A Superconducting Demonstrator Magnet for Magnetic Density Separation

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Magnetic Density Separation?

MDS: novel recycling technology

Ferrofluid + Vertical magnetic field gradient

Particles are separated by mass density

Flow laminator

Separation chamber

Separator blades

Post-processing

(plenum)

Saturated ferrofluid

Magnet

(nomagnetic) waste input
Basic MDS operating principle

At a height $z_{eq}$, the net force on a (non-ferromagnetic) waste particle is zero:

$$F_z + F_{buoyancy} + F_{mag}(z) = 0$$

Vertical field gradient desired that:

- varies with $z$
- is **constant** in horizontal directions

$$|H|(z) = H_0 \exp \left(-\frac{2\pi}{\lambda} z \right)$$ does the trick!
Why use superconductors in MDS?

Higher **field strength** \((H_0)\) & larger **periodicity** \((\lambda)\):

- Enhanced separation **resolution**
- Wider density **range**
- Deeper usable fluid bed
- More **dilute** ferrofluid (lower OPEX)

**Project goal: demonstrator magnet**

- 3 NbTi racetrack coils
- 5 T peak field
- \(\lambda = 60\) cm
- Targeted application: electronic waste
Contents

1) Coils
2) Cryostat
3) Cassette
4) Pillar structure

Minimize magnet-fluid distance
Mechanical strength
Thermal isolation
**Single-walled cryostat**

- **Direction of particle movement**
- **Fluid bed**

**Sumitomo Cryogenics**
**GM Cryocooler. 1.5 W at 4.2 K**

~1.1 m x 1.6 m
Single-walled cryostat
Magnet to be mounted on alu plate, plate can slide into cryostat

Room-temperature steel pillars support the top plate and help minimize top-plate thickness
Cassette to keep coils in place

High-strength aluminum alloy two-part cassette
- Shrink fits around coils upon cool-down
- Holes for RT pillars
Cassette bottom view

Connection to cooler

G11 warm-cold pillars

Pure aluminum busbars to reduce $\Delta T$
Pillars optimized to balance buckling strength and heat in-leak

Euler’s buckling criterion

\[ Q_c = \frac{\overline{k} \Delta T \pi}{L_2} \frac{1}{4} \left[ \sqrt{\left( \frac{64 L^2 F}{C \pi^3 E} + D_i^4 \right)} - D_i^2 \right] \]

Fourier’s law

Solid rod: \( D_i = 0 \)

\[ Q_c = 2 \overline{k} \Delta T \frac{L}{L_2} \sqrt{\left( \frac{F}{C \pi E} \right)} \]

SS: \( \frac{4.5}{\sqrt{195}} \approx 0.32 \), 77→4 K

G11: \( \frac{0.21}{\sqrt{20}} \approx 0.047 \), 293→4 K
Conclusions

**MDS**
Recycling technology, allows separation on non-magnetic materials based on mass density

**NbTi**
Demonstrator magnet under construction at University of Twente
Conduction-cooled
To be installed at Delft University

**Design**
Balances heat in-leak vs mechanical strength vs magnet-fluid distance
Thank you for your attention

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