Advanced combustion control for a wood log stove, Expert workshop - Highly Efficient and Clean Wood Log Stoves

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Publication date:
2015

Document Version
Peer reviewed version

Link back to DTU Orbit

Citation (APA):
Advanced combustion control for a wood log stove

Expert workshop - Highly Efficient and Clean Wood Log Stoves
Berlin 29 October 2015

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Intelligent Heat System
High-energy efficient wood stoves with low missions

• Collaboration between HWAM A/S and DTU Chemical Engineering
• Periode 2011 – 2015
• EUDP - project
  (Energy Technology Development and Demonstration Program)

Development of a new automatically controlled wood stove with:
• High energy efficiency
• Reduced emissions (CO, particles etc.)
• High comfort for the wood stove users
Main results

• A new advanced control system has been developed based on experiments conducted at experimental facilities at HWAM og DTU Chemical Engineering

• HWAM has launched an automatically controlled modern wood stove on the market

• Field and laboratory tests has shown reduced emissions and higher efficiency for stoves with the control system - and high comfort for the wood stove users
Content

• Background for the project – why an automatic control system?

• Concept of the automatically controlled wood stove

• Our results from
  – Field tests
  – Experiments at the wood stove set-up at DTU Chemical Engineering
# Regulation and legislation

New wood stoves are approved according to national and European standards.

## Standards:

<table>
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<tr>
<th>Approval of Wood stoves</th>
<th>Eff. (%)</th>
<th>CO (mg/Nm³)</th>
<th>PM (mg/Nm³)</th>
<th>PM (g/kg)</th>
<th>OGC (mg/Nm³)</th>
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<td>≤1250</td>
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<td>Swan label (from 2017)</td>
<td>≥76</td>
<td>≤1250</td>
<td>&lt;2</td>
<td>&lt;100</td>
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</table>

The emissions can be much higher when the stoves are used by ordinary wood stove users.
Challenges

The emission level can be high due to challenging conditions:

• batch firing in small combustion chambers

• wide range of various wood types and wood log sizes

• combustion air flows and fuel loads are manually controlled

Difficult to achieve an optimal combustion
Improved technologies

Modern stoves with air staging:

Three combustion air inlets:

• Primary air at the bottom (ignition)

• Secondary air at the top of the front window (air-wash, second combustion)

• Tertiary air at the back wall (high temperature gas combustion)

However, well-designed stoves can also cause high emissions and low efficiency
Field tests – measurements at stoves in private homes

Measured 1 week:
- Existing (modern) stove
- Automatically controlled wood stove
- $O_2$, $CO_2$, CO, flue gas temp.
- Amount of wood
- Temp. in– and outdoor

It is difficult to control the combustion air flows manually in an optimal way.
Manually controlled wood stove – 1

One combustion cycle

Lack of combustion air in the flame phase and too much air in the char combustion phase
Manually controlled wood stove – 2

High excess air and temperature in both the flame phase and the char combustion phase

A large potential for improving the combustion process by optimizing the combustion air flows

Four combustion cycles
Automatically controlled wood stove

Modern wood stove
+
Air box (3 motor-controlled valves and a software program)
+
Process control (the process parameters are the $O_2$ concentration and the temperature in the flue gas)
+
Remote control to starts the combustion and set the room temperature
Control of the air supply

The three air inlets are automatically controlled by

• a software program based on the definition of five combustion phases

• and the process parameters – measured temperature and O$_2$ in the flue gas
Software – overall concept

**Phase 0**
(Cold stove)

- Primary
- Secondary
- Tertiary

Regulation: None

**Phase 1**
(Ignition)

- Primary
- Secondary
- Tertiary

Regulation: Temp. and $O_2$

**Phase 2**
(Flame)

- Primary
- Secondary
- Tertiary

Regulation: Temp. and $O_2$

**Phase 3**
(Char combustion)

- Primary
- Secondary
- Tertiary

Regulation: Temp. and $O_2$

**Phase 4**
(Shut down)

- Primary
- Secondary
- Tertiary

Regulation: None

**Phase Change:**
Temperature, $O_2$ and air flow – in combination
Temperature and O₂ concentration constant and optimal during most of the combustion cycle

Phase 1:
- Ignition of wood
- A few minutes

Phase 2:
- Combustion of pyrolysis gases
- Intensive combustion with flames.
- 25 - 30 minutes

Phase 3:
- Combustion of char
- The combustion intensity decreases
- The temperature decreases, the O₂ and CO emission increase
Manually controlled

Lack of combustion air in the flame phase and too much air in the char combustion phase

Automatically controlled

Stable $O_2$ and temperature, and low CO

The same user
The same user

**Manually controlled**
High excess air and temperature in both the flame phase and the char combustion phase

**Automatically controlled**
Lower O$_2$ and temperature, and *much* higher efficiency
Experimental setup

Including: woodstove, stack, dilution tunnel, sampling sites, filters for particle collection and panel for gaseous analysis.

PM measurements:
- Filter collection based on the Noweigan Standard NS-3058
- Scanning mobility particle sizer (SMPS)
• Increase in CO/VOC/PM in phase 1
• PM peak in phase 2 but low CO/VOC
• Increase in CO (VOC) but low PM in phase 3
PM composition

- Condensable organic compounds
  
  *Example hexane (T_{boil} = 69 °C)*
  
  *Example benzene (T_{boil} = 80 °C)*
  
  *Initial release of volatiles from fuel*
  
  *Temperature/mixing in the combustion zone*

- Soot/Black carbon
  
  *High temperature & O_2 lean formation*
  
  *Potentially caused by insufficient mixing*

Charge 1: 1.8 ± 0.2 g / kg dry

Charge 2: 1.8 ± 0.8 g / kg dry

Charge 3: 1.4 ± 0.4 g / kg dry

Charge 4: 0.5 g / kg dry
Conclusions

- A first version of an automatically controlled wood stove, HWAM IHS, has been developed and launched on the market.

- Results from a development and demonstration project have shown significantly reduced emissions and high efficiency for the automatically controlled stoves compared to manually controlled stoves.

- The new control system ensures improved stove operation even when used by private wood stove owners.
Thanks for your attention