On the design of biomass-fired heat-storing stoves for the heating of buildings

Finnish-Swedish Flame Days 2013
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Introduction

- Wood firing is a traditional heating method in Nordic countries.
- Wood is a renewable and local energy source.
- Integration of wood firing into zero-energy buildings needs to be considered.
What’s new?

• Plenty of work on wood burning has been carried out by people studying fire safety.
• Can any of that work be applied in energy engineering?
Methodology

Main focus in this work

Real-life engineering

Simple models

Complex models

\[ \dot{Q} = at^2 \]

\[ \ddot{v}_x \frac{\partial v_x}{\partial x} + \ddot{v}_y \frac{\partial v_x}{\partial y} = -\frac{\partial \bar{P}}{\partial x} + \frac{1}{Gr} \left( \frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} \right) \]

\[ \ddot{v}_x \frac{\partial v_y}{\partial x} + \ddot{v}_y \frac{\partial v_y}{\partial y} = -\frac{\partial \bar{P}}{\partial y} + \frac{1}{Gr} \left( \frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \bar{T} \right) \]
Firewood specification

Assume: $b = 10\ \text{cm}$, $L = 30\ \text{cm}$
Each log contains 6 kWh of chemical energy
Burning time vs. heat release rate

Case TT051

- Burning time 15 min / Spec. HRR 172 kW/m²
- Burning time 30 min / Spec. HRR 86 kW/m²
- Burning time 60 min / Spec. HRR 43 kW/m²
- Burning time 120 min / Spec. HRR 21 kW/m²
- Burning time 240 min / Spec. HRR 11 kW/m²
What next?

• Conclusions:
  – Normal-size wood logs cannot really be burned at a rate which would match the heat demand of the building.
  – Two things will be needed to solve the problem:
    (1) the burning rate must somehow be limited and
    (2) the stove must have significant heat storage capability.

=>  Study the burning of cribs to handle (1).

=>  Study stoves with massive walls to handle (2).
Wood cribs

• Developed for use as ignition sources in fire experiments (repeatability).
• Can be designed to achieve desired burning characteristics (burning time, heat release rate).

A wood crib before a fire test (left) and after the test (right).
Effect of crib design

![Graph showing the effect of crib design on Specific HRR. The graph plots Number of layers against Specific HRR [kW/m²]. Two series are shown: Series 1.90-5-X and Series 1.90-7-X. Series 1.90-5-X has a nearly constant Specific HRR across different numbers of layers, while Series 1.90-7-X shows a decreasing trend.]
Heat storage capability

Schematic view of a heat storing stove with side channels for better utilization of the heat content of the flue gas.
Temperature evolution in the stove wall

Temperature of stove material
(assumed to consist of one or two layers, both of them assumed to be thermally thin)

Calculated using the lumped-capacity model (thermally thin walls). This needs to be improved.
Conclusions

- Heat storage capability is an essential feature of good wood-fired stoves.
- Appropriate fuel preparation and firing practices must be employed.
- Modeling work will be continued on heat release rate and heat storage behavior.
- Main emphasis on simple models.

Thank you for your attention!