Microwave Pre-Treatment of Coal and Coal Blends to Improve Milling Performance

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Aims and Objectives

- Quantify grindability changes as a result of treatment
  - Determine influence of coal type on produced energy savings

- Optimisation of microwave treatment for different coal types
  - Cavity type
  - Microwave power and irradiation time
  - Microwave delivery method

- Quantify influence of microwave treatment on coal burnout behaviour

- Preliminary techno-economic analysis of microwave assisted coal grindability at pilot scale
Background and Previous Work

• Coal grinding for power generation is highly energy intensive

• Strong drivers to reduce energy consumption and also produce finer product size distribution

• Many workers have suggested application of MW energy to coal
  • desulphurisation
  • drying
  • thermal embrittlement

• Significant technical interest but economics were often poor
Microwave Heating Basics

- Conventional heating
  - entire furnace is hot
  - sample hotter on surface (initially)

- Microwave heating
  - only sample is heated
  - heating is volumetric
  - sample ends up hotter in centre
  - heating can be highly selective
  - relies upon dielectric properties of individual phases
Industrial Microwave Heating System

Diagram:
- **Incoming Supply**
- **Microwave Power Unit**
  - Power supplies and protection systems
  - Magnetron or klystron tube
  - Circulator
- **Water Load**
- **Control and Automatic Systems**
- **High Frequency Breakdown Phenomena**
- **Conventional Heating Equipment or Heat Pump or Other Electrical Heating Systems**
- **Applicator**
- **Vacuum Processing**

Hybrid System
Multi-Mode Applicators

- Field distribution within a load depends on dielectric properties, size and location

- Multi-mode applicators best suited to large volume loads (>50% vol.)

- Small loads give non uniform temperature distribution due to uneven field distribution

- Can use turntable or mode stirrer to ‘smear’ the electric field

- Reliable scale up is very difficult
Single Mode Applicators

• By far the most efficient applicator
• Field pattern is well defined and target load positioned accordingly
• Very high power densities (electric field strengths) and heating rates possible
• Formation of standing wave limits physical size (maximum diameter is one wavelength)
• Used for heating low loss factor (hard to heat) materials
Methodology

• Characterisation of coals both pre and post treatment (6 coals)
  – Size analysis
  – Proximate analysis
  – Petrographic assessment
  – Hardgrove grindability
  – Ball Mill grindability tests
  – Intrinsic reactivity

• Microwave treatment
  – Initial work focused on batch treatment using single mode cavity
  – Heating rate orders of magnitude faster than previous testwork

• Pilot scale >t/hr grinding
  – Lupulco Mill
  – Ball Mill
Microwave Treatment

3-15kW @ 2.45GHz, 0.1 S
Example Results e.g. La Loma

La Loma +16.00-19.00mm  
MW-Treated  
Untreated

La Loma +9.50-13.20mm  
MW-Treated  
Untreated

La Loma +4.75-6.70mm  
MW-Treated  
Untreated
Example Results e.g FF Indonesian

**Graph 1:**
- **FF Indonesian +16.00-19.00mm**
- **MW-Treated**
- **untreated**

**Graph 2:**
- **FF Indonesian +9.50-13.20mm**
- **MW-Treated**
- **untreated**

**Graph 3:**
- **FF Indonesian +4.75-6.70mm**
- **MW-Treated**
- **untreated**
Why Does the Grindability Change?

Macro scale fissures created by MW-treatment

Micro scale fissures created by MW-treatment

(320x mag)
### How is the Coal Influenced?

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<th></th>
<th>Volatiles</th>
<th>Fixed Carbon</th>
<th>Fuel Ratio</th>
<th>Volatiles</th>
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Preliminary Conclusions

- MW treatment can significantly improve the grindability of coal
  - High moisture content
  - Hard coals

- Treatment induces slight change in moisture content

- Little change in:
  - Volatile content
  - Fuel ratio

- Scale up needs to be addressed:
  - Cavity design
  - Continuous treatment
Cavity Design Issues

Power Density Plot

(EM simulations by Stellenbosch University, South Africa)
Continuous Tunnel Applicator

- Self cancelling steps to achieve vertical uniformity
- Good lateral uniformity inherent in design
- Confirmed by single and multiphase simulation
- Watt for Watt, this is the best design to maximise throughput

*(EM simulations by Stellenbosch University, South Africa)*
Effect of Reflection Step

(EM simulations by Stellenbosch University, South Africa)
Processing Uniformity

- Lateral uniformity very good

- Vertical uniformity acceptable due to step

(EM simulations by Stellenbosch University, South Africa)
Commissioned Design

3-15kW, 2.45GHz >8t/hr -19mm feed
Acknowledgements

• BCURA for funding this project
• E-ON and EDF Energy for providing coal samples and test assistance
• University of Stellenbosch, South Africa for electromagnetic simulations