Overview of Burner tests in Vattenfall’s Oxyfuel Pilot Plant

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Gerd Weiß
Vattenfall, BU R&D Projects

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Start up test operation Sept. 2008

Until 17,000 operating hours in total, from it 13,200 in Oxyfuel mode, captured CO₂ approx. 10,660 t

CO₂ removal rate > 90 %

High plant availability

Good CO₂ quality for transport, storage and CCU

Thermal capacity: 30 MWₜₜ
Coal demand: 5.2 t/h
Investment: 80 Mio. €
Total costs: 150 Mio. €

Technology partner:
Boiler and Measurement points

Furnace

2\textsuperscript{nd} draft
Soot blower before each superheater and eco

Measurement level 1, +17500
Measurement level 2, +16500
Measurement level 3, +14500
Measurement level 4, +13000
Measurement level 5, +12000
Measurement level 6, +10000

Level 12
Level 13
Level 14

Floor level, +0

30 MW burner top mounted

Front wall
Left side wall
Right side wall

~1000
~1050
~1050
~1050

~1000
~1000
~1050
~1050

~1000
~1000
~1050
~1050

~1000
~1000
~1050
~1050

3
2
1
2
5

OFA 1 & 2
SCR 1
SCR 2
SCR 3

13m high
4x4m cross area

Ash transport

Burner

Steam drum

Eco 1
Eco 2
Eco 3
Eco 4
Eco 5

L 7, +9000
L 8, +11500
L 9, +15500
L 10, +18500
L 11, +21000
Direct coal dosage to burner

Combustion behaviour can only be judged in connection with coal dosage
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## Requirements on burners

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<th>Burner characteristic</th>
<th>Requirements</th>
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| Fast start ability, stable ignition, stable flame | - Ignition within 5 seconds  
- Hot-, warm- and cold start ability           |
| High combustion quality:                      | - O₂ excess in flue gas (downstream boiler) < 4%  
- compliance emission limits (CO, NOₓ, dust)  
- unburned in ash < 2%                         |
| Flexibility for fuel quality                  | - high range of particle size distribution  
- Variation to LHV                           |
| Transport and combustion gas                  | - Combustion gas: air or O₂-mixed flue gas (21%-39%)  
- Fuel transport gas: air or CO₂-rich flue gas  
- Fuel loading up to 5 kg / kg transport gas   |
| Possibility to swirl of secondary airs        | - Optimal intermixing of coal stream by swirl of secondary airs  
- Influence on flame characteristics regarding heat transfer behaviour |
Overview of tested burner

Burner 1: comb. Jet-/swirl burner

Burner 2: pure swirl burner

Burner 3: pure swirl burner

Burner 4: swirl burner as pre-mixed burner

Burner 5: swirl burner with pre-mix possibility
## Overview of constructions

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<th>Burner type</th>
<th>Characteristics</th>
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| **Combined Jet-/swirl burner** | - concentric formation of one core pipe for oxidant supply, one fuel/transport gas and **three** secondary oxidant cross-sections  
- length of flame nearly up to exit of firth path of the boiler |
| **Pure swirl burner**       | - concentric formation of one core pipe for oxidant supply, one fuel/transport gas and **two** oxidant cross-sections  
- Conduct of flame with a high swirl rate  
- Flame is short and shows characteristic bell shape |
| **Pre-mixed swirl burner**  | - concentric formation of one core pipe for oxidant supply, one fuel/transport gas and **three** secondary oxidant cross-sections  
- swirl generator located in secondary and tertiary oxidant supply. Option to modify the angle of swirl generator  
- Injection of fuel directly into third oxidant supply cross section |
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Overview of burner tests

- Flame characteristics and heat transfer
- Switch from Air to Oxyfuel operation and back
- $O_2$ concentration in combustion air (burner lambda, boiler lambda)
- Reduction $O_2$ excess at compliance emission values
- Swirl variation
- In-flame measurements
- Optimization firing behaviour with variation OFA
- part load behaviour
- different lignite qualities (sulfur, particle size distribution)
Comparison of operational points in Oxyfuel

characteristic diagram for different burner test

O2 in oxidant (in %)

O2 in fluegas (Vol %,f)

TC = Test Campagne of burners

TC 3
TC 4
TC 5
TC 6
TC 7

TC = Test Campagne of burners

VATTENFALL
Emissions in Oxyfuel: NOx, CO vs. excess O_2 (TC 5)
O$_2$-Mix: Pre-mixed mode, Expert mode und Hybrid mode

Pre-mixed mode

Expert mode

Hybrid mode
Comparison of burner operational area on varied operation mode and in respect to emission limits

![Graph showing comparison of O2 in flue gas and Oxidant with different operation modes.]

- Pre-mixed Mode
- Expert-Mode
- Air operation
- Hybrid-Mode

O2 in flue gas (Vol.-%, w)

O2 in Oxidant (Vol.-%, w)
Influence of swirl change on flame shape and temperature

Before adjustment
swirl SA1/SA2

After adjustment
swirl SA1/SA2
# Overview of burner tests

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<th>Burner tests</th>
<th>Results</th>
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<tr>
<td>Flame characteristics and heat transfer</td>
<td>Stable flame without pulsation, - Flame shape (volume and length)</td>
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<td>Switch from air to Oxyfuel operation and back</td>
<td>In general in 20 minutes realized</td>
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| $O_2$ concentration in combustion air (burner lambda, boiler lambda)          | Variation $O_2$ content 21% to 39% in different burner register  
Reduction $O_2$ excess at compliance emission values                          | Stable operation $< 3\% \text{ } O_2$ excess possible                                                                                   |
| Swirl variation                                                              | Swirl of secondary air flows necessary                                                                                                                                                           |
| In-flame measurements                                                        | Validation for CFD burner model possible                                                                                               |
| Combustion behaviour with variation OFA (staged combustion)                  | Optimisation OFA has influence of combustion behaviour (reduce NOx/CO)                                                                  |
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Features of OxyAir Burner 5

- Low-NO$_x$-Technology
- Load Range 100% down to 30%
- Fuel Load up to 4 kg/kg
- Applicable for Oxyfuel and Air Operation Mode
- Flame Stabilizer and Swirler for reliable Ignition and stable Flame
Test of ignition by Microwave-Plasmatron

Microwave-Plasmatron:
- No electrodes that could wear, low afford of maintenance
- Easy construction
- Low power consumption for ignition
- Technology is in development, currently no commercial solution available
- Limited in size
- Due to high temperature of plasma flame an external cooling is required

Concept:
- Direct Ignition of dried lignite by Microwave Plasmatron
- Usage of up to 3 plasma lances for ignition during tests operation
- Control of ignition by control box on-site
- Supply of external media e.g. power, compressed air and cooling water

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Ignition of 30 MW dry lignite burner with plasma lances
# Test results electrical Ignition

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<th>Criteria</th>
<th>Target</th>
<th>Actual</th>
<th>Comments</th>
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<tr>
<td>Number of plasma lances</td>
<td>3 - 1</td>
<td>1</td>
<td>All major issues of optimization are carried out with one plasma lance</td>
</tr>
<tr>
<td>Position of plasma lance</td>
<td></td>
<td></td>
<td>Optimal position is dependent on burner design</td>
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<tr>
<td>Boiler temperature</td>
<td>Cold boiler</td>
<td>43°C</td>
<td>Successful ignition in cold boiler</td>
</tr>
<tr>
<td>Start up load of burner</td>
<td>15 MW</td>
<td>3 - 15 MW</td>
<td>Successful Ignition over a wide Range, lowering of start performance on 10% (3 MW )</td>
</tr>
<tr>
<td>el. load for ignition of plasma lance</td>
<td>3 kW</td>
<td>2 kW</td>
<td>Successful Ignition with 2 kW el. Load</td>
</tr>
<tr>
<td>Temperature of combustion air</td>
<td>Without pre-heating</td>
<td>30 °C</td>
<td>Successful ignition without preheating of combustion air</td>
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<tr>
<td>Long term experience</td>
<td></td>
<td>&gt; 100 Start</td>
<td>Get more information about ignition behaviour after long term deposition in boiler</td>
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Summary and outlook

- Vattenfall cooperated with many technology partners for the burner development for Oxyfuel (5 burners from 4 different manufactures)
- Verified stable ignition and burnout behaviour
- Stable operation with high O$_2$ concentration in oxydant and low O$_2$ excess. All emission limits are reached.
- Pre-mixed mode for commercial CCS plant sufficient
- Burner design depends on firing concept
- Electrical ignition burner is an economical alternative

➡️ Vattenfall is ready to scale up for a demo plant
Thank you for your attention!