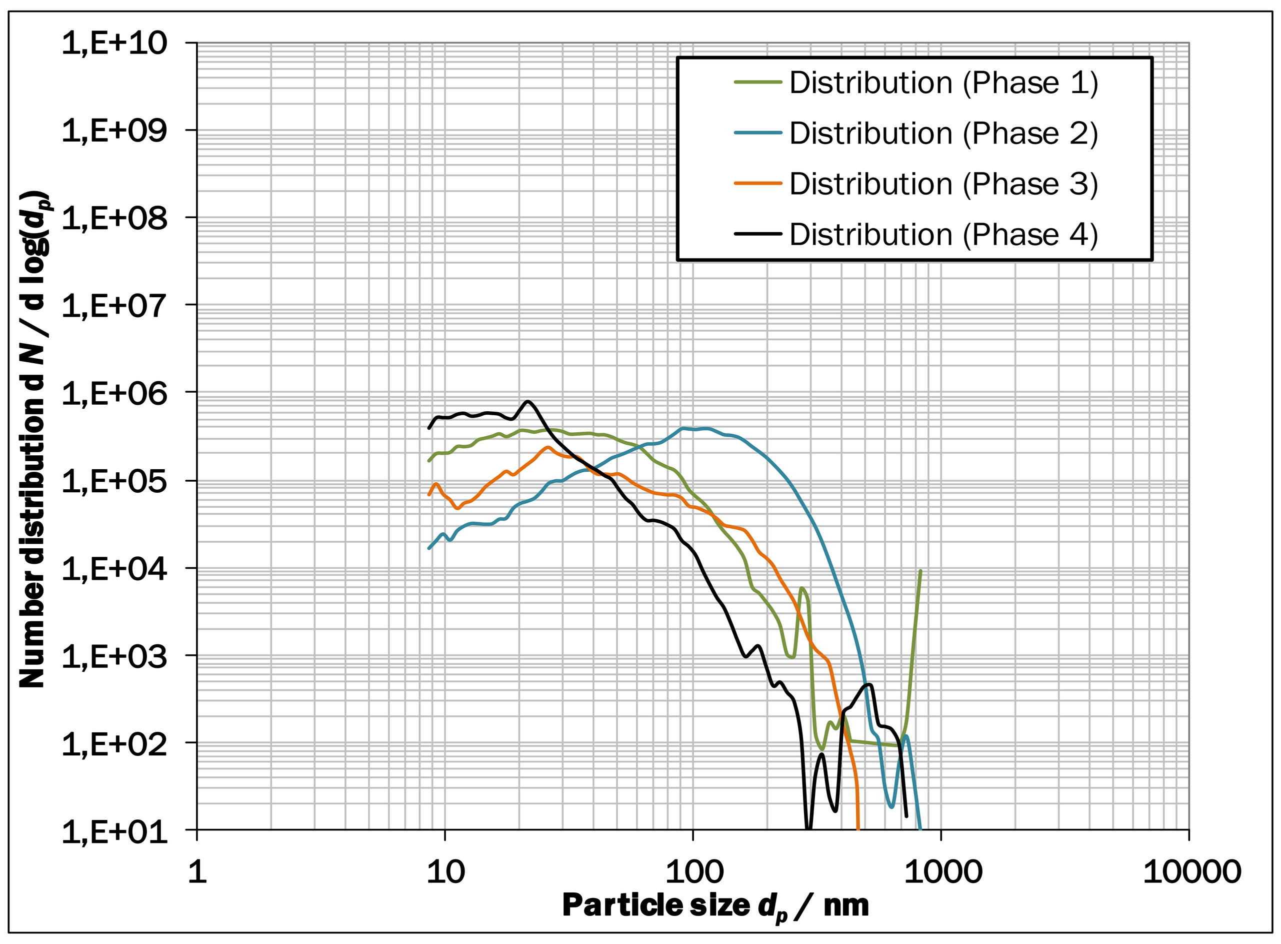

Fig.2: Particle distribution in different combustion phases (see section analysis)

Low gaseous and particulate pollutant emissions

- Almost complete oxidation in a wide range of operation - low CO concentration from 3 to 8 vol.-% O_2 without catalyst - and with catalyst even wider range between 2 and 16 vol.-%.
- Low particle number concentration - maximum below 1×10^6 (In general, maximum values above 1×10^7 measured at other firing systems.)
- Particle mass concentration on average below 10 mg/m³ - best values below 5 mg/m³
- Average Org.-C (FTIR) value is sum of different qualitative measured hydrocarbons. Comparative measurements with FTIR and a FID showed that the observed values are quantitatively all below 5 mg/m³ (at STP and based on 13 vol.-%)

Tab. 1: Average values for flue gas composition in four sequenced operation phases based on STP and 13 vol.-% O_2

Phase	PM	O_2	CO	Org.-C (FTIR)	NOx
	mg/m³	vol.-%	mg/m³		
1	4	9,3	46	46	167
2	4	2,8	14	35	115
3	6	10,3	23	48	149
4	8	12,3	26	59	142

Conclusion and Outlook

- Low pollutant emissions for small-scale combustion is possible
- Further development of automatic controlled firing system suitable for daily use in low-energy buildings and passive houses

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With support from
Federal Ministry of Food and Agriculture
by decision of the German Bundestag

Micro-scale biomass combustion system with very low emission

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Micro-scale combustion

The use of biomass for heat production in small scale combustion systems provides an on-site energy supply from renewable resources. Low pollutant emissions as well as heat output on demand are the basis for the application of environmentally friendly and efficient systems. In line with improved thermal insulation of buildings heat production furnaces in the low power range gain relevance. Low-energy and passive houses represent future requirements for energy supply. Especially for low power systems, the adjustment of optimal combustion conditions is difficult. Insufficient or excess air supply as well as fuel overload can lead to high concentration of pollutants. Further development of special adapted furnaces for the low power range is necessary. Primary and secondary measures may contribute to the combustion systems to achieve high efficiency and low pollutant emissions.

A micro-scale combustion system has been configured at the Deutsches Biomasseforschungszentrum (DBFZ) with a heat output between 1 and 2 kW. The furnace is based on the downdraught combustion principle and has a special developed grate zone pyrolytic decomposition. Comminuted wood pellets are used as fuel and dosed continuously into the grate zone during combustion operation. Primary and secondary air supply can be varied with mass flow controllers to investigate different combustion states and adjust the system for optimal combustion conditions. Beside primary combustion modifications, also the integration of a catalyst can improve the conversion of the combustion gas to carbon dioxide and water. Therefore a catalyst, specially adapted to stoichiometric combustion, has been purchased and integrated into the firing system at a temperature level of 400-600 °C.

Analysis

The pollutant formation under different combustion conditions was observed by variation of primary and secondary air supply. In this manner, the combustion with excess and deficient air was investigated amongst others. The analysis of the combustion operation has been carried out using a sequence of the following four combustion phases:

- 1 – optimal conditions
- 2 – lack of oxygen
- 3 – optimal conditions
- 4 – excess of oxygen

The particulate matter emissions were measured with a Scanning Mobility Particle Sizer (SMPS) and the mass concentration in the flue gas has been measured gravimetrically according to the method in VDI 2066. Gaseous flue gas components have been measured by a Fourier transform infrared spectroscope (FTIR) and a paramagnetic oxygen analyzer.

Results – Low pollutant emissions

The flue gas characterization of the four investigated combustion phases showed low concentration of pollutant emissions during a wide range of combustion-air ratios. In Table 1 average values for the flue gas concentrations of several pollutants during the investigated combustion phases are listed. These results show the good combustion behavior of the developed furnace.

Table 1: Average values for flue gas concentration downstream of the micro-scale biomass combustion system during the four sequenced combustion phases (average values are based on STP and 13 vol.-% O_2)

Phase	PM	O_2	CO	Org.-C (FTIR)	NOx
	mg/m³	vol.-%		mg/m³	
1	4	9,3	46	46	167
2	4	2,8	14	35	115
3	6	10,3	23	48	149
4	8	12,3	26	59	142

An almost complete conversion of the fuel for a wide range of operation has been observed. The CO concentration has been below 50 mg/m³ in all combustion phases. The analyzation of the single CO values as a function of the oxygen concentration shows that a low CO concentration and therefore a good burnout is possible between 3 and 8 vol.-% O_2 without catalyst - and with catalyst even in a wider range between 2 and 16 vol.-%. A graphical representation of the behavior is shown in Figure 1.

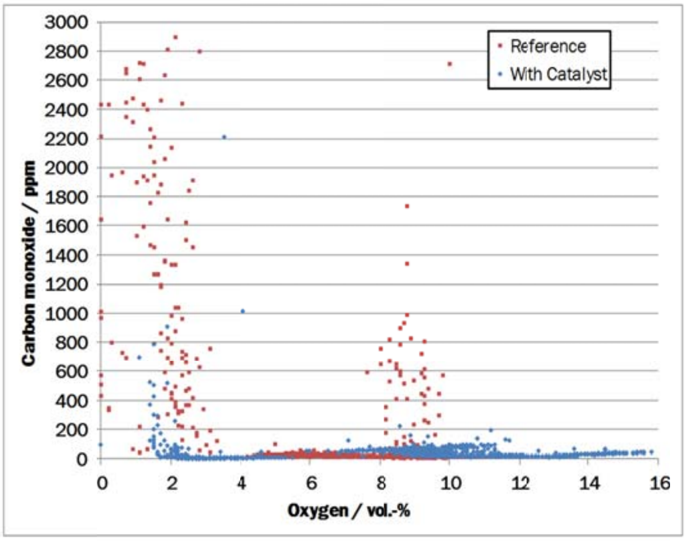

Figure 1: Oxygen dependent CO concentration measured in the flue gas during all investigated combustion phases

The presented average Org.-C (FTIR) values in Table 1 are a sum of several qualitative measured hydrocarbons. Comparative measurements with FTIR and a FID showed that the observed values are quantitatively all below 5 mg/m³ (at STP and based on 13 vol.-%), which means there has been also achieved a stable low hydrocarbon concentration during all combustion phases.

Just as the low gaseous pollutant concentrations also the particulate matter concentration has been quite low. The gravimetrically measured particle mass concentration has been on average below 10 mg/m³ (based on STP and 13 vol.-%) and the best values have been even below 5 mg/m³. Beside the low mass concentration also the measurement of particle number concentration showed outstanding results for small-scale combustion of biomass. The maximum particle number concentration has been during all combustion phases below 1×10^6, see Figure 2. In general, maximum values above 1×10^7 are measured at other firing systems. The maximum of the curve shifted to lower particle sizes during operation with excess of air and to higher particle sizes during operation with lack of oxygen. Entrainment as well as residence time for particle growth and coagulation can explain this behavior.

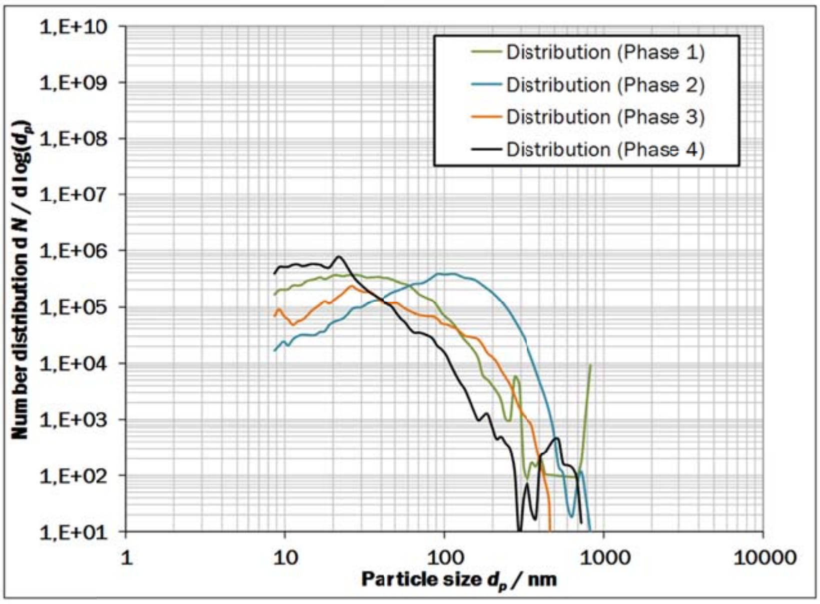

Figure 2: Particle number distribution for the different analyzed combustion phases in comparison (Phase 1 – optimal conditions, Phase 2 – lack of oxygen, Phase 3 – optimal conditions, Phase 4 – excess of oxygen)

Conclusion and Outlook

The developed micro-scale combustion system with a heat output of 1-2 kW shows that an efficient heat supply with low pollutant emissions is possible even in the low power range. The emissions fell below the current limit values by law and also undercut common values from state of the art stoves or boilers with an output below 10 kW.

By now the combustion system is in a lab-scale development state. Therefore, further investigation will be carried out to develop an automatic controlled firing system suitable for daily use in low-energy buildings and passive houses.

Abbreviations

FTIR	Fourier transform infrared spectrometer
FID	Flame ionization detector
SMPS	Scanning mobility particle sizer
STP	Standard temperature and pressure
CO	Carbon monoxide
Org.-C	Sum of organic carbon
O_2	Oxygen

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