Recent developments concerning pellet combustion technologies in Austria

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Overview

- Overview of the pellet market and general framework conditions in Austria
- State-of-the-art of Austrian pellet boiler technology
- Pellet boiler innovations in Austria
  - Furnace optimisation and development based on CFD simulations
  - Flue gas condensation
  - Multi fuel concepts
- Emissions
- Future developments
  - Reduction of particulate emissions
  - Utilisation of herbaceous biomass fuels
  - Micro and small-scale CHP systems
- Summary
Development of small-scale pellet furnaces in Austria

Source: [Lower Austrian Chamber for Agriculture and Forestry, 2006]

Number of newly installed pellet central heating units

Year


0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000 10,000

- Feed from storage tank
- Feed from storage room

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Pellet production in Austria – present state and outlook

Source: [Geisslhofer, 2000: Wood pellets in Europe; own enquiries]

* estimate
Pellet consumption in Austria (year 2005)

- About 37,000 pellet central heating systems already installed in Austria
- Total nominal boiler capacity installed: about 690 MW
- Annual utilisation rate: about 74%
- Boiler full load operation hours: 1,500 h p.a.
- Net calorific value of pellets: 4.9 kWh/kg (w.b.)

Pellet consumption in Austria approximately 287,000 t/a
(related to pellet central heating systems)

Additional amounts related to pellet stoves (9,000 units already installed) and medium-scale pellet furnaces (100 to 1,000 kW<sub>th</sub>)

Difference to production: mainly export
General framework in Austria

- Investment subsidies granted in Austria between 20 and 25% (depending on the Austrian provinces)

- Currently 17 pellet producers active or near start-up in Austria (total pellet production in Austria almost 500,000 t in 2005)

- Pellet quality, transport and storage regulated by ÖNORM M 7135, M 7136 and M 7137

- Quality of pellet furnaces regulated by ÖNORM EN 303-5

- Supply of pellets in Austria assured throughout the country by a well organised distribution network

- About 30 manufacturers of small-scale pellet furnaces in Austria
Pellet combustion systems

Pellet stoves

Source: [RIKA Metallwaren-ges.m.b.H. & Co KG, Austria]

Pellet central heating systems

Grate fired pellet boilers for medium-scale applications
(150 to 300 kW\text{th})

Source: [GUNTAMATIC Heiztechnik GmbH, Austria]

Pellet burners

Source: [Gilles Energie und Umwelttechnik GmbH, Austria]

Source: [KWB Kraft und Wärme aus Biomasse GmbH, Austria]
Common and proven features of state-of-the-art pellet boilers

- Proven control systems based on combined load and combustion control
  - Load control by regulation of the fuel and primary air feed guided by the feed water temperature
  - Combustion control:
    • By regulation of the secondary air feed
    • Usually guided by the O₂ concentration in the flue gas (lambda sensors)
    • Partly guided by the furnace temperature

- Air staging (primary and secondary combustion zone with separate air feed)

- Burn-back protection (by automatic extinguisher system, cellular wheel sluice or fireproof valve)
Overview of the state-of-the-art of Austrian pellet boiler technology (2)

- Resistant materials for the combustion chamber (stainless steel, firebrick or silicon carbide)
- Vertical fire tube boilers
- Automatic or semi-automatic boiler cleaning (with a clear tendency towards automatic boiler cleaning systems)
- Ash compaction or de-ashing in external ash containers
- Proven feeding systems (flexible or inflexible screw conveyors, pneumatic systems, agitators or combinations)
- Storage rooms with a storage capacity of 100 to 150% of the annual fuel demand (used by 90% of the users) or with integrated storages to be filled on a weekly or monthly basis (used by 10% of the users)
Relevance of automatic control systems

Notes:

- Data related to the current operating conditions
- Change of load from 15% part load to nominal load

Importance of automatic control systems to guarantee low CO, TOC and fine particulate emissions at all load conditions (start-up, shut-down, load changes, full and part load operation)
Basic principles of wood pellet combustion systems concerning pellet supply

- Underfed burners
- Horizontally fed burners
- Overfed burners

Source: [Handbook of Biomass Combustion and Co-Firing, IEA, 2002]
Basic wood pellet burner designs (1)

**Retort furnaces**
(only in combination with underfed burners)

**Grate furnaces**
(only in combination with horizontally or overfed burners)

Source: [KWB Kraft und Wärme aus Biomasse GmbH, Austria]

Source: [Windhager Zentralheizung GmbH, Austria]
Basic wood pellet burner designs (2)

Step grate

Hinged grate

Source: [GUNTAMATIC Heiztechnik GmbH, Austria]
Example for an underfed burner (retort furnace)

Source: [KWB – Kraft und Wärme aus Biomasse GmbH, Austria]
Example for an overfed burner with hinged grate

Source: [GUNTAMATIC Heiztechnik GmbH, Austria]
Pellet boiler innovations already available on the Austrian market

- **Furnace optimisation and development based on CFD (Computational Fluid Dynamics) simulations**

- **Flue gas condensation** (increase of efficiency, reduction of dust emissions)

- **Multi fuel concepts** (e.g. pellets/firewood or pellets/wood chips combinations)
Furnace optimisation and development based on CFD simulations

- Nowadays furnace development and optimisation is often based on test runs and operating experiences
  - Time and personnel intensive
  - Without detailed knowledge about the processes ongoing in the furnace

- Several advantages of CFD simulations (new approach)
  + Provide detailed knowledge about ongoing processes in the furnace
  + Three-dimensional visualisation over the whole furnace volume is possible (e.g. profiles of temperature, flue gas flow, $O_2$ and CO)
  + Better understanding about the combustion process as well as weak points can be provided
  + Shorter development times and higher reliability of the developments
  + Number of prototypes needed can be minimised
Design and optimisation of the nozzles for the injection of secondary air by CFD

Vectors of the flue gas velocity [m/s] in the horizontal cross-section right over the secondary air nozzles

Basic nozzle design

Improved nozzle design

→ CFD-based furnace and nozzle design of great relevance

Source: [BIOS BIOENERGIESYSTEME GmbH, Austria, 2002]
Pellet furnace with integrated flue gas condensation

- First pellet boiler with integrated flue gas condensation
- Market introduction: 2004
- Efficiency: 103%
  (according to type test by BLT Wieselburg)
- Nominal capacities: 8, 10, 15 and 20 kW

Source: [ÖkoFEN, Austria, 2004]
Flue gas condensation systems for retrofitting conventional pellet furnaces

- Several retrofitting flue gas condensation systems are close to market introduction

Schräder Hydrocube

POWERcondenser

ÖkoCarbonizer

Source: [Schräder, Germany, 2006]

Source: [POWERcondens, Switzerland, 2006]

Source: [Bschor, Germany, 2006]
Boiler efficiency as a function of flue gas temperature and O₂ concentration in the flue gas

Source: [BIOS BIOENERGIESYSTEME GmbH, Austria, 2002]
Efficiencies of pellet boilers with and without flue gas condensation

With flue gas condensation

Without flue gas condensation

Efficiency [%]

Source: [Austrian Bioenergy Centre GmbH, Austria]
Fine particulate emissions of pellet boilers with and without flue gas condensation

Source: [Austrian Bioenergy Centre GmbH, Austria]
Framework conditions for flue gas condensation

- Return temperature from the heating system as low as possible
  - Preferably below 30°C
  - Possible with properly dimensioned floor or wall heating
  - Optimisation is possible by integration of the boiler loading circuit (by pre-heating the fresh water)

- Chimney must be fire resistant, non-sensitive against moisture and corrosion resistant

- In case of operation with overpressure the chimney must be pressure-tight

- Flue gas condensation can reduce particulate emissions
In Austria, the condensate of small-scale pellet boilers with flue gas condensation can be discharged to the sewer without cleaning and neutralisation according to the Austrian waste water emission act (Abwasseremissionsverordnung), if the following requirements are fulfilled:

- Fuel power input below 400 kW
- Use of pellets according to ÖNORM M 7135
- A positive type test of the respective furnace exists
- Respective emission limits must be met (the concentrations of Pb, Cd, Cr, Cu, Ni, Zn and Sn in the condensate are limited)
- Corrosion resistant material must be used for the heat exchanger and the discharge pipe for the condensate
- A regular inspection of the furnace is required
Multi-fuel concepts of pellet boilers

- Proven concepts are already available on the market
  
  - Wood pellets / wood chips combinations (automatic operation for both fuels)
  
  - Wood pellets / firewood combinations, different levels of automation depending on the type:
    - Simple boiler concepts have to be adjusted and operated manually in case of operation with firewood
    - Sophisticated boilers identify the fuel automatically
    - For both boiler types several applications are available
Boiler for wood pellets / wood chips operation

- Nominal thermal capacity: 150 kW
- Innovative rotary grate furnace (robust, calm bed of embers, optimised gasification conditions)
- Innovative cyclone combustion chamber (optimised by CFD simulations, efficient fly ash separation, flue gas recirculation)
- Fuels: wood chips (up to w50) and wood pellets
- Automatic operation for all fuels

Source: [KWB – Kraft und Wärme aus Biomasse GmbH, Austria]
Boiler for wood pellets / firewood operation

- Nominal thermal capacity: 2 types with 14.9 and 25.0 kW
- Fuels: wood pellets and firewood
- Automatic fuel identification
- No manual adaptations needed
- Automatic operation for all fuels (ignition of firewood with the pellets burner)

Source: [sht-Heiztechnik aus Salzburg GmbH, Austria]
Emissions

Source: [Spitzer et al, 1998; BLT Wieselburg, 2006]
CO emissions – comparison between old and new pellet furnaces

Source: [Jungmeier et al, 1999; BLT Wieselburg, 2006; results from test stand measurements]
Dust emissions – comparison between old and new pellet furnaces

Source: [Jungmeier et al, 1999; BLT Wieselburg, 2006; results from test stand measurements]
About 90 to 95% of the total dust emissions are fine particles (< 1 µm)

The fine particles consist of 2 fractions: organic and inorganic aerosols

Organic aerosols are due to incomplete gas phase burn-out (formed by condensation of hydrocarbons)

Inorganic aerosols are due to nucleation and condensation of ash forming vapours (main elements: K, Na, S, Cl, Zn, Pb)

A relevant factor to minimise fine particulate emissions is therefore to achieve a complete burnout in order to avoid organic aerosol formation

The chemical composition of the fuel strongly influences fine particulate emissions (the amount of inorganic aerosols formed)
Fine particulate emissions – influence of the fuel composition

Explanations: Emissions related to dry flue gas and 13 vol.% O₂; d.b. ... dry basis; results from measurements at grate furnaces with nominal capacities between 400 kW_th and 50 MW_th.
Future developments

- Reduction of particulate emissions (especially PM1)
  - Electrostatic precipitators for micro-scale applications
  - Metal fabric filter
  - Flue gas condensation (already discussed, further research activities ongoing as additional potential for particulate emission reduction is given)

- Utilisation of herbaceous biomass fuels

- Micro and small-scale CHP systems
  - Stirling engines
  - Thermoelectric generator
Several research activities regarding electrostatic precipitators (ESP) and metal fabric filters for residential applications are known.

Focus of further developments:

- Reduction of costs
- Achievement of a high availability of the systems
- Improvement of the collection efficiency
ESP developed by the Swiss Federal Institute for Materials Research and Testing (1)

Source: [Schmatloch, 2005]
Laboratory and field tests have been performed over several months for small wood fired appliances (fireplaces, stoves, ovens)

- Collection efficiency of up to 80% in laboratory tests
- Collection efficiency of up to 60% in field tests
- No automatic cleaning (measurements performed with clean unit)
- Adaptation of the system for the use in automatic heating systems (first tests with an automatic pellet boiler showed an overall collection efficiency of about 90%)

- Aim: applications for pellet boilers and stoves with nominal boiler capacities < 30 kW
- Status: prototype, small series production with 50 units planned in autumn 2006 (company: Rüegg, Switzerland)
Utilisation of herbaceous biomass fuels in small-scale pellet boilers

- Several R&D activities are ongoing concerning the thermal utilisation of herbaceous biomass fuels in the residential heating sector (especially the use of corn or straw pellets in automatic appliances like pellet boilers)

- Herbaceous biomass fuels have several drawbacks regarding thermal utilisation
  - Increased ash content (up to 12 wt.% (d.b.), consequently reduced convenience for the end user)
  - Increased contents of S, Cl, N and K (compared to woody biomass fuels)
  - Problems regarding dust and aerosol emissions, corrosion, deposit formation and slagging must be expected
  - Higher NO$_x$, SO$_x$ and HCl emissions are to be expected

- Thermal utilisation of herbaceous biomass fuels in the residential sector can not be recommended!
Ongoing research project at the Austrian Bioenergy Centre, Graz

Basic intention is to produce at least the auxiliary electrical power needed by the pellet boiler in order to make independent operation possible

Electric efficiency of TEGs: 5 to 6% (increase to 10% by future developments probably possible)

Targeted electric plant efficiency: around 1% (sufficient to ensure independent operation)

Available as prototype
Advantages of TEGs:

- Long maintenance free operation
- Noiseless operation
- No moving parts

Disadvantages:

- Lifetime is still low
- Considerable further development work is required
- The main challenge is the integration of TEGs in pellet burners and their optimisation with regard to electricity generation and availability

Source: [Austrian Bioenergy Centre GmbH, Graz, 2006]
Newly developed micro-scale CHP technology based on a Stirling engine for pellet furnaces

- CHP unit developed for residential pellet boilers
- Existing pellet furnaces can be retrofitted with the CHP module
- Nominal electric capacity: 1 kW\textsubscript{el}
- Electric plant efficiency: about 6%
- Main aim: production of sufficient electricity for an average household
- Field tests with 40 units are planned for the winter 2006/07

Source: [SPM Stirling Power Module Energieumwandlungs GmbH, Austria, 2006]
New small-scale CHP technology based on Stirling engines for wood chips and pellet furnaces

- **1st pilot plant:**
  - Nominal electric capacity: 35 kW\(_{el}\)
  - Start-up: 2002
  - Operating hours up to now: 12,000

- **2nd pilot plant:**
  - Nominal electric capacity: 75 kW\(_{el}\)
  - Operating hours achieved in test runs between October 2003 and December 2005: > 7,000

- Electric plant efficiency: approximately 11 to 12%

- Fuels:
  - Pellets, wood chips, sawdust

- Comprehensive field tests ongoing

Source: [BIOS BIOENERGIESYSTEME GmbH; MAWERA Holzfeuerungsanlagen GesmbH, Austria, 2005]
Stirling engine and hot combustion chamber

Stirling engine

Flue gas flow towards Stirling engine
Still rapidly expanding pellet market in Austria

Proven feeding and combustion technologies available from many furnace manufacturers which ensure a fully automatic operation at low emissions and high efficiencies

Pellet boiler innovations available on the market (CFD based developments, flue gas condensation, multi-fuel concepts)

Several research activities and promising developments focusing on the reduction of fine particulate emissions as well as micro and small-scale CHP systems

Utilisation of herbaceous biomass fuels (straw, corn) in small-scale applications not recommended
Forthcoming book

- Publication in the book series “Thermal biomass utilisation” of the Institute for Resource Efficient and Sustainable Systems, Graz University of Technology
- Publication of the German version: autumn 2006
- Translation to English is planned, to be published in 2007
- Pre-order available via Internet: http://www.bios-bioenergy.at/