Introduction

Scale generation decreases power generation efficiency in thermal power plants.

- What is scale?
  - Iron oxide generated by corrosion of water supply system pipes
  - Thermal conductivity is about 10% of pipe material
  - Adhesion on pipe wall decreases in power generation efficiency.

Removal of the scale can prevent decreases in power generation efficiency and reduce CO₂ emission.

Water treatment in thermal power plant

- Heat treatment (thermal power plant)
  - AlVolte Treatment
  - HGMS System and practical place to install

Main component of the scale

- Hematite (Paramagnetic) Fe₂O₃
- Magnetoferrous Fe₁₋₂O₄
- Goethite (Paramagnetic) α-FeOOH (γ=1.2-10)

In this study, we targeted Oxygenated Treatment (OT) scale.

Lab-scale magnetic separation of hematite

- Purpose of analysis
  - To investigate change in the hematite capture performance of the filters used in the HGMS system by the temperature.

- Analysis conditions
  - Analysis conditions
    - Filter conditions
      - Filter number: 60
      - Mesh opening: 0.32 µm
      - Wire diameter: 0.3 mm
    - Filter material: Magnetite
      - Magnetic field direction: Right
      - Fluid direction: Right
      - Fluid temperature: 80 ℃

- Calculation method
  - The saturated trapping capacity of hematite per filter was estimated from the inflection point of the particle trajectory calculation.

- Results and Discussion
  - At high temperature, the drag force becomes smaller due to the decrease in viscosity, and the saturated trapping capacity is expected to increase.
  - The capture amount was larger than that of the experimental value, which may be due to the deposition of hematite particles not in a close-packed structure.

HGMS System and practical place to install

- High gradient magnetic separation method (HGMS)
  - When a ferromagnetic filter is installed in the magnetic field, the field gradient is generated around the filter, and ferromagnetic and paramagnetic materials are trapped by the magnetic force.

- Magnetite force (force received from the filter)
  - Magnetic field strength (B) × B
  - Drag force (force received from fluid)
  - Fluid velocity (v) × Fluid velocity (v)

- Particle radius (r)
- Magnetic susceptibility (χ)
- Permeability of vacuum (µ₀)
- Magnetic flux density (B)
- Viscosity coefficient (μ)
- Fluid velocity (v)
- Particle velocity (u)

When magnetic force > drag force, the scale magnetic separation is possible.

Removal with high-gradient magnetic separation (HGMS)

- Operable under high temperature and high pressure
- Low pressure drop due to coarse filters
- Filters can be reused by cleaning

Solidsaid superconducting magnet

Water flow

HGMS diagram

Ferromagnetic filters

Removal with HGMS by soluble paramagnetic particles

- Removal of Iron Oxide Scale from Boiler Feed-water in Thermal Power Plant by Magnetic Separation -
  - Aggregation States of Oxygenated Treatment Scale -

- Purpose of experiment
  - To investigate magnetic separation properties of hematite and compare with analytical results.

- Experimental conditions
  - Experimental equipment of HGMS
    - Filter number: 60
    - Mesh number: 0.32 µm
    - Wire diameter: 0.3 mm
    - Applied magnetic field at the center
      - 11-15 T
      - 70 cm/sec
      - Separation (200 ppm)

- Experimental results
  - The overall separation rate of hematite was 20.9% at 500 ppm and 16.0% at 500 ppm.
  - The average capture amount per filter for the 1st stage separation from the inlet side was 0.12 g at 200 ppm and 0.23 g at 500 ppm.
  - From the experiment at 500 ppm, the calculation of capture particles is reasonable.
  - From the empirical formula, it was estimated that the capture rate of hematite is 40% at 25 ℃ and 98% at 80 ℃, using 150 filters.

- Results and discussion
  - From the particle trajectory calculation and the experiment, the calculation of capture particles is reasonable.
  - It was estimated that about 98% of scale can be captured by 150 filters at 80 ℃.

Summary

- From the particle trajectory calculation and the experiment, the calculation of capture particles is reasonable.

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