Influence Of Temperature On The Dielectric Properties Of Unburnt Carbon In Ash From Stoker Furnace Bottom Ash

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Sugar Mill Stoker Furnace

Stoker furnace with an over-grid feeding system

Source: ValveExport
Inside the Furnace
Aim: Gain an understanding of how dielectrics carbon in ash vary with carbon content, mineral composition and temperature

Objective: Develop methodology of measuring carbon in ash in real time using dielectric properties

Experiment:

• Tested 3 industrial ashes and several minerals with varying carbon contents different cavities to ascertain dielectric properties at different carbon contents

• Tested 3 industrial ashes at high temperatures to see how dielectric properties vary with temperature
Dielectric Properties

- All materials interact with materials under the influence of an electromagnetic field.

- The electrical interaction of materials is described by its permittivity.

- The absolute complex permittivity ($\varepsilon$) of a material is:

$$\varepsilon = \varepsilon' - j\varepsilon''$$

- Where $\varepsilon'$ is the dielectric constant and $\varepsilon''$ is the dielectric loss factor.

- $\varepsilon'$ describes a material's ability to absorb electrical energy, while $\varepsilon''$ is a material's ability to reject this energy as heat.
Dielectric Properties at Different Frequencies
Dielectric Properties of Common Materials at 2.45 GHz

- Alumina Ceramic
- Fused Quartz
- Borosilicate Glass
- PTFE
- Silicon Coated Glass Fibre Belt
- PVC
- Rubber Nitril
- S01
- S02
- Water @25°C
- Water @85°C
- 0.1 Molar NaCl Solution
- Potato @25°C
- Ethanol
- Snow @-20°C
- Ice @-12°C
Cavity 1 – Proof of Concept

- Copper cavity connected to network analyser
- 5 different frequencies between 937 MHz and 5.6 GHz tested
- 3 industrial ashes and 4 minerals tested with varying carbon contents (by weight)
- Carbon contents: Fly Ash 1 - 2.2%, Fly Ash 2 – 10%, Fly Ash 3 – 6.6%
Cavity 1 – 937 MHz – Fly Ash 1

![Graph showing power vs frequency for different ash compositions.](image-url)
Cavity 1 – 937 MHz – Minerals – Calcium Carbonate

![Graph showing frequency response with different percentages of carbon.](image-url)
Cavity 2 – Cavity Perturbation Technique

- Vector Network Analyser
- Automated motor
- Associated computer and screen
- Furnace
- Cavity
- Furnace Temperature control unit
Dielectric Constant of Fly Ash 1 with Varying Carbon Content
Dielectric Loss of Fly Ash 1 with Varying Carbon Content

![Graph showing dielectric loss with varying carbon content in different fly ash compositions.](image-url)
High Temperature Dielectric Properties of Coal

The graph shows the variation of dielectric constant $e'$ and dielectric loss $e''$ with temperature ($°C$) for two frequencies: 910 MHz and 2470 MHz. The dielectric constant $e'$ generally decreases with increasing temperature, while the dielectric loss $e''$ increases sharply above a certain temperature.
High Temperature Dielectric Constant of Ash at 2470 MHz
High Temperature Dielectric Loss of Ash at 2470 MHz
Summary

• Proof of concept tests show that the dielectric properties of ash varies with carbon content

• Signal depends on carbon content and mineral composition of the ash

• Dielectric properties of coal and unburnt carbon in ash are very different

• Up to 400 degrees, dielectric constant of industrial ashes is stable, and then drops with increasing temperature

• Knowledge of dielectric properties can be used to develop continuous inline monitoring system for carbon in ash contents
Thank you for listening

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