A new furnace design to improve the thermal demagnetization in paleomagnetism

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Imperfect thermal demagnetization

The samples should be in zero magnetic field during thermal demagnetization. However, magnetic field noise, including residual magnetic fields of material and induced fields caused by the heating current in the furnace are always present.

(Zheng et al., 2010)
Configuration of non-inductive heating wires

- Solenoids arranged in opposite direction (a)
- Bifilar solenoid wrapped (b)
- New heating element made by solenoid and connected with a straight wire in series at one end for new developed demagnetizing furnace (c).
Simulation of solenoid magnetic field

Solenoid:

\[
\begin{align*}
\frac{dB_x}{dz} &= \frac{\mu_0 I}{4\pi} \left[ \frac{(z_0 - a\theta)R\cos\theta - (y_0 - R\sin\theta)a}{(x_0 - R\cos\theta)^2 + (y_0 - R\sin\theta)^2 + (z_0 - a\theta)^2} \right] d\theta \\
\frac{dB_y}{dz} &= \frac{\mu_0 I}{4\pi} \left[ \frac{(z_0 - a\theta)R\sin\theta + (x_0 - R\cos\theta)a}{(x_0 - R\cos\theta)^2 + (y_0 - R\sin\theta)^2 + (z_0 - a\theta)^2} \right] d\theta \\
\frac{dB_z}{dz} &= \frac{\mu_0 I}{4\pi} \left[ \frac{(y_0 - R\sin\theta)R\sin\theta + (x_0 - R\cos\theta)R\cos\theta}{(x_0 - R\cos\theta)^2 + (y_0 - R\sin\theta)^2 + (z_0 - a\theta)^2} \right] d\theta
\end{align*}
\]

Straight Line:

\[
\begin{align*}
\frac{dB_x}{dz} &= -\frac{\mu_0 I}{4\pi} \frac{y_0 a d\theta}{\left[ x_0^2 + y_0^2 + (z_0 - a\theta)^2 \right]^{3/2}} \\
\frac{dB_y}{dz} &= -\frac{\mu_0 I}{4\pi} \frac{x_0 a d\theta}{\left[ x_0^2 + y_0^2 + (z_0 - a\theta)^2 \right]^{3/2}} \\
\frac{dB_z}{dz} &= 0
\end{align*}
\]

Length: 1 m
Pitch: 4 mm
ϕ: 8 mm

Solenoid-Straight Line
Magnetic field measurement

<table>
<thead>
<tr>
<th>Model</th>
<th>Induce field (nT/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sogo-fine-TD</td>
<td>260</td>
</tr>
<tr>
<td>ASC-TD48</td>
<td>9260</td>
</tr>
<tr>
<td>MMTD80</td>
<td>840</td>
</tr>
<tr>
<td>TD-PGL100</td>
<td>130</td>
</tr>
</tbody>
</table>

![Diagram](image)

(e) Magnetic field (nT) vs. Position (m)

- 100 Hz
Degaussing the shield cylinder

A solenoidal (a) and toroidal (b) degaussing coil embody the shield cylinder, and residual field in the shielding cylinder after demagnetization (c) with winding method according to figure (b). After demagnetization with this procedure, the residual magnetic field in the sample region can be less than 1 nT.
The heating current can be adjusted by Single-phase Voltage Module, which can reduce the current when approaching the target temperature. Its advantage is to ensure temperature stability and reduce the induced magnetic field. The temperature of heating process can be recorded in USB memory.
Experimental Method

Synthetic hematite specimens

TRM and Demagnetization

Reheated by TD48

Reheated by PGL100

Natural specimens

Heated by TD48

Heated by PGL100

the remanent magnetization of completely demagnetized specimens would remain unchanged during re-demagnetization

????
Specimen and Demagnetization of TRM

(a) TEM

(b) particle size

(c) hysteresis loop

(d) ZFC curve

Remanent Moment (10^-6 Am²)

Temperature (°C)

Remanent Moment (10^-6 Am²)

Temperature (°C)

Remanent Moment (10^-6 Am²)

Temperature (°C)
Re-demagnetization of Synthetic specimens

It proved that the extra undesirable remanence acquired during the thermal re-demagnetization process
Reason for obtaining remanence
Suppose that detrital remanence (DRM) is typically an order of magnitude weaker than TRM, noise fields in furnace may have a large impact on thermal demagnetization data obtained from sedimentary rocks.
Thermal demagnetization of natural specimens
Conclusions

1. The new heating element design can significantly reduce magnetic field noises in thermal demagnetizer

2. The experiments confirm that magnetic field noise in various furnaces can have an observable and detrimental impact on demagnetization behavior

3. The new furnace represents an important improvement in the design of thermal demagnetizers and allows for extremely weak specimens to be successfully measured.
Acknowledgements

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